THE COST OF MINING

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THE COST OF MINING

AN EXHIBIT OF THE RESULTS OF IMPORTANT MINES THROUGHOUT THE WORLD

BY

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PREFACE

This book is the result of experience in the mining business covering some twenty years, in the earlier of which I had to do in rapid succession with such diverse operating conditions as those presented by Lake Superior iron mines, gold mining in Ecuador and Colorado, and lead mining in Idaho and Missouri. The profound differences in methods imposed by natural conditions could not fail to impress themselves on one's attention.

Some six years ago a discussion started by Messrs T. A. Rickard and W. R. Ingalls of the *Engineering and Mining Journal* on the "Cost of Mining" attracted considerable discussion from mining engineers throughout the world, and I contributed some articles. It was natural to continue the investigation of the subject. In 1908, at the suggestion of Mr. Ingalls, I undertook to prepare some more extended articles for the same journal with a view of rationalizing the subject to show how the natural factors inevitably impose certain costs that sound engineering must recognize, and that to attempt economies unjustified by the conditions is the rankest extravagance.

This book is the outgrowth of those articles and to a lesser extent of some lectures given at Harvard University and a large amount of discussion and correspondence. The subject is one that is inherently interesting to mining men and mining engineers and it seems possible that it may interest a somewhat wider field. Those who are interested in financial and economic developments can hardly escape some contact with the mining business.

A full treatment of the subject would be encyclopedic, but no attempt is made here to give the work that character. I have merely tried to give a certain perspective of the business in coal, iron, lead, zinc, copper, gold, and silver, concentrating my effort largely on an attempt to exhibit facts in their proper proportion. The principal source of facts is the official reports of mining companies which are not in some fields so numerous as could be wished, and, in fact, from some districts are not to be had at all. The best and most numerous reports are issued by copper, lead, and gold mining companies.

In the coal business, reports of a certain kind are abundant and generalized statistics are exceedingly abundant, but little is to be had in the way of detailed information necessary to a satisfactory cost analysis. Consequently, the chapters on coal mining are more general than those on other subjects; but while a detailed treatment of this immense business would require a volume in itself, it may be remarked that coal mining is the simplest form of the industry and a sketch of its essential features does not need to be a long one.

A single corporation accounts for 55 per cent. of the iron output of the United States, and at the same time its reports are far more luminous than those of any other concern in this business. Accordingly much attention is given to the results and statistical history of the United States Steel Corporation. The independent companies are either utterly secretive or give only financial statements that do not yield much to analysis.

The discussion of lead mining covers the results obtained by companies typical of the conditions under which 80 per cent. of the American product is secured.

In zinc mining information is not very satisfactory, but it is possible to give some idea of the operating conditions under which some 80 per cent. of the American product is obtained.

In copper mining a great deal of detailed information is to be had showing results in a fairly satisfactory way in districts that produce nearly 90 per cent. of the North American copper. A few examples are taken from the outside world.

In gold and silver, the United States is not pre-eminent and examples are taken rather freely from all parts of the world.

It will be seen that the work deals largely with results; matters of an engineering or technical nature are generally left out even to the extent of ignoring such matters as the assay values of ores. This is done in order to make the conclusions base themselves on strictly practical and conservative grounds. It happens by way of coincidence that this volume will serve as a kind of supplement to Mr. H.C. Hoover's work on the "Principles of Mining," which deals with the processes of valuation, organization, and administration, and the methods used in mining the more precious metals. The reader will find in Mr. Hoover's book an outline of some of the technical problems not dealt with here.

I must acknowledge the assistance given by various friends in the preparation of this work. Professor H. L. Smyth of Harvard University in particular has aided with many important suggestions and is responsible for portions of Chapters I and II. Mr. W. R. Ingalls, editor of the *Engineering and Mining Journal*, has kindly allowed me to republish from the "Mineral Industry" of 1908 his important study of the cost of "Silver-Lead Smelting," which forms the whole of Chapter XVI. Mr. Raphael Welles Pumpelly has given great assistance in looking over many reports. Messrs. F. W. Bradley, T. A. Richard, J. Parke Channing, Dr. Douglas, Courtlandt E. Palmer, H. M. Chance, George S. Rice, and many others have all contributed from time to time valuable suggestions and criticisms.

I cannot help feeling that, while all of the material in this book is either old or public property to the extent of being known to at least a portion of the profession, there is nevertheless something new in it in that it presents a view of the economics of mining on a grand scale and in broad outline. It does not seem possible that a mining man can fail to understand my meaning. If the facts are right the book is right. But in the great range of facts that I have tried to look into many things are more or less obscure and it is difficult to be sure that my information is authoritative. I shall be greatly obliged if the readers of this book will point out errors or supply information. If there is any demand for it I shall be glad to prepare a revised edition later, filling in some of the shortcomings of the present one.

J. R. FINLAY.

NEW YORK, September, 1909.

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THE COST OF MINING

CHAPTER I

VALUE OF MINING PROPERTY

Popular tendency to take fragmentary view of mining industry — Its real extent and growth — Basis of valuation of mines — Average prices — Average costs — The concurrent fluctuation of prices and costs — General principles of relation of cost to price — Types of mining enterprises — The nature of a mining investment — Algebraic discussion of the calculation of present values of mining stocks from determined factors — The most profitable length of period for working out mines with known ore reserves.

In this volume I propose to discuss the business of mining on broad lines. Most people who connect themselves with this most important industry are interested only in certain sections of it, even to a point of almost forgetting that there is a mining business outside of their own particular field. People who have been engaged, for instance, in gold mining are apt to think of coal and iron mining as a different business. We find people talking about mining stocks in an unjustifiably restricted sense. A certain group will think of mining stocks as referring to shares in highly speculative precious metal enterprises, and will not even consider as coming within their range such really stable and valuable securities as those of the Homestake, Treadwell, or of the many great gold-mining enterprises controlled by British capital. The public does not know that the class of speculative gold and silver mines which depend on the discovery of an occasional bonanza, which is very likely to be exploited much more vociferously in the newspapers and on certain stock exchanges than its value warrants, forms only an insignificant fraction of the mining business. Such properties really depend more on psychology than on values. It is instinctive with a certain fraction of the human race to be enormously attracted by the glitter of gold.

Another section of the mining public is that which devotes itself to speculation in copper shares, ignoring on the one hand, as too speculative, ventures in gold, silver, or lead, and on the other hand, as too slow, ventures in coal, iron, or building material. We have a very much larger group of people interested in coal and iron, who look upon their business as being more allied to manufacturing and devoid of the speculative element that is supposed to enter so largely into the mining business.

Extent and Growth of Mining Business

As a matter of fact the real mining business of the United States or of the world at large is too vast to be readily comprehended by any single person. The technical part of copper mining or of oil production is in itself a sufficient study for any man who wishes to devote himself to it; but from the standpoint of the investing public not directly concerned with the management of properties there is no necessity for dwelling in much detail on the separate sections of the mining business. Ultimately there is no essential distinction between mining brick clay and mining diamonds. They are equally natural products; they must be looked for and handled on pretty much the same principles. It is probably a fact that brick clay is just as profitable and just as valuable as the rock which contains the almost infinitesimal proportion of diamonds which give it value.

It may be a matter of surprise to many business men to learn that in 1907 the total mineral production of the United States in a crude form at the mines or metallurgical works was $2,069,000,000; that the total number of men employed in this business must be approximately 2,500,000; that of this total output the value of silver is less than 2 per cent.; of gold less than 4½ per cent.; copper less than 9 per cent.; while pig iron accounts for 25 per cent.; coal, 30 per cent.; natural gas and petroleum equal the value of copper; and structural materials such as clay, cement, lime, and stone amount to 15 per cent. The contemplation of these figures will be a great help to one's sense of proportion in the mining business. I accordingly present the following tables of mineral production from the reports of the U. S. Geological Survey:

Products	1898		1907	
	Quantity	Value	Quantity	Value
Metallic				
Pig iron (spot value) .... long tons	11,773,934	$116,557,000	25,781,361	$529,958,000
Silver, commercial value .... troy ounces	54,438,000	32,118,400	56,514,700	37,299,700
Gold, coining value .... troy ounces	3,118,398	64,463,000	4,374,827	90,435,700
Copper, value at New York City ...... pounds	526,512,987	61,865,276	868,996,491	173,799,300
Lead, value at New York City ..... short tons	222,000	16,650,000	365,166	38,707,596
Zinc, value at New York City ..... short tons	115,399	10,385,910	223,745	26,401,910
Quicksilver, value at San Francisco ..... flasks	31,092	1,188,627	21,567	828,931
Aluminum, value at Pittsburg .... pounds	5,200,000	1,716,000	17,211,039	4,926,948
Antimony, value at San Francisco .... short tons	3,238	532,101	2,022	622,046
Nickel, value at Philadelphia .... pounds	11,145	3,956	—	—
Tin .... pounds	—	—	—	33,285
Platinum, value (crude) at New York City .... troy ounces	225	1,913	357	10,589
Total value of metallic products	—	305,482,183	—	903,024,005
Non-metallic (Spot Values)				
Fuels:				
Bituminous coal .... short tons	166,593,623	132,608,713	394,759,112	451,214,842
Pennsylvania anthracite .... long tons	47,663,076	75,414,537	76,432,421	163,584,056
Natural gas	—	15,296,813	—	52,866,835
Petroleum .... barrels	55,364,233	44,193,359	166,095,335	120,106,749
Total fuels	—	267,513,422	—	787,772,482
Structural materials	—	123,592,445	—	305,847,526
Abrasive materials	—	1,098,784	—	1,646,919
Chemical materials	—	12,387,719	—	30,759,684
Pigments	—	2,962,055	—	9,761,595
Miscellaneous	—	10,236,246	—	30,376,985
Total value of non-metallic mineral products.	—	417,790,671	—	1,166,165,191
Total value of metallic products	—	305,482,183	—	903,024,005
Estimated value of mineral products unspecified	—	1,000,000	—	100,000
Grand total	—	724,272,854	—	2,069,289,196

Total Value of Mineral Products Since 1880

	1880	1881	1882	1883
Metallic products	$185,649,163	$187,549,908	$214,061,009	$196,547,259
Non-metallic products	173,279,135	206,783,144	231,340,150	243,812,214
Unspecified	6,000,000	6,500,000	6,500,000	6,500,000
Total	$364,928,298	$400,833,052	$451,901,159	$446,859,473
	1884	**1885**	**1886**	**1887**
Metallic products	$179,230,899	$172,491,087	$203,249,225	$236,598,254
Non-metallic products	221,879,506	241,312,093	230,088,769	270,989,420
Unspecified	5,000,000	5,000,000	800,000	800,000
Total	$406,110,405	$418,803,180	$434,137,994	$508,387,674

	1888	1889	1890	1891
Metallic products	$237,574,422	$247,768,701	$292,649,877	$282,617,183
Non-metallic products	286,150,114	282,623,812	312,826,503	321,767,846
Unspecified	900,000	1,000,000	1,000,000	1,000,000
Total	$524,624,536	$531,392,513	$606,476,380	$605,385,029

	1892	1893	1894	1895
Metallic products	$281,514,539	$219,436,649	$185,804,594	$245,874,431
Non-metallic products	340,028,842	323,257,318	362,570,173	393,897,097
Unspecified	1,000,000	1,000,000	1,000,000	1,000,000
Total	$622,543,381	$543,693,967	$549,374,767	$640,771,528

	1896	1897	1898	1899
Metallic products	$251,445,519	$265,209,975	$305,482,183	$487,831,631
Non-metallic products	388,098,702	380,782,607	417,790,671	525,524,074
Unspecified	1,000,000	1,000,000	1,000,000	1,000,000
Total	$640,544,221	$646,992,582	$724,272,854	$1,014,355,705

	1900	1901	1902	1903
Metallic products	$511,632,891	$480,006,859	$599,916,009	$583,433,948
Non-metallic products	594,398,501	660,993,170	722,186,708	907,495,032
Unspecified	1,000,000	1,000,000	1,000,000	1,000,000
Total	$1,107,031,392	$1,142,000,029	$1,323,102,717	$1,491,928,980

	1904	1905	1906	1907
Metallic products	$502,149,624	$702,453,101	$886,110,856	$903,024,005
Non-metallic products	860,522,721	922,282,724	1,017,696,178	1,166,165,191
Unspecified	400,000	400,000	200,000	100,000
Total	$1,363,072,345	$1,625,135,835	$1,904,007,034	$2,069,289,196

I have not been able to cover the whole field of the mining business, but I shall endeavor to present some idea of the business as applied to coal, iron, gold, copper, silver, lead, and zinc. These materials amount to over 70 per cent. of the total mineral output and it is fair to believe that the principles governing the exploitation of this much will apply also to the remainder.

The above tables should not be dismissed without some further comment. They emphasize not only the importance of the mining business, but also its increasing importance. The mineral output per capita in the United States in 1880, which was a boom year, was less than $7.50, while in 1907 it had risen to $25. There is not the slightest indication that the increase in the use of minerals has anywhere nearly reached its limits. On the contrary, the development is in full career and is likely to continue for many decades. So long as the United States has two thousand billion tons of accessible coal within its borders and vast tracts of irrigable and swamp lands still undeveloped and a rapidly increasing population daily becoming more accustomed to increasing standards of efficiency and an increasing scale of comfort, we may look forward to great increases of business. There is no other field in which activity promises to be more widely extended than in mining which furnishes the basis for most of the characteristic manufactures of modern civilization.

Valuation of Established Mining Concerns

It is in this particular field also that the process of consolidation of unit enterprises into larger, more stable, and more effective groups is most noticeable. It is inevitable that this process will mean an extension of ownership among a larger number of holders, concurrent with the concentration of management in proportionately fewer but more effective hands. The great enterprises of the present are usually far beyond the resources of any individual capitalist. Shares of most of our great corporations are divided among many thousand people. The expansion of this kind of ownership is as inevitable as the expansion of business itself. I regard it, therefore, as an important function of the mining engineer and mining investor of the immediate future to study and fix the valuation of industrial shares, based partly or wholly on mining enterprises, as well as of single mining properties. My purpose is to explain how the valuation of mining properties depends on some cardinal principles that are easily understood in general terms, but may easily be obscured in concrete cases. These principles of course apply not to speculation but to serious investment. The basic factors are: first, average market prices; secondly, average costs; thirdly, the life of the mine. While each of these factors is so easily understood as to be practically axiomatic their application always involves questions that are not always easy to answer.

Average Prices. — The average price of any article for a period of years in the past is usually very easy to determine, but we are immediately confronted with the fact that prices determined with accuracy for certain periods of years do not agree with equally well determined prices of other periods of years. For example, the price of copper for the last fifty years has averaged something under 16 cents per pound. For the last twenty years it has averaged 13.85 cents per pound, while for the last ten years it has averaged 15.82 cents per pound. Now since the question is not what prices have been in the past, but what they are likely to be in the future, it is evident that we must select from these various averages the one that seems most likely to conform with the probable conditions ahead of us. Such a selection involves the consideration of a great variety of subjects. A thing that throws most light on this problem is the course of prices themselves. If these prices are plotted in a curve for a long period of years it will be found that there have been a series of high-price periods followed by another series of low-price periods. It may and will make a good deal of difference with our prediction of the future whether the crest of each high wave is higher than that of the one preceding it, and the low wave not quite so low as the one that preceded it. If we find such a state of affairs, we are probably justified in concluding that the average price of such a commodity is rising.

One will be influenced in like manner by the demand for a given article in comparison with other articles. If we should find, for instance, that the amount of lead used in 1890 was equal to the amount of copper used, while in 1900 only one-half as much was used, and in 1910 only one-quarter as much, it would seem to be well worth while to look into the reasons for such changes. These reasons might be complex and obscure. It might be that they would argue either for higher or for lower prices for either of the articles in question. If the consumption of lead were proportionately diminished, it might be explained by a deficient supply which would argue for higher prices, or it might be due to a substitution of other materials for the uses to which lead had been put; which would argue for lower prices. It is well to point out that these are precisely questions that people engaged in trade are constantly considering. But for the man who is looking for general tendencies and not for the conditions of the moment the ideas of such people are too much fixed on near considerations. Their eyes are apt to focus not on the developments of a decade, but on those of a week or month. It is against the judging of great and stable securities on these momentary considerations that it is most necessary to protest.

Average Costs. — The determination of average costs is the

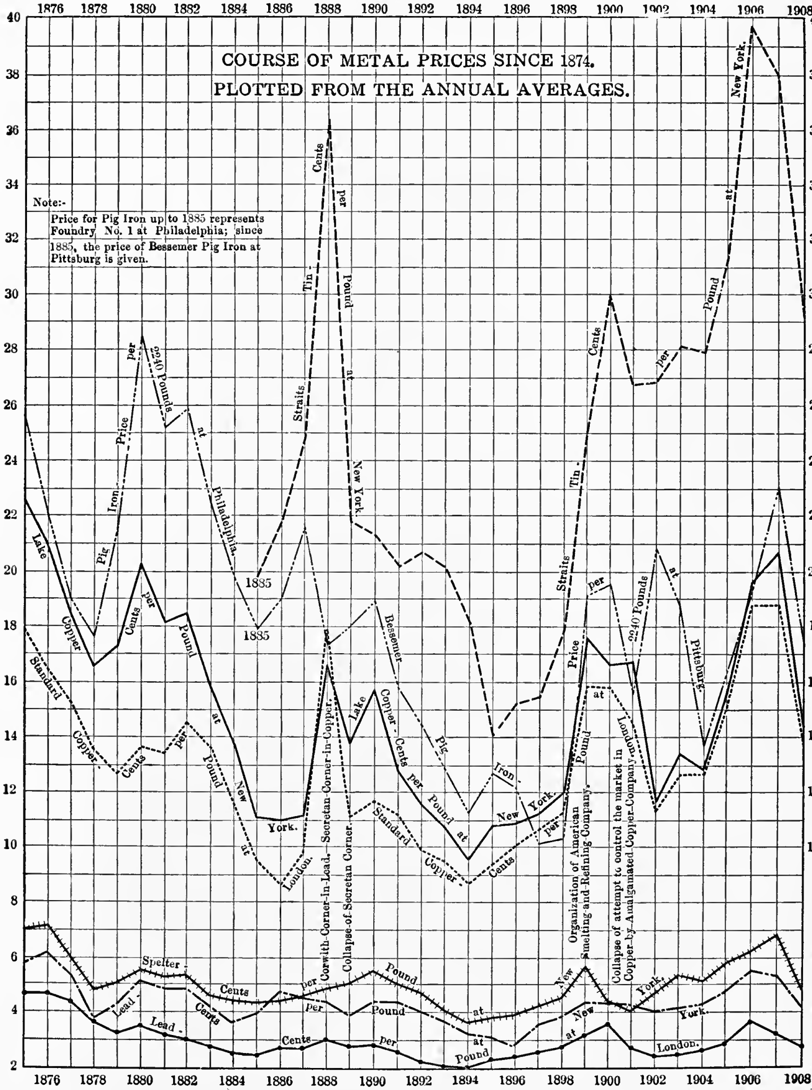


FIG. 1

principal matter discussed in this volume. It is necessary to introduce here a consideration that is easily overlooked, namely, that if prices vary, costs vary also, but not to the same extent. The value of securities is too often affected by a hasty conclusion on the part of the public that a rise in prices will go wholly to profits, or that a drop in prices will be taken wholly out of profits. As an illustration of this fallacy I reproduce here an article published in the beginning of 1908 in the *Engineering and Mining Journal* on the *Vanishing Point of Profits* :

Concurrent Fluctuation of Costs and Prices

"The Federal Mining and Smelting Company's report for 1907 shows a net profit of $2,232,249 after taking out a "development account" of $300,000. This came from 130,373 tons of concentrates containing 3,689,298 oz. of silver (worth 68 cents per ounce, or $2,508,722.64) and 59,746 tons of lead (worth $116 per ton, or $6,930,536), the total gross value being $9,439,258.64). On this output the profits amount to 23.6 per cent. and the costs must therefore be 76.4 per cent., giving an apparent cost for lead of 4.43 cents per pound and for silver of 51.95 per ounce.

"At first thought one is apt to assume that with costs the same the company would receive no profit unless the prices were above 4.43 cents for lead and 51.95 cents for silver. How false such an assumption would be appears from the following:

"The Cœur d'Alene mining companies, of which this is one, do not smelt their own concentrates but sell them to smelting companies under contracts somewhat as follows: The smelter pays for 90 per cent. of the lead at 90 per cent. of the New York price, or 81 per cent. of the full quantity and price when lead sells at 4.10 cents per pound or under. When the price rises above 4.10 cents per pound the smelter pays 81 per cent. and one-half the additional price. Thus if lead sells at $4.50 per pound the smelter pays 81 per cent. of 4.10 plus one-half of 0.40 = 3.251. The smelter pays for 95 per cent. of the full value of the silver. A freight and treatment charge of $16 a ton is deducted from the value of average concentrates. Applying this rule to the output for 1907 we find that the cost of producing concentrates was $23.39 a ton, thus:

	Selling Price	Contract Price
Lead	5.80	4.171
Silver	68.00	64.60

916.54 lb. lead at 4.171 cents	$38.23
28.298 oz. silver at 64.60 cents	18.28
Total value per ton	56.51
Freight and treatment charge	16.00
	$40.51
130,373 tons at $40.51	$5,281,410.23
Profits	2,232,249.00
Total cost of production	3,049,161.23

$\frac{\$3,049,161.23}{130,373}$ .... $23.39 cost per ton produced

"Now let us see what would happen to the Federal Mining and Smelting Company were the prices reduced to the point where profits apparently vanish according to 1907 experience. The concentrates contained: lead, 45.827 per cent., 916.54 lb., and silver, 28.298 oz. per ton. The value is figured as follows:

	Selling Price	Contract Price
Lead	4.41	3.426
Silver	51.95	49.353

916.54 lb. lead at 3.426 cents	$31.40
28.298 oz. silver at 49.353 cents	13.97
Total value	$45.37
On this our costs are:	
Freight and treatment charge	$16.00
Mining and milling	23.39
	$39.39

"We have a profit remaining of $5.98 per ton. This on 130,373 tons would be $779,630.54 or 34.9 per cent. of the profit at 1907 prices. On this basis we may figure the real vanishing point for lead as follows:

"Let the silver price remain stationary and we shall have in our concentrates silver worth $13.97. Our cost is $39.39; therefore, 916.54 lb. of lead must be worth $25.42 or 2.773 cents per pound. But as this is only 81 per cent. of the selling price the latter will figure 3.421 cents. It would seem, therefore, that we have reached the vanishing point of profits as far as the Federal

Mining and Smelting Company is concerned with lead at 3.421 cents and silver at 51.95 cents at New York.

"But this deduction may also be wrong, for the company has a chance to select its ores and produce a higher grade product. Suppose it produces from its more favorable mines only 65,000 tons of concentrates instead of 130,373 tons, and that the selected concentrates carry 56 per cent. lead and 38 oz. silver. Suppose this ore cost 10 per cent. more for mining and milling and 12.5 per cent. more for freight and treatment and we have a cost of

Mining and milling	$25.75
Freight and treatment	18.00
	43.73

"But the ore will be worth as follows:

Lead, 1120 pounds at 2.773 cents	$31.06
Silver, 38 ounces at 49.353 cents	18.75
	$49.81

"Thus we have a profit of $6.08 still or $395,200, and in addition the company is keeping in its mines a very large amount of ore that may be available at better prices. With the above grade of concentrates, supposing that silver remains the same, the vanishing point of profit on lead will be reached at 2.230 cents by contract or 2.753 cents at New York.

"Even yet we have not reached the limit of the company's resources. It is safe to say that if lead had to be sold at 3 cents per pound, supplies to the mines would be cheaper and wages could be reduced."

General Principles of Relation of Cost to Price

A simpler explanation of the point explained here may be taken from the following considerations: A normal price for copper may be assumed to be 15 cents a pound. Let us suppose that a company under ordinary conditions can produce copper for 10 cents a pound, making, therefore, a normal profit of 5 cents. Let us suppose that copper goes up to 20 cents a pound and analyze roughly the conditions which would take place under such a rise of price and the effect of those conditions on the cost of production.

Such a considerable rise of price could only be due to a deficiency in the supply. Apart from the cutting off of important sources of supply by war or other calamity, generally this deficiency must be caused either by a shortage of ore or by a shortage of labor or by both. In the case of an individual mine a shortage in the supply of ore would naturally mean either impending exhaustion or an insufficient amount of development. In an ordinary mine the volume of copper could be increased by utilizing some low-grade ores which would not ordinarily be worth working. Under the stimulation of a higher price the management would naturally utilize these low-grade ores which it could not work at 10 cents or even at 15 cents copper. It follows as a natural and almost inevitable result that each mine would, at 20 cents copper, undertake the working of a proportion of lower grade stuff at very much increased cost.

But the mere undertaking of increased production implies an increased use of labor. Both the efficiency and the supply of labor are variables. The efficiency generally depends on the supply. Where an enterprise is well established and wages are high the number of miners is apt to exceed by a certain percentage the demand. In other words, there is always a number of men looking for a job. The existence of a crowd of unemployed men always acts as a spur to the exertion of those who are fortunate enough to have jobs. The sudden expansion of the business will take away the surplus of labor. The men who come out of the shafts at night no longer see their employment threatened by competition. They accordingly take things easier and the immediate result is a lowering of efficiency. This means an increase in cost. Sometimes it means a very great increase of cost.

If the enterprise is not paying a rate of wages sufficient to cause an over-supply of labor under normal conditions, then any attempt to increase the scale of operations will be immediately thwarted by lack of men to do the work. If the company finds it necessary under such conditions to increase its operations it must first secure an increased supply of labor. The usual way out of such a difficulty is to raise the wages.

Furthermore, if copper is scarce and in great demand it is usually a corollary that other products are scarce and in great demand. Very likely the railroads will be congested with freight; manufacturers of machinery overcrowded with orders. These are all factors that increase cost. A mining company wishing to get out a large output at 20 cent copper, when it usually gets only 15 cents, finds itself under a drain of heavy expense, bidding up prices of labor and supplies of all kinds in order to accomplish its purpose. In extreme cases it is quite probable that the cost is so much increased by these factors as to absorb the whole advantage of the increased price. That a certain proportion will be absorbed may be considered inevitable.

The phenomenon of such increases of cost through such conditions of trade as have been described is familiar to any business man who has lived through one or two panics. When you see in the newspapers or in reports of industrial concerns complaints of a shortage of labor and the inefficiency of labor you may prepare for a panic.

It is a corollary from the same considerations that in periods of depression costs will be reduced. Let us suppose that our copper company which has been used to 15-cent copper finds itself unable to sell for more than 11 cents. This must mean that the demand for copper has diminished. It is no longer necessary to produce so much. There is no longer the necessity for active development. Copper that is needed can be produced from selected ores. Since fewer men will be needed the work will be done by selected men who will work under a greatly increased stimulus of competition. Wages may be reduced. The cumulative effects of such conditions may mean that the company which has produced copper normally at 10 cents may produce it for a period at 8 cents or even less and of course find a considerable margin of profit.

Reduction of Costs Per Ton not a Sign of Prosperity

Also we should not fail to note another general tendency in every important mining enterprise, and that is the tendency for costs to become reduced as time goes on. In part this tendency is due to general improvements in machinery and methods, new inventions, better transportation facilities, etc., which the individual enterprise shares with the industry at large. But the larger part comes from the settling down of the enterprise itself to a steady gait, to its better organization, to the better results secured from labor, and usually to a larger scale of operation whereby the unit cost of production is reduced by increasing the number of tons by which the fixed items on the cost sheet are divided. It is furthermore to be noted that a diminished cost per ton due to these causes hardly ever results in an increased profit per ton when the price of the product remains constant or even when it increases. Many reasons bring about this result, but the most important undoubtedly is the equally general tendency to a reduction with time in the metallic content of the ton of ore. This in many cases comes from an actual impoverishment with depth, which forces the adoption of better methods, resulting in lower costs through the inexorable necessity of diminishing returns. The Calumet & Hecla is a conspicuous example of the achievement in the last ten years of lower costs under the necessity imposed by a fall of one-third in the yield of its ore. But the enlarged scale of operation itself works in the same direction even more effectively. The mill or reduction works is nearly always overbuilt for the ore developed. To get a low cost per ton it must be operated to its capacity. This puts a strain on the mine, with the result that in order to keep up the tonnage certain stopes are worked which yield rock from which only a small profit or none at all is realized. Furthermore, in many mines with ores of several grades the lowering of costs automatically, as it were, enlarges the available tonnage that may be handled with some profit, the effect being precisely the same as an increase in the price of the product. This result is shown very clearly by several of the newer Lake Superior Copper Mines, where an enlargement of the mill and of operations generally has resulted not only in a diminished cost per ton, but also in a diminished yield per ton. It is also conspicuously shown by most of the gold mines on the Rand.

These considerations may be summed up in a few words. A diminished metal content in the ton of ore makes it necessary to reduce costs, and a reduced cost per ton, which always comes with time and enlarged operations, permits the handling at a profit of lower and lower grade ore. Therefore, quite independently of the course of prices, we have a tendency for cost and metallic content per ton to fall together, and the net result of this tendency almost invariably is a diminished profit per ton.

From these considerations it will appear that there is no great danger in calculating on average costs bearing a certain proportion to average prices. I feel like insisting that the only rational way of calculating mining profits is to consider both with the greatest possible care.

In this connection I wish to point out that in calculating costs great attention must be given to capital charges as well as to operating charges. Undue attention to details of cost and too much attention to statements covering single months or years are apt to befog one's vision as to the real proportion of capital expenses. This is an error into which I have been particularly careful not to fall.

In the discussion of costs to be presented in the following chapters I have given great attention to the problem of entering in capital or construction costs in due and fair proportions. It seems worth while to state at the outset that in the metal mines of the United States the total cost for the life of a mine is apt to exceed the operating charges from 20 per cent. to 40 per cent.

Nature of Mining Investments

Mining companies may be divided into:

I. Those which own a single mine confined to a single orebody or a definite tract.

II. Those that own various mines each with its individual capabilities for expansion.

III. Those that combine mining with other business such as transportation, smelting, or manufacturing.

It should be plain that these variations afford a great range of considerations from simple to complex, and that there is room for the exercise of much talent and experience in the appraisal of the earning power of a property or of a company. In the case of a circumscribed property it is often possible to fix a valuation from purely physical considerations; but in the case of corporations doing a general mining business there are brought into prominence the technical and financial ability of the management and the financial state of the corporation. By the last consideration we mean whether it is in debt or not and whether its indebtedness can easily be disposed of, or whether the debts will drown the earning power of the property rendering the equity of it only nominal value.

Now in the case of mining property of all kinds there is one salient fact that should never be forgotten for a moment, namely, *that it is a wasting asset which is always in process of distribution.* This is true whether we are to consider only a single producing unit or a vast aggregate of such units.

A mine has been likened to a bank account. The analogy with an account in a going bank is imperfect, because such an account may be swelled by new deposits, while new ore cannot be added to that which a mining property already possesses, although the actual amount may not be known until the property is exhausted. With an account in a bank being wound up by a receiver, however, the analogy is absolute. The receiver, as he realizes on the assets, pays the account back to its owner in instalments which are called dividends. Dividends from mining property are of precisely the same nature, namely, they are not interest on capital which remains unimpaired, but are the capital itself distributed in instalments. When the last asset is realized, the payment of instalments ceases and nothing is left.

It would be a considerable public service if one could make clear to investors the difference between an ordinary investment and a mining investment. What is an ordinary investment? The term may describe real estate, railroad securities, mortgages, etc., in which the property is permanent and in which it is assumed that the principal will remain intact. The question that determines the value of such property is: What annual income does it yield?

In the case of a mining property two concurrent questions must be answered in order to determine its value: What will be the sum total of dividends? and how long will it take to realize them?

Determination of Present Value from Known Factors

If these questions can be answered it is easy to arrive at the value of the property as an investment. The general principle at the root of the matter is that the annual dividends must yield a good annual interest on the sum invested, and also permit a certain sum to be set aside each year, which securely invested at compound interest will repay the investment when dividends cease on the exhaustion of the mine.

The present value of a mining property may be expressed algebraically as follows:

Let A = number of tons in the deposit; let x = number of years necessary to mine this tonnage; and therefore $\frac{A}{x}$ = yearly tonnage mined; let p = profit per ton; let y = yearly sum set aside to sink the investment; let d = rate + 1 at which the sinking fund can safely be invested. Then, $\frac{pA}{x}$ = yearly profit; $\frac{pA}{x} - y$, yearly dividend. Therefore the present value is the sum on which this dividend is a fair return, or if z is the rate expected,

$$\text{Present value} = \left(\frac{pA}{x} - y\right)\frac{100}{z}$$

But if y is invested every year at compound interest the sum of these investments at the end of x years will return the capital invested now. Hence

$$\text{Present value} = y\,(d + d^2 + d^3 + d^x)$$
$$= y\frac{d(d^x - 1)}{d - 1} = yS$$

From these two values of the present value we find

$$y = \frac{100pA}{x(zS + 100)}$$

and we therefore have

$$\text{Present value} = \left[\frac{pA}{x} - \frac{100pA}{x(zS + 100)}\right]\frac{100}{z} \quad \text{........ (1)}$$
$$= \frac{100pA}{xz}\left(\frac{zS}{zS + 100}\right) \quad \text{.............. (2)}$$

This formula will be easily understood if we use it to work out an example. The Miami Copper Company is said to have an orebody containing at least 14,000,000 tons of ore averaging 2.8 per cent. or 56 lb. of copper to the ton. Of this, 80 per cent. or say 45 lb. per ton can be recovered and marketed at an outside cost of 9 cents a pound. The company, which is capitalized at 600,000 shares, is said to have enough money in the treasury to bring it to the point of production at this rate. Let us assume that the deposit is worked at the rate of 700,000 tons a year, and therefore will be exhausted in 20 years if no more ore is found; that the average price received for copper during this period will be

15 cents a pound; that the interest on the investment should be 7 per cent. after providing for a sinking fund, and that the sinking fund can be securely invested at 4 per cent. compound interest. With these data what is the present value of the stock? Let us make the computation on a per share basis in order to simplify the numerical calculation. The annual product, 700,000 tons, is 1.166 tons per share. The profit per pound is 6 cents, which on a saving of 45 lb. per ton would be \$2.70 a ton, or \$3.148 per share.

$$S = \frac{1.04\ (1.04^{20}\ 1)}{.04} = 30.97$$

$$y = \frac{100 \times 3.148}{100 + 7 \times 30.97} = \$0.994$$

The yearly sum set aside out of dividends for the sinking fund is therefore about \$1.00 a share.

Present value $= (3.148 - 0.994)\ \frac{100}{7} = \$30.78$ a share. On the assumptions made this should be the value of the stock when the mine and plant are in full operation. If it takes two years to reach that condition the present value is subject to two years discount. It is to be understood, of course, that this example is merely illustrative, and the conclusion depends wholly on the truth of the assumptions.

Two other principles may be stated. The first is that a mining property being an asset in process of liquidation, the more rapidly (other things being equal) that asset is distributed and the business wound up, the greater its present net value. This principle is subject to two reservations or limitations. One of these reservations is that it cannot generally be applied on a large scale in the case of any mineral product except gold without flooding the market and depressing the price, thus defeating its own object. The other limitation is the cost of the increased development and equipment necessary for the larger product. To develop and equip a property for a production of 2000 tons a day costs more than for 1000 tons a day, and this capital expenditure must be deducted from the present net value. The capital expenditure may be roughly expressed as a multiple of the yearly product. For example, taking account of the capital expenditure our equation becomes

Present net value = Present value − Capital expenditure.

$$= \left(\frac{pA}{x} - y\right)\frac{100}{z} - \left(\frac{nA}{X} + C\right)$$

when C is a constant sum and n is the cost per ton of annual product.

Since both the capital expenditure and the present value increase with the shortening of the period of exhaustion there must be some period of exhaustion for which the difference between them or the present net value will be greater than for any other period, and this of course will be the most favorable period for which to develop and equip the mine. For purposes of illustration let us take the example already worked out — that of the Miami mine — and assume that development and equipment costs $4 a ton of annual product and that C = $200,000. If we take several different values of x in succession, say 3, 6, 9, 12, and 15 years, we obtain the following net values:

x 3 years; value per share	$24.03
x 6 years; value per share	33.30
x 9 years; value per share	32.80
x 12 years; value per share	32.04

The most favorable period, therefore, would be somewhere between 6 and 9 years; the gain, however, over a longer period is small on account of the large sinking fund required, and might be more than balanced by the difficulty of getting the extra capital necessary, and especially by the danger that the shorter period of realization might coincide with a period of depressed prices. This of course would not apply to a gold mine except favorably. But where the product is sold on a variable market it is undoubtedly wiser to prolong the period of realization over a sufficient period to include the crests as well as the troughs of waves of prosperity, unless it can be made to cover the crests alone.

CHAPTER II

FACTORS GOVERNING VARIATIONS

What the cost consists of — Factors divided into external and internal groups — External factors: labor, supplies, climate, transportation, water — Internal factors: orebodies, attitude, concentrating qualitites, smelting qualities — Mining and metallurgical losses and their effects upon costs — Elements of a complete cost statement — Character of actual reports — Management — How rich mines are more costly to operate than low-grade mines — Hoover's theorem on the ratio of treatment capacity to ore reserves — Economy and speed — Private management and public interest.

It is necessary first to define what we mean by the cost of mining. It may be divided into three parts:

(*A*) The use of capital in acquiring the opportunity to mine, *i.e.*, ownership of ground, or leases. Since the value of this kind of property is only a speculative anticipation of profits to be won by operating, and is moreover often appraised in a fanciful or even dishonest way, I prefer to leave this element out of the discussion. I am quite aware, however, that as a matter of practical finance this cost must generally be considered.

(*B*) The use of capital for equipping and developing a mine, for providing mills and smelters.

(*C*) Current operating costs, including taxes, the maintenance of company organization, insurance, litigation, etc.

For present purposes I select *B* and *C* and my definition is: The complete cost of developing, equipping, and working out a mine, allowing interest on the capital required for these purposes until it is returned in dividends.

As any one with the most meager acquaintance with the subject must know, the cost of mining at different places is subject to great variations. I am not sure that the factors governing these variations have ever been fully stated.

A general division may be made between factors that are external or fortuitous and those introduced by the internal make up of the orebodies. It is evident that no quality in the deposit itself can influence any of the following groups of conditions:

(1) The cost and quality of labor and supplies.

(2) The climate, altitude, or distance from populous centers.

(3) The hardness of surrounding rocks, the amount of water, the depth from surface.

(4) The facilities and cost of transportation to milling or smelting centers or markets.

All of the above conditions vary from place to place and introduce differences in the cost of mining, though not such great differences (as will be shown later) as are caused by the inherent qualities of the orebodies themselves.

Cost of Labor and Supplies

The wages in the mines of the United States vary between 20 and 60 cents an hour. Usually the difference is partly made up by the varying efficiency of the men. Where wages are low the supply of labor is meager, the best men are constantly leaving for more favorable localities, those employed are not subject to the spur of a keen competition, and the results are constantly disappointing. On the other hand, where wages are high, the most ambitious and intelligent men are attracted and they compete with each other for the places.

It is hard to fix any figure for the compensation thus effected, but it would perhaps be safe to say that one-half of the apparent difference is made up. Some authorities will say it is nearly all made up. Messrs. Taylor & Brunton tell me that in operating sampling mills at Cripple Creek, Colo., where the wages are 40 cents an hour, and at Salt Lake City, where the wages are 25 cents an hour, there is but little difference in the labor cost per ton sampled. If we assume that while the difference in wages is represented by 20 and 60, and the difference in cost efficiency by 40 and 60 (or 70 and 100), we find that the variation in labor cost is only about 30 per cent. from the maximum. Since the labor accounts generally are about 60 per cent. of the total current cost of mining, differences in wages are not likely to account for a variation of more than 18 per cent.

In the world at large, outside of the United States, there may be instances where the differences in wages are more important than within the United States. Nevertheless, in the few important mining districts of which I have any knowledge, such as the Transvaal, India, and Mexico, where native labor is employed very largely at very low rates, it is well known that the costs are not lower than in the United States for similar work. It appears that where labor is very low there is little or no acquaintance with machinery and the performance per man is correspondingly low. Where large numbers of natives, ignorant of all civilized mechanical appliances, are employed at a large plant, they must be supervised by white men who do little actual work and get wages higher than those they receive at home.

In the English-speaking countries where mining is an important industry, it may be said that the conditions as regards labor are almost identical with those of the United States. It does not appear probable, therefore, that my conclusions regarding the variations caused by wages in the United States need to be essentially changed when applied to the important producing centers of the world at large. Extreme variations must be confined largely to isolated and abnormal localities.

The cost of supplies affects the cost directly. The important supplies are fuel, timber, explosives, steel, and tools. In the United States the price of these commodities does not vary enormously among the important mining centers, certainly not much more than 50 per cent. from the maximum. Since the collective cost of the various supplies is rarely more than 20 per cent. of the total current mining cost, a variation of 50 per cent. in the price will produce a difference of only 10 per cent. in that cost.

The cost of supplies in the world at large is apparently subject to about the same degree of difference as the cost of labor, but it is to be remarked that in any country, such as India and South Africa, where the price of labor is nominally low, the cost of supplies is usually distinctly higher than in the United States. In the Transvaal, for instance, Ross E. Browne estimates that the additional cost of supplies as compared with California accounts for approximately 10 per cent. of the total cost of mining.

Underground Conditions

The hardness of the rock is likewise a comparatively unimportant factor. In any case the hardness affects only one division of the underground work; namely, breaking the ground. The stability of the ground is much more important than the hardness. Timbering is often an important item.

Increase in depth adds something to the cost of hoisting and pumping, but it is to be remembered in this connection that if a mine is only 100 ft. deep, machinery must be provided for these purposes and a complement of men employed to operate it. As depth increases, the only change that comes in is the requirement of heavier machinery and additional power. The increase of cost, therefore, is far from being proportional to the depth. One consequence of extreme depth that might easily be overlooked is the daily cost of transporting the men to and from their working places. In the case of the Calumet & Hecla, the hoisting engines are in use two hours each shift in lowering the men and hoisting them out again. Not only does this represent a considerable expense in itself for mere hoisting, but far the greater part of the time of the workmen for this period is lost to the company.

The temperature of underground workings often becomes a matter of considerable importance. A high temperature may be caused by the climate, or by great depth, or by the presence of hot waters or heat-producing chemicals. It is only in the last case that the heat can be called an inherent quality of the orebody itself. There have been cases of such high temperatures in mines as almost to prevent working altogether, but ordinarily temperatures of 80 or 90° F. are about the limit reached in important mines. Such temperatures affect the energies of the men adversely, although men grow accustomed to them and suffer no ill consequences in the way of health. The importance of this factor is extremely difficult to appraise in figures, although in the case of the Calumet & Hecla, Anaconda, and United Verde, to cite conspicuous examples, the loss of effectiveness in labor through this cause must represent annually a very large sum.

These remarks are intended to apply only to underground mines. Where the work is done wholly upon the surface, the facilities for working are so much superior that mines of this character must be considered separately.

Climate, Altitude, and Population

The influence of climate, though indirect, is powerful through its effect on human life and effort. Sometimes in places where there is an excessive rainfall or excessive heat or unhealthful conditions, the effect may be to limit the scope of operations. For instance, in Ecuador, South America, a plant has been running 25 years, but on account of the climatic influences it has never been possible to secure more than about 60 effective miners, although the economical management of the property requires the employment of several times as many.

Excessive altitude, and great distance from lines of transportation, place similar limitations upon enterprise. Where several factors of this kind are present at the same locality, the aggregate effect is to place almost unsurmountable difficulties in the way of successful operations, but as a general rule in places where important mines have been discovered, most of these difficulties have been overcome. For instance, in the San Juan region of Colorado, and in the Cerro de Pasco in Peru, adequate transportation facilities have been provided and the only adverse conditions still remaining are the altitude and disagreeable climate which have in both instances a pronounced ill effect upon the performance of the labor.

Transportation and Marketing the Product

Transportation facilities may be described as adequate when they are sufficient to handle the output of a mine and to deliver with promptness the necessary supplies; but adequacy in this sense does not mean cheapness. Transportation is in very many cases one of the most vital elements in the cost of mining. This is particularly the case when the products have to be shipped considerable distances. In the case of coal and iron it is a matter of common knowledge that transportation is often the all-important factor, and even in the case of precious metals sometimes the cost of transporation to mills and smelters equals, if it does not exceed, the cost of actual mining. The intimate bearing of this fact upon mining methods and results aside from the mere question of transportation cost in themselves will be described later on.

Another factor that is often of considerable importance is the commercial matter of marketing the products. This is sometimes done by contract with selling agencies; and sometimes by the company itself. In either case there is to be taken into condsideration, in addition to the cost of marketing, the success achieved in disposing of satisfactory quantities of the product. It is in this respect particularly that the cost of mining may be greatly influenced by this factor in determining the volume of operations.

Coincidence of External Factors

One would scarcely expect that all these various factors would move in unison, *i.e.*, that they should all be equally bad in one place and equally good in another. So far as the natural conditions such as rock hardness, depth, and amount of water to be pumped are concerned, it is indeed extremely unusual that such factors are at a given place at either extreme; but it must not be forgotten that the remaining external factors have their effect through the efforts of man himself. If the mine is situated far from populous centers the reason is apt to be that the climate or the altitude is unfavorable. This generally means that labor is dear and inefficient, supplies costly, transportation difficult and expensive. These factors are likely, therefore, to be affected together, and if one is favorable they are all likely to be favorable and *vice versa.*

The sum total of cost variations that may be due to the coincidence of these external factors is therefore considerable and is sufficient to prevent the working of abundant yet valuable products such as coal, iron ore, or salt at places where these conditions are all bad. It may be said that the above factors are those which as a rule govern the variations in the cost of low-priced and bulky mineral products.

Internal Factors

The internal factors are: (1) The size and attitude of the ore-bodies; (2) the relation the valuable material bears to the enclosing gangue or material; (3) the problems involved in metallurgical treatment.

These factors introduce immense differences of cost. For instance, in gold mining we find that the Alaska-Treadwell has mined, treated, and marketed its ore for $1.48 per ton, while the Camp Bird in Colorado producing gold ore subjected to the same process costs $12.50 per ton. The wages are the same, the rock is of the same hardness, the water is no problem in either case, the method of mining even is practically the same. The general management of the Treadwell is probably more economical than that of the Camp Bird, but the difference is not to be laid to this score. The difference comes in the factors mentioned above and those factors are so important that they are worth a more extended consideration.

If we have a body of homogeneous material more than four feet thick and continuous, it is evident that the mine openings can be made very largely, if not wholly, in the stuff to be extracted. Practically every blow struck produces ore. But reduce the thickness to be mined to one foot and we are at once confronted with the necessity of taking out three feet of worthless material for one foot that is valuable, besides having to take pains to keep them separate. Here we introduce at once an enormous proportion of wasted expense that must be borne by the valuable ore. Now break the continuity of the deposit and it is evident that openings have to be made entirely through waste material merely to find and open up the scattered bodies. This evidently increases the cost still more. Now, since it costs about as much to handle one kind of rock as another, it is very evident that the cost of handling narrow and non-continuous orebodies may be many times greater than the cost of mining orebodies large enough to afford room to work in. A sort of dead line is established by a thickness of approximately four feet. Orebodies thicker than four feet are only moderately cheaper to handle than those of about that thickness.

The attitude of an orebody has a great deal to do with the cost of extracting it. For instance, in the anthracite coal-fields, in Pennsylvania, and in various other coal-fields, the beds are thrown into a succession of folds with constantly varying slopes. The effect of this is double. First it renders more difficult the taking of the material from the working places to the haulage roads, and secondly it renders necessary a large amount of dead work in order to reach the various parts of the beds and also prevents regular systematic working. These two factors are sufficient to introduce a great increase of cost over that of mining a flat and unbroken seam.

Faulting of the beds or veins and the occurrence of barren patches introduce complications similar to those caused by folding, but very much more variable in their nature. The folding of the formation is invariably regional and is felt rather uniformly by all of the mines in a given district, while a series of faults may affect only one mine in a group and while that mine may have just as good ore and as much of it as its neighbors its costs will be higher.

Homogeneity of Ore

The homogeneity of the ore is a factor of great importance. This quality determines whether it is necessary to subject to metallurgical treatment the whole or only a part of an orebody. If only a part need be so treated we have a concentrating ore. The manner in which the valuable mineral lies in the enclosing rock determines how the concentrating must be done. In any case the process of concentration involves loss and expense, and the question of how far this loss and expense is justified depends on the cost and character of the subsequent metallurgical treatment.

The cost of the metallurgical treatment depends primarily on the proportion of ore that must be treated. This proportion varies at different mines from 2 to 100 per cent. Obviously, where only 2 per cent. must be treated the cost of treatment as applied to the whole orebody will be less than where all is treated. The inherent metallurgical problem is therefore only reached when the question of selection is settled.

Low Costs in Mining may Mean Greater Expense Elsewhere

The above seems a sufficient explanation of the fact that it is necessary to a discussion of mining to include a consideration of the processes by which the ore is to be treated. It is not possible to run a mine intelligently without achieving whatever economy there may be in dressing the ore so that the further handling will be facilitated. Efforts to make "records" of low costs per ton have in many cases actually resulted in good mines being run at a loss. In this connection I can do no better than repeat some remarks from an article published in the *Engineering and Mining Journal* some years ago on "Mining Costs at Cripple Creek."

"Let us take as a practical example a body of 10,000 tons of ore, running 1 oz. gold per ton. This ore can be shipped without sorting at a handsome profit, as follows:

Gross value of ore	$200,000
Cost of mining 10,000 tons at $3 per ton	$ 30,000
Freight and treatment, $8.25	82,500
Total cost	$112,500
Profit	$87,500

"But suppose we reject half of this ore by sorting. By so doing we throw away 5,000 tons that will average $2.50 per ton, or $12.500. The cost of sorting, at 50 cents per ton, will be $2,500 more. Then our shipment will be as follows:

5,000 tons, at $37.50 per ton	$187,500
Cost of mining and sorting, $6.50 per ton	$ 32,500
Freight and treatment, $11.25	56,250
Total cost	$ 88,750
Profit	$ 98,750

"In other words, the gross receipts in this case have fallen $12,500. The cost of mining per ton is more than twice as great; the cost for freight and treatment per ton is $3 greater. The apparent showing by the superintendent is very bad; but nevertheless he has made for the company $11,250 clear profit on the transaction.

"In the first case our total cost for mining, freight, and treatment is only $11.25 per ton; in the second case it is $17.75 per ton, but there is more money in the higher cost. This is an example that has been worked out in practice."

A false economy often results also from mining too much in a mere attempt to produce a greater output than the development of the mine really warrants. This invariably results in mining waste at a dead loss, but as this loss is on the same basis as the above, there seems no need to follow the discussion further.

Effect of Losses in Determining Costs

Mining, milling, and smelting losses often foot up to a total that is simply alarming. Now since it is almost self-evident that crude methods involving high losses may be cheap as regards operating costs, there is always likely to be a question whether there is any economy in low costs obtained at the expense of undue waste, or whether, on the other hand, high efficiency of methods may not be at the expense of excessive cost. I think it has seldom been considered that there are such substantial losses in each department of the business. If we hear a discussion of mill losses in a given district it is to be noticed that the question of mine losses is apt to be ignored; if attention is called to mine losses there is apt to be silence on the subject of smelting losses. It seems desirable, therefore, to draw attention to some of the salient facts in regard to losses.

There never was a mine from which all the available ore was extracted. The ore is exposed to wastage from a variety of causes. If the orebody is large, soft, and homogeneous, as in the Lake Superior iron mines, ore is lost through absolute failure to mine it. Some is forgotten until the openings to it are caved and lost. Some ore is constantly being mixed with sand or rock and left because its grade has been lowered. Some is surrounded by the caving of the overburden into the mine openings in such a manner as to be irrecoverable. System, care, and expense will do much to diminish these losses. It may happen that beyond a certain point the cost of perfecting the extraction may increase very rapidly, may indeed necessitate a different and more costly method of mining.

Since mines are worked for the profit and not for the gross value of their output it may be more economical to choose a cheap method in which the waste of ore may be great. For instance, suppose an ore worth $2 a ton can be mined with a 90 per cent. extraction for $1.25 a ton, but that by another method at a 75 per cent. extraction, it can be mined for 90 cents a ton. One hundred tons of ore in the ground would in the two cases yield the following results:

Ore worth $2 per ton

	Tons	Cost	Value	Profit	
First case........	90	$112.50	$180.00	$67.50	
Second case......	75	67.50	150.00	82.50	= $15 gain.

ORE WORTH $5 PER TON

	Tons	Cost	Value	Profit	
First case........	90	$112.50	$450.00	$337.50	
Second case......	75	67.50	375.00	307.50	= $30 loss.

It is evident, therefore, that even in the most homogeneous materials the cost of mining is directly affected by the value of the product.

SMYTH'S FORMULA

Prof. H. L. Smyth works out the mathematical expression for the proportion of the deposit that may be abandoned in order to secure a lower mining cost per ton as follows:

Let Q equal the total number of tons of ore in a deposit recoverable by the most perfect method; X, the number of tons abandoned by any other method; p, the profit per ton by method Q; and p', the profit by the other method. When $(Q - X)\ p'$ equals $Q\ p$, the two methods are equally desirable. Therefore,

$$\frac{p}{p'} = \frac{Q - X}{Q},$$

and

$$\frac{X}{Q} = 1\left(\frac{1 - p}{p'}\right) = \frac{p' - p}{p'}$$

Then $p' - p$ equals the saving per ton effected by the second method. The proportion of the deposit that may be sacrificed therefore depends on the ratio of the saving to the profit per ton. This ratio increases as the profit diminishes; therefore for a given saving a larger proportion of ore of low value may be sacrificed than of high value.

OTHER CAUSES OF LOSS

In flat deposits in hard rock it is nearly always necessary to leave some ore in pillars. Where the deposits are steeply inclined some ore is usually left in pillars unless the body is exceedingly small. In the case of very large bodies of low-grade ore, like the Alaska-Treadwell, large amounts are left in this manner, not only to insure the safety of the mine but also to insure cheapness of working. In every case where pillars are left there is a likelihood of portions being ultimately lost.

Where ores are sorted, *i.e.*, where they are not homogeneous, some good material is always rejected through ignorance or carelessness. Where filling is introduced into a stope there is invariably a certain amount of good ore that falls in with it and is lost. Where low-grade ores are sorted out and stowed underground because they cannot be shipped and treated except at a loss, there is a great loss of metallic value, but since it cannot be said that such material is payable it cannot under present conditions be called a loss.

These mining losses are, I believe, seldom measured. More or less accurate guesses are made by the engineers on the ground, but the losses in mining are almost never seriously reported. In a general way we may place mining losses at from 5 to 30 per cent. of the developed ore.

Losses in Milling and Smelting

Milling losses are in some localities painfully and accurately studied; in other places they are casually guessed at or ignored. It is usually fashionable to guess the extraction at 80 to 90 per cent. for concentrating and at about 95 per cent. for cyaniding or chlorinating. Sometimes, as a matter of fact, losses in concentration amount to 40 per cent. or even more. When the milling is not systematically and accurately checked the losses as a rule are much higher than the owners imagine. Little definite information is to be had.

Smelting losses are probably determined much more accurately than either mining or milling losses, but they are almost never mentioned in reports to stockholders. In this department of the business it is necessary to take more or less general statements of metallurgists.

The importance and economic bearing of the losses sustained in some representative districts are shown in an accompanying table. Much care must be exercised in the interpretation of these figures for economic purposes. The values thrown away are theoretical values. The practical limit of extraction invariably falls short of 100 per cent. The real purpose of the table is to show in current practice the debatable ground in which the curtailment of losses is confronted by a rising scale of costs.

PROPORTIONATE RECOVERY AND LOSSES IN 100 TONS OF ORE IN SOME IMPORTANT MINING DISTRICTS

	Pittsburg Coal	Lake Superior Iron	S. E. Missouri Lead	S. W. Missouri Zinc	Lake Superior Copper	Cripple Creek Gold
Gross value in the ground	$110	$800	$460	$500	$280	$1000
Gross value recovered by mining	88	$600 to 760	400	$375 to 475	246	$850 to $950
Gross value recovered by milling			$300 to $340	187 to 300	186	782 to 912
Gross value recovered by smelting		550 to 744	270 to 332	163 to 260	180	840 to 940
Gross aggregate losses	$22	$56 to $250	$128 to $190	$240 to $337	$100	$60 to $160
Per cent. recovered	80	70 to 93	58 to 72	33 to 52	64	78 to 94

The aggregate losses represent the maximum of additional operating expense theoretically justifiable by the extinguishment of losses.

It has been shown in the case of Cripple Creek ores how a mining cost may be too low, and it may be shown in the same way that milling and smelting costs may be too low. As a matter of fact they are very apt to be too low; rather more often too low than too high. Nevertheless it is perhaps well to point out that the economical cost is always a function of the value of the product. Of the various products of mines gold is the only one whose value is fixed. Where the product is variable in price the proportion of the losses is constantly changing, and the amount of expense warranted by the pursuit of such losses also varies. Since the operation of a mine, mill, or smelter is usually a thing that does not lend itself to a ready adjustment, we find that refinements of methods designed to limit losses are fixed to those that will be economical at rather low prices. For instance, we find copper plants are planned to make savings that will be economical at 13-cent copper instead of at 25-cent copper; lead plants are planned for 4-cent lead and not for 6-cent lead, etc.

WASTE IN EXPLOITATION

At this point it may be pertinent to remark that questions of mere economy and profit may come into conflict with public policy. Much has been said about the necessity of conserving the forests of the United States. A forest when denuded is not beyond the possibility of ultimate replacement; an orebody or a coal seam, on the other hand, once destroyed is gone forever. It is very likely out of the sphere of the Government to interfere in the disposition of properties that have passed to private ownership, but it is quite feasible for the Government to take measures to prevent undue waste in the exploitation of the lands that it still retains; and it seems fully worth while for large private proprietors to consider the future as well as the present and to take measures to prevent some of the shameful wastes that are going on.

For instance, no one will deny that ultimately the world will need every ton of coal that can be had. Future generations will be very glad to mine coal from 2-ft. seams, many of which are now utterly destroyed by the working out of thicker seams not far below them. Similarly, it would seem worth while for land owners to bring pressure to bear in the working of metal deposits like those of southwestern Missouri where there is a waste of at least 50 per cent. of the zinc, and at Lake Superior where there is an enormous waste of low-grade iron ores which have been caved in and left behind during the extraction of richer portions. Wherever the introduction of these economies in material can be effected without financial loss, their introduction can do the operators no harm and will certainly be a benefit to the land owners and to the public at large.

Statement of Mining Costs

A true statement of mining costs, therefore, should with due consideration of the above factors fall under the following headings:

(1) General expense of the company		1
(2) Mining	Exploration and development	2
	Stoping cost	3
	Stoping and sorting losses	4
	Amortization of mining plant	5
(3) Milling	Transportation to mill	6
	Operating costs	7
	Losses	8
	Amortization of milling plant	9
(4) Smelting, refining and marketing	Transportation to smelter	10
	Operating costs	11
	Losses	12
	Amortization of smelting plant	13

Unfortunately it is impossible to treat the subject so comprehensively owing to the absence of adequate reports. Most companies are ignorant of both their costs and their losses; some know their costs but do not know their losses; very few know both. Some of the most scientifically managed concerns, like the American Smelters Securities Company, issue very few reports, although the management of this company does publish one report, that of the Esperanza Limited, which tells the whole story, but even in that model statement there is no specific reference to the amortization costs nor to mining and smelting losses.

Where a company does not own a mill or smelter it cannot, of course, state details for any amortization charges or operating costs or losses for those departments. Nevertheless, these things cannot be ignored either scientifically or commercially. Charges for them are fixed by contract. When a mine sells its ore to a smelter it pays commercially for amortization and operation of the smelter under treatment charges and for the losses by arbitrary deductions.

In the absence of such reports as will give the essentials the most feasible plan of treating the subject seems to be to divide the costs into three main headings: (1) Mining, including development; (2) milling, including transportation from mine; (3) smelting, refining, and marketing, including transportation from mill and to markets.

Generally the reports, or reliable information, are sufficient to give a fairly close approximation to the costs. It is seldom indeed that any statement can be found showing the charge to be made under each of these headings for amortization of plants, but there is usually some means of getting an idea of it. This can be done many times by simply ignoring credits to capital on construction accounts over a considerable period of years. This can be done on the logical principle that since the construction is all for the benefit of the operation of the mine it should all be absorbed in operating accounts. It will hardly be advisable to give in all cases the sources of information on which the cost estimates are based; but it is possibly worth while to assert that the figures are not far from the truth in spite of certain differences from published statements.

Management

In discussing the factors that determine the cost of mining I have touched thus far only upon the tangible and definite ones of whose importance we can get a more or less logical measure; but the discussion would not be complete without some mention of the intangible and unmeasured but important factor of management. I wish to apply the term in its broadest sense and include in it the financing of an enterprise, the determination of its scope, the selection of its methods, and its administration.

To begin with, it is noticeable that enterprises in a given district have much in common and are apt to differ in methods from the enterprises of other districts. For instance, in Cripple Creek it is rare for a mining company to treat its own ores, while in Butte most companies have done so; in the Lake Superior copper mines the underground work is done largely by contract with the miners, while in Arizona this is exceedingly rare, and so on. Each district has its own peculiar methods.

There is a probability that the methods of a given district are pretty nearly correct because they are inevitably the result of experiment, or evolution, and the fit have survived. It is logical to expect this. When a man comes into a district that is new to him and says that the industrial methods in use there are wrong, he does nothing less than declare that the thousands of people who have developed those methods are either ignorant or stupid or lacking in enterprise. Once in a thousand times he may be right; in 999 cases he doesn't know what he is talking about.

To illustrate how profoundly true this principle is even in the face of reasons to the contrary, I may be pardoned for relating an experience of my own: While traveling on the slopes of the Andes in Ecuador ten years ago I noticed that my traveling companion, a Spanish-American, did not wash or bathe, but carried in his vest pocket a small bottle of camphor with which he occasionally rubbed his nose. Whenever we came to a stream I would very likely take a bath. To this Rodriguez objected vigorously, saying, "If you want to live in this country, without getting the fever you must observe two rules, namely, sleep in a closed room, and don't bathe out of doors." I told him, and thought, that the true laws of health demanded fresh air and cleanliness, and probably every Anglo-Saxon would have said the same thing. But, on returning to this country a few months later, I heard of the mosquito theory of malaria and saw a new light. Rodriguez was right. Observation had taught the natives empirically two ways of keeping off mosquitoes and fairly effective ways. They could not give the reasons but they got results. It is quite true that a mosquito net is just as good as a coat of dirt to ward off the fever-bearing insect, and that by means of it one may also enjoy the luxury of fresh air; but the point is the *mosquito must be kept out.* The person who does not realize this is running a risk of death from sheer ignorance. The same thing may be said of superficial criticism of customs in general and of mining customs in particular. There is very apt to be a "joker" in the game for the rash innovator and he may find himself and his new methods up against a hand of five aces.

I feel, therefore, that, as a general rule, it is unfair and stupid to measure the methods of one district by the standards of another, but this does not mean that the methods in use are always the best. Among operators in the same district, where all are equally conversant with the governing factors of the situation, we will invariably find some who get better results than others. We will find, running side by side, mines that show great and apparently inexplicable differences in cost. We will find in any district examples of mines that have failed under one management and succeeded under another. While the effect of management is well understood by every one, it does not lend itself to expression in figures; nevertheless there are some things that may be said of it of a nature pertinent to this discussion.

One thing has been noted as a rule; viz., rich mines cost more to run than low-grade mines. It is generally conceded that this is to be explained by the liberality of the carefree. There is something more than this. Suppose two deposits are found 20 miles apart, one of ore worth $5 a ton, and the second worth $2 a ton. The first is opened up by the first method that occurs to the owners, the ore is shipped and it is discovered that it costs $3 a ton to mine it. The owners congratulate themselves on their 40 per cent. profits. Their business is established; they are making lots of money; to make changes and improvements is laborious, expensive, may involve delay in marketing the product and may not turn out well after all. Why not leave well enough alone?

The second body of only $2 ore, after being opened up, is left alone for a while. It is considered too low-grade to pay. But some enterprising person at last comes along who thinks it may be worked. He chooses for a superintendent, not the first man he meets, last of all some friend or relative but some one he thinks able to get results. All possible methods are studied in order to choose the cheapest. All possible precautions are used to avoid unnecessary expenditures on plant. Every employee is impressed with the necessity of efficiency. After the enterprise is finally going it proves that the ore is being mined at $1.20 per ton and the triumphant owner of the $2 ore also secures 40 per cent. profit on his product.

Logical Reason for Rich Mines Costing More

There may be no physical reason for this difference in cost; there may be no intentional liberality on the part of the owners of the richer property. Nevertheless, there is a logical ground for a difference in the selection imposed by necessity. In the rich mine there is no necessary selection; *ergo* there is no selection. We may, therefore, count on a certain increment, sometimes very large, sometimes very small, of additional expense in mining rich ores as compared with poorer ores.

Necessity may work vast economies in the same mines. The Champion iron mine at Beacon, Mich., was producing ore in 1892 at $2.50 a ton. It had then been running 25 years and was reputed to be a very well managed mine. In 1899, the mine was deeper, the orebodies smaller, wages the same, the plant the same, the management the same, but the ore only cost $1.25 per ton. Necessity had worked this change through the panic of 1893. Similar changes were wrought in other mines.

Hoover's Theorem

The economic ratio of treatment capacity of ore reserves is a question that has been brought up by H. C. Hoover and vigorously discussed by many prominent engineers. Ross E. Browne ("Working Costs on the Witwatersrand") has recently brought additional evidence to bear out the correctness of Mr. Hoover's conclusions that economically mines should be worked out with great rapidity and that additional plant should be provided for the extraction of discovered ores within periods of from three to six years. There seems to be no doubt of the mathematical correctness of this conclusion, but it seems to apply logically only to gold mines where there is no practical limit to the sale of the output. In the mining of products other than gold it seems that a limitation is put upon the output by the market. In the case of Lake Superior iron ores, for example, there are fifteen hundred million tons in sight. To work these all out and convert them into pig iron in six years is not only a physical impossibility, but would be economically absurd. It is not at all absurd, however, for an isolated operator among many to apply this principle to his own profit. It may be that the application of this very principle has resulted in the formation of gigantic trusts. It seems probable that the growth of the Carnegie Steel Company in competition with its neighbors may have been largely due to the application of this idea to steel manufacturing; but in course of being fully worked out, the result was the formation of the United States Steel Corporation which now controls 75 per cent. of the iron ores of Lake Superior and from mere extent of growth has landed in a position where the application of Mr. Hoover's principle is no longer possible.

Economy and Speed

It is to be remarked in this connection that a wide-awake manager may see his way clear to overlook questions both of a high percentage of extraction and of cheap work to reap the benefits incident to speed. Take, for example, a body of soft iron ore of limited cross-section pitching rather steeply into the earth. The requirements of thorough extraction and cheap working would very likely be satisfied by the use of the slicing system of mining, but in such a case the volume of product would be limited because the area on which slicing can be conducted is practically limited to a single horizontal section of the orebody. This limitation of the product during years of high prices might be a very serious handicap and it would probably be wise to adopt a different system, perhaps less effective and more costly, but which would allow the working of a number of levels at once and the turning out of a large output at an advantageous time.

The management of large properties may come into conflict with public economy in the following way: Large sums of money are locked up in the purchase of great tracts of mineral lands, far in excess of the requirements of the immediate future. The sums thus invested are usually raised by bond issues and the interest on these, together with taxes, amount annually to large sums which the public must pay. These charges are inevitable, and are quite independent of any desire on the part of such holders to raise prices through the opportunities afforded by the existence of partial monopolies. Conspicuous examples of this state of affairs are afforded by the United States Steel Corporation, especially since it has absorbed the Tennessee Coal, Iron, and Railroad Company, and by the Philadelphia & Reading Coal and Iron Company. Both of these great corporations have mineral lands sufficient to guarantee their product far into the future, but they represent investments on which charges of many million dollars a year must be paid, and paid by the public.

CHAPTER III

PARTIAL AND COMPLETE COSTS

Terminology and method of analysis — Partial and complete costs — Operating, maintenance, depreciation, and amortization — Dividend costs and selling costs — Examples of depreciation — Analysis of cost statements — Amortization tables — Table of plant cost per annual ton and life of mines — Investors' precautions.

I KNOW from experience that many operating men, though deep in details, are only acquainted with partial costs. Their point of view does not reach the *tout ensemble.* For instance, a man may be in charge of a mine and called manager or superintendent. His business ends when the ore is delivered into cars to be shipped to the mill. Up to that point he thinks he is familiar with the costs. Probably he is not, though he may be. It is more likely that he knows little or nothing about the capital invested in the mine and the average annual value of it. He is probably full of information about the current operating costs of his one department — the mine. He does not know what is involved in transportation to the mill, in milling, in smelting, in general expense. His knowledge of the business as a whole is very limited. In talking with other mining men he may be elated or depressed at learning that his costs are lower or higher than theirs, but he may find out later that he has reasoned from false premises. He is really talking about a segment of the business to men who are also talking about segments of the business, and the segments may be, and are very likely to be, different in each case.

Now such a man is very apt to graduate into a mining engineer and to examine mines and report on them without once giving consideration to the limitations he is under. He repairs by experience some of his misapprehensions, but his conception of the business is very likely to remain only a partial conception;

at the best he is clear about only a part and hazy about the rest.

The costs reported to stockholders and investors are very apt to be only partial costs. They are almost never so expressed as to give one a true understanding of the business. This may not be intentional; merely a narrow view of the financial realities. In the following chapters I shall review the statements of many mining companies and it will be seen that I have reconstructed nearly all of them, putting my own interpretation upon their figures and in many cases rejecting their figures as inadequate and substituting others. I would not be rash enough to do such things without reason. It is in every case merely drawing an irresistible conclusion, such conclusions as no two men would argue about so long as they had the same point of view. I propose here to describe my method and point of view in cost analysis; but first I shall define certain expressions that are in common use in this discussion.

There is a certain confusion in the use of the terms, *operating*, *maintenance*, *depreciation*, and *amortization*. In this book I intend to have a perfectly clear meaning for three of these terms. *Maintenance* is a term to which I attach little importance. It is simply the cost of keeping things in good order and is an undeniable operating item. I shall assume under all circumstances that maintenance is included under the head of operating.

Operating, or current operating, charges are those that relate to the obtaining of product. It includes all the labor, salaries, and supplies used on the actual yield of a mine for a limited period, but excludes all charges that may be a preparation for a yield to be obtained later. Note that I say "for a limited period"; for I make it a cardinal and self-evident axiom that whenever we extend our point of view to the whole life of a mine or property, we immediately abolish the difference between operating and capital costs. Then *all* expenses are operating expenses.

The capital charges of *depreciation* and *amortization* are only suspense accounts intended to exhibit the difference between operating for a short period and operating for the whole period. Now unless we are holding a post-mortem examination on a dead mine we never know just what the difference is. These items then are estimates, and I feel it necessary, in order that one may understand my cost analyses, to explain carefully how I make these estimates.

Frequent reference will be found in coming chapters to *dividend costs* and to *selling costs.* By selling cost I mean the real or complete cost, the cost at which the product must be sold to justify the enterprise. It includes the whole cost, including all capital employed, with interest for the whole period of operating. Obviously, if these total expenditures amount to say $10,000,000 and the total return is only $9,500,000, the enterprise is not a successful one. But suppose that of the ten millions spent, the sum of three millions is represented by two millions spent on initial plant and one million for interest on that sum at 5 per cent. for 10 years during which there were no dividends. These three million dollars are not operating charges, at least they are not the current daily operating charges that the mine manager knows about. His operating charges are only $7,000,000, while the proceeds are $9,500,000. Here we have $2,500,000 to be paid in dividends. Here our *selling cost* is $10,000,000. Our enterprise is really and truly a failure unless our returns equal that amount. But our dividend cost is only $7,000,000. This sort of a difference is practically universal in mining cost statements. I never knew of one in which the real selling cost was calculated.

As a general rule the cost of production is understated much more than it would be in this case if it were given at 7 instead of 10. Why is this? Because 7, the dividend cost, is in itself a composite figure. It consists of two elements: (*a*) those costs that plainly belong to merely getting out the product, and (*b*) some other costs that seem to be creating something permanent, but really are not. These things are apt to be euphemized into "capital charges." In our hypothetical case our 7, being the dividend cost, is very apt to be made up of the figures 5 and 2; the first being "working charges" and the second being "construction." This construction seems to be permanent; it is "doing great things for the property," "working wonders." In fact it is absolutely essential; but it must be paid for before dividends appear, and therefore is included in the dividend cost: but our euphemistic report gives the working cost, the cost of production, at 5.

Remembering that we found at the very beginning that the real cost was 10, we must explain that the difference is made up of *amortization* and *depreciation.* Amortization accounts for the difference between 10 and 7, depreciation accounts for the further difference between 7 and 5. The omission of these sums may not, possibly, be of any injury to any one; but it certainly results in an outrageous underestimate of costs.

By *depreciation,* then, I mean current construction costs; improvements. Until a mine is dead and ready to be buried in a watery grave there are always expenses of this kind. Depreciation means literally the process of losing value: practically it means the exact opposite; it means expenses undertaken to counteract loss of value. I hear it asked, why is this not maintenance? It *is* maintenance. It only *seems* not to be maintenance because the items that compose these charges have the appearance of being new plant, not merely replacements of old plant. I shall give some examples.

Let us suppose a mine to be started on a very large tract of land (to avoid all complications except natural ones, let us get rid of our neighbors), with a vein running north and south and dipping vertically. Two shafts are started, a mill erected and the property put in operation. At the depth of 500 ft. the south shaft runs out of the ore. The manager is alarmed, the directors thunderstruck. But the north shaft is in good ore at 700 ft. Ah! we have an ore shoot pitching north! Every level goes farther in that direction than the one above it. A new shaft must be sunk, No. 3, further north. It must be sunk 1500 ft. at a cost of $150,000 before it produces anything. The south shaft barely lasts till No. 3 goes into commission. You may be sure that this situation is fully explained to the stockholders. No. 3 shaft is "capital expenditure," etc., etc. "It will not be necessary to undertake anything of the kind again!"

This statement is utterly misleading. The construction and equipment of No. 3 shaft is pure depreciation — an expenditure that should be written off to operating as fast as it is made. No. 3 does nothing but take the place of the south shaft.

Again, our original north shaft has reached the bottom of the ore. "We have again been disappointed. It was unfortunate that we equipped No. 3 as we did," I might quote from an imaginary, but very frequent, report, "because certain unforeseen conditions have arisen that make it evident that a different plant would have served our purpose better. It is found now that the ore shoot has a pitch averaging 45° to the north along the plane of the vein. Evidently a shaft inclined to the northward at that angle would follow the ore. A single shaft like that would accomplish our purpose as well as a number of vertical ones, or a series of long drifts from a single vertical one. Moreover, we find that at the 1500-ft. level of No. 3 shaft the vein, instead of standing vertical as it has above, is now dipping to the west at an angle of only 45°. After mature consideration it has been decided that our best course will be to put a curve in No. 3 shaft and change it into an incline below the 1500-ft. level, following the oreshoot in a northwesterly direction. This will necessitate changing our equipment. Our flat rope hoist, designed for handling cages in a vertical shaft. must be replaced by a round rope engine with a drum. We must install skips, for which our engineers assure us it will be best to cut underground loading pockets." It is useless to proceed further, except to explain that here is another great capital expenditure "that will never occur again." It is pure depreciation. It isn't even new. It is the same problem that caused the sinking of No. 3 shaft. The solution, however, appears new.

I could cite "capital charges," "construction" or whatever it is called, in hundreds of cases like the above. The same thing appears in all kinds of disguises. There are always expenditures going on that appear to be for permanent improvements, really are for permanent improvements, but which are really nothing but expenses required to keep the property from depreciating; in other words, to enable it to be a good plant and not get antiquated, or no longer adequate to changed requirements. Money is even spent uselessly, often merely for fashion; for fashion is so far from being confined to women's finery that it reaches the methods and appliances in the gruesome depths of mines.

I would not be misunderstood about these charges. Sometimes construction that amounts to nothing but depreciation is combined with construction that does make a real addition to capacity and earning power and is truly capital. Obviously it is impossible for me to familiarize myself thoroughly with all such circumstances. I am not trying to go into niceties. My purpose only is to exhibit the mining industry in its broad and fundamental outlines, unobscured by detail. It is necessary, therefore, to explain that in the analyses of costs in the following chapters I have not followed any exact rule. My analysis is founded on the circumstances exhibited by the reports. These, however, fall into two general groups: rich mines that have built up their plants entirely out of profits or in which at least there has been a continuous growth so that the original capital is only an insignificant fraction of the total investment; and low-grade mines not rich enough to start themselves and not profitable enough to make the original investment soon disappear. In the first case I make no attempt at calculating amortization, but adopt the much simpler method of writing off all expenditures, over as long a period as I can get figures for, to the cost of the production. In the second case I charge all expenditures of every kind to capital up to the time when the mine is producing. After it is producing I charge to capital those expenditures made to increase the capacity until the mine has reached what appears to be an average production. Then this total is written off, with interest, over a period that seems reasonable, by charging up each year a sum calculated to retire the investment within the required time.

This charge is the *amortization* of capital.

Ordinarily I put the period of initial capital expenditure as far back as possible and, unless the increase of capacity is very considerable, I charge off the yearly new construction to operating and call it *depreciation*. It seems hardly necessary to go more into detail because in most cases those who are interested will see from the cost analyses themselves the method adopted.

A word further about amortization. When the sum to be written off is determined it is necessary to fix two further elements: the rate of interest to be charged and the period in which the principal must be extinguished. The first I have taken in all cases at 5 per cent. The second is the great field where judgment and experience come into play; wherein the mining business exhibits its peculiarities and where it is different from any other form of commercial enterprise. We must discuss it fully, but first let us show the methods by which amortization may be calculated. One way is shown by the following table in which a sum of money is returned to the investor in equal instalments, which are supposed to be part interest and part principal. The part that represents the return of principal for each year is deducted from the original sum, and for the next year interest is calculated only on the diminished principal; but, since the yearly instalments are equal, as the yearly interest requirements diminish the part applying to the return of principal will increase so that the extinction of capital becomes progressively more and more rapid.

AMORTIZATION TABLE. — 5 PER CENT.

Showing number of years in which $1,000 is cancelled at 5 per cent. annual interest and 5 per cent. amortization, or $100 annual instalment.

Years	Amortized	Interest	Balance Due
1	50.00	50.00	950.00
2	52.50	47.50	897.50
3	55.12	44.88	842.38
4	57.88	42.12	784.50
5	60.77	39.23	723.73
6	63.81	36.19	659.92
7	67.00	33.00	592.92
8	70.35	29.65	522.57
9	73.87	26.13	448.70
10	77.56	22.44	371.14
11	81.44	18.56	289.70
12	85.51	14.49	204.19
13	89.79	10.21	114.40
14	94.28	5.72	20.12
15	98.99	1.01	0.00

Another method of extinguishing capital by annual instalments is by creating a sinking fund which will increase by investment. The sum of the investment of annual instalments with accrued interest is supposed to equal the capital at the end of the required period.

PRESENT VALUE OF AN ANNUAL DIVIDEND OVER —— YEARS AT —— PER CENT. AND REPLACING CAPITAL BY REINVESTMENT OF AN ANNUAL SUM AT 4 PER CENT.

Years	5 Per Cent.	6 Per Cent.	7 Per Cent.	8 Per Cent.	9 Per Cent.	10 Per Cent.
1	.95	.94	.93	.92	.92	.91
2	1.85	1.82	1.78	1.75	1.72	1.69
3	2.70	2.63	2.56	2.50	2.44	2.38
4	3.50	3.38	3.27	3.17	3.07	2.98
5	4.26	4.09	3.93	3.78	3.64	3.51
6	4.98	4.74	4.53	4.33	4.15	3.99
7	5.66	5.36	5.09	4.84	4.62	4.41
8	6.31	5.93	5.60	5.30	5.04	4.79
9	6.92	6.47	6.08	5.73	5.42	5.14
10	7.50	6.98	6.52	6.12	5.77	5.45
11	8.05	7.45	6.94	6.49	6.09	5.74
12	8.58	7.90	7.32	6.82	6.39	6.00
13	9.08	8.32	7.68	7.13	6.66	6.24
14	9.55	8.72	8.02	7.42	6.91	6.46
15	10.00	9.09	8.34	7.79	7.14	6.67
16	10.43	9.45	8.63	7.95	7.36	6.86
17	10.85	9.78	8.91	8.18	7.56	7.03
18	11.24	10.10	9.17	8.40	7.75	7.19
19	11.61	10.40	9.42	8.61	7.93	7.34
20	11.96	10.68	9.65	8.80	8.09	7.49
21	12.30	10.95	9.87	8.99	8.24	7.62
22	12.62	11.21	10.08	9.16	8.39	7.74
23	12.93	11.45	10.28	9.32	8.52	7.85
24	13.23	11.68	10.46	9.47	8.65	7.96
25	13.51	11.90	10.64	9.61	8.77	8.06
26	13.78	12.11	10.80	9.75	8.88	8.16
27	14.04	12.31	10.96	9.88	8.99	8.25
28	14.28	12.50	11.11	10.00	9.09	8.33
29	14.52	12.68	11.25	10.11	9.18	8.41
30	14.74	12.85	11.38	10.22	9.27	8.49
31	14.96	13.01	11.51	10.32	9.36	8.56
32	15.16	13.17	11.63	10.42	9.44	8.62
33	15.36	13.31	11.75	10.51	9.51	8.69
34	15.55	13.46	11.86	10.60	9.59	8.75
35	15.73	13.59	11.96	10.67	9.65	8.80
36	15.90	13.72	12.06	10.76	9.72	8.86
37	16.07	13.84	12.16	10.84	9.78	8.91
38	16.22	13.96	12.25	10.91	9.84	8.96
39	16.38	14.07	12.34	10.98	9.89	9.00
40	16.52	14.18	12.42	11.05	9.95	9.05

Annual Rate of Dividend	Number of years of life required to yield — per cent interest, and in addition to furnish annual instalments which, if re-invested at 4 Per Cent. will return the original investment at the end of the period.					
Per Cent.	5 Per Cent.	6 Per Cent.	7 Per Cent.	8 Per Cent.	9 Per Cent.	10 Per Cent.
6	41.0	—	—	—	—	—
7	28.0	41.0	—	—	—	—
8	21.6	28.0	41.0	—	—	—
9	17.7	21.6	28.0	41.0	—	—
10	15.0	17.7	21.6	28.0	41.0	—
11	13.0	15.0	17.7	21.6	28.0	41.0
12	11.5	13.0	15.0	17.7	21.6	28.0
13	10.3	11.5	13.0	15.0	17.7	21.6
14	9.4	10.3	11.5	13.0	15.0	17.7
15	8.6	9.4	10.3	11.5	13.0	15.0
16	7.9	8.6	9.4	10.3	11.5	13.0
17	7.3	7.9	8.6	9.4	10.3	11.5
18	6.8	7.3	7.9	8.6	9.4	10.3
19	6.4	6.8	7.3	7.9	8.6	9.4
20	6.0	6.4	6.8	7.3	7.9	8.6
21	5.7	6.0	6.4	6.8	7.3	7.9
22	5.4	5.7	6.0	6.4	6.8	7.3
23	5.1	5.4	5.7	6.0	6.4	6.8
24	4.9	5.1	5.4	5.7	6.0	6.4
25	4.7	4.9	5.1	5.4	5.7	6.0
26	4.5	4.7	4.9	5.1	5.4	5.7
27	4.3	4.5	4.7	4.9	5.1	5.4
28	4.1	4.3	4.5	4.7	4.9	5.1
29	3.9	4.1	4.3	4.5	4.7	4.9
30	3.8	3.9	4.1	4.3	4.5	4.7

Let us now return to the problem of fixing the time for the amortization of invested capital. As remarked above, this is easy in the case of a worked-out mine. To do it accurately in the case of a living and prosperous mine is, frankly, impossible. But as this is a vital question for every investor it is absolutely necessary to give an answer, be it correct or not. For, whether the investor realizes it or not, he is always staking his capital on the probability of having it returned within a certain time. In other words, he is gambling on the life of the mine. If a man invests money in a mining stock which yields only 5 per cent. on

Kind of Material Mined	Name of District	Name of Property	Amount in Sight, Tons	Annual Output, Tons.	Life Guaranteed, Years	Reasonable Expectation of Life, Years	Reasonable Rate of Amortization. 5 Per Cent. Interest	Capital Employed per Annual Ton	Cost per Ton for Amortization	Cost per Ton for Depreciation Assuming 6 Per Cent. on Capital	Cost per Ton for both Amortization and Depreciation	Remarks
Bituminous Coal	Pittsburg	Pittsburg Coal Co.	1,200,000,000	16,000,000	75	75	5½	1.00	0.055	0.06	0.115	Plant only, cost of lands not considered.
	Pittsburg	Small Property	15,000,000	500,000	30	30	7	1.00	0.07	0.06	0.13	Plant only, cost of lands not considered.
Anthracite Coal.	Pennsylvania	Phila.&Reading	1,000,000,000	10,000,000	100	100	5¼	2.00	0.115	0.12	0.215	Plant only, cost of lands not considered.
Pig Iron........	Lake Superior	U. S. Steel	650,000,000	10,000,000	65	75	5½	32.50	1.897	2.07	3.967	Plant only, working capital not considered. I do not use these figures in cost estimates, believing that in this case the depreciation figures are excessive and are provided for in working costs.
Copper, Disseminated Ores...	Lake Superior	Calumet&Hecla	50,000,000	2,500,000	20	20	8	6.00	0.48	0.36	0.84	Plant only. This is only a theoretical estimate for future. This mine

													created its own plant, and in calculating its costs I have written off all plant expenditure to operating.
	Lake Superior	Copper Range	Not given	2,000,000	—	25	7	4.00	0.28	0.24	0.52		
	Utah	Utah Copper Co.	65,000,000	2,500,000	26	30	7	2.50	0.175	0.15	0.325		
Copper ores in fissure veins..	Butte, Montana	Anaconda	Not given	1,400,000	—	10	15	5.00	0.75	0.30	1.05		Plant only, crudely estimated.
	Globe, Arizona	Old Dominion	Not given	—	—	10	15	—	—	—	—		
Altered Pyrites..	Bisbee, Arizona	Calumet & Arizona	Not given	—	—	5	25	7.00	—	—	—		
" " ..	General	—	Very little	—	Uncertain	2–10	15–50	—	—	—	—		
Pyrites.........	Utah	Utah Consolidated	1,400,000	280,000	5	15	10	4.50	0.45	0.27	0.82		
Disseminated lead ores	S. E. Missouri	—	—	—	—	15	10	5.00	0.50	0.30	0.80		
									0.80		1.40		
Lead ores in fissure veins....	General	—	—	—	—	5–20	8–25	0.00	2.50	0.60	3.10		
Lead ores from altered sulphides	General	—	—	—	—	1–5	25–100	—	—	2.50	—		
Gold in quartz pyrite veins ..	Alaska	Treadwell	4,000,000	750,000	6	15	10	3.00	0.30	0.18	0.48		
	S. Dakota....	—	20,000,000?	1,500,000	13	20	8	3.50	0.28	0.21	0.49		
	S. Africa.....	—	100,000,000?	20,000,000	5	25	8	10.00	0.80	0.60	1.40		
Telluride ores...	Cripple Creek.	Portland	Not given	250,000	Uncertain	5	25	—	—	—	—		
	General	—	—	—	—	1–10	15–100	—	—	—	—		

the price he pays for it, and if at the same time he can get 5 per cent. on a well-secured bond, he must calculate that the mine is as permanent as the bond. If he gets a dividend of 10 per cent. and calculates that 5 per cent. is a sufficient interest on his money, it follows that he is counting on a life of at least fifteen years for the mine.

It happens that the probable life of mines varies between wide limits. In the case of coal, building stone, cement, iron ore (and in sporadic cases among precious metal ores), it has been proved possible to find enough ore in a few years to assure the life of the enterprise twenty or more years in advance. Of course the period of activity in sight is the minimum amortization period; the longer the period the more stable the investment, because the longer the life the greater the probability of equalizing vicissitudes. But in general the mines that can see ahead twenty years or more are rare. Many profitable ones have not a single year's ore in sight and yet the probabilities may be in favor of a considerable life. The only means by which one may form an opinion of the probabilities are acquaintance with the history of mines and ore deposits, and acquaintance with the state of development of the property, the rate of extraction, the ore in sight, and the soundness of the management. It will be quite useless to attempt here any discussion, that would have any approach to adequacy, of these factors. I can go no further than to give a table showing the length of life and rate of amortization that seem to me reasonable in a variety of cases. It is impossible to fill out the various factors even in all the cases to which I refer. The cardinal point for the reader's attention is the varying life estimate for various types of mines, and the highly variable rate of amortization that this estimate imposes.

How these Figures Interest the Investor

The question is often asked, What bearing do these theoretical or half-forgotten questions about capital originally invested, and its theoretical retirement, have for the investor who buys to sells stocks in mining properties at valuations that have not the slightest reference to the original investment or how it is disposed of? To this various answers may be given. I have already pointed out, but may as well repeat (it cannot be repeated too often), that exactly the same considerations apply to the extinguishment of the price paid for a share of stock, which is the form in which investment is made by the average man, as apply to the capital used to build a mill. To those who say that people who buy mining shares never think of such things I answer that this applies only to the "suckers." In some places they are more euphoniously called "lambs." The most important investors in mining property do, most emphatically, take these facts into consideration. It is no argument to say that mining shares are mainly used as counters in a game. That is partly true. That it is true at all, to any greater extent in the case of mines than for other securities, is due only to the fact that a portion of the public is imposed upon by false analogies. In other words, they are often induced to buy highly speculative mining stocks on the same income basis as they buy the soundest securities. The very mining shares that I have called "highly speculative" might in many instances at a sane valuation be just as "sound" as the soundest.

A sound business must be a paying business; one that is good for both interest and principal. The great fault with the mining business from the point of view of the moderate investor is that it is very easy for the sake of a fair amount of interest to lose the principal. There is no need of this. By studying out the vital question of the life of a mine with its concurrent rate of amortization, and by steadily refusing to believe that the current construction is "capital," one may eliminate overvalued properties pretty rapidly. It is a good rule not to buy stocks in concerns that are too wise to issue full reports. If there is any business in the world where a full knowledge of certain elemental facts is necessary for a safe and sane investment it is surely mining.

Furthermore, at the last analysis the price of a commodity must be governed by its cost. It is highly important, therefore, to know when prices are excessive and therefore unstable. It is one of the objects of this book to show what the cost of production on a grand scale in various important products of mines really is. In such computations the capital charges are a vital factor and I have thought it desirable to explain as fully as possible my conception of a proper treatment of them in order that the reader may be able to judge for himself the justness of my conclusions.

CHAPTER IV

STATISTICS OF COAL PRODUCTION

Growth of the coal industry in the United States — Production of the different states — Total production to end of 1907 — Prices of coal — Coal resources of the country — Coal production of the world.

THE following statistics on the production, growth, prices, and resources of the coal-mining industry of the United States is taken, with a few comments, from the pamphlet issued by the United States Geological Survey on the Production of Coal in 1907. It is not likely that any other statement to be had gives a truer perspective of the essential features of this business, which may justly be said to be one of the great fundamental elements of the prosperity of the nation. Nothing can be more important than that the public at large shall be acquainted with the real condition of this industry, for it is not unlikely that good public policy will require some changes in the conduct of it, and without the support of public opinion nothing beneficial can be done.

COAL STATISTICS

"The combined production of anthracite and bituminous coal in the United States in 1907 amounted to a little more than 480,360,000 short tons.

"With an average of 30 cars of coal to the train, and of 50 tons to the car, the number of trains required to transport this product was 320,300, and the combined length of these trains would extend two and two-thirds times around the world at the equator. The hole left in the ground by the extraction of this fuel is equal to 17,585,000,000 cu ft., and if the entire quantity of coal extracted were built into one cube, it would have the dimensions of 2605 ft., or nearly half a mile on each edge. A rectangular column with a 1000-ft. base to represent the coal production of the United States in 1907 would extend nearly 3.4 miles into the air."

"Some idea of the growth of the coal-mining industry within the last quarter of a century is shown by the fact that in 1907 the production was considerably more than double that of 1898, more than three times that of 1890, more than four times that of 1886, and considerably more than five times that of 1881.

"Compared with 1906, when the total production amounted to 414,157,278 short tons, valued at $513,079,809, the output in 1907 showed an increase of 66,206,146 short tons, or 15.99 per cent. in quantity, and of $101,719,089, or 19.83 per cent. in value. Of this increase, 12,787,412 long tons, or 14,321,901 short tons, were in the production of Pennsylvania anthracite, and 51,884,-245 tons in the production of bituminous, semi-bituminous, sub-bituminous, lignite, and scattering lots of anthracite. The value of the Pennsylvania anthracite production increased $31,666,362, and the total value of the other grades of coal showed an increase of $70,052,727. It is worthy of note that of the 31 states and territories of the Union in which coal was produced during 1907, there were only two which did not participate in the general increased production. The two exceptions were California and Oregon, both unimportant as coal-producing states, both on the Pacific coast, and the decrease in both states being due to the same cause — the largely increased production of fuel oil in California and its use for railroad and manufacturing purposes. The percentages of increase in the various states ranged from 1.79 in Maryland to 51 in Michigan, and in only three cases where the production increased was the percentage of increase in value less than the percentage of increase in quantity. These three exceptions were Alabama, Illinois, and Indiana. The largest increase in quantity was in the production of Pennsylvania bituminous coal, which showed an increase of 20,849,971 short tons, with a gain of $25,373,375 in value. Pennsylvania anthracite showed the next largest gain in quantity, the increase in this output being 14,321,901 short tons, while the gain in value exceeded that of Pennsylvania bituminous coal, amounting to $31,666,362. The total increase in Pennsylvania's production was 35,171,872 short tons, while the aggregate value of Pennsylvania's production showed a gain of $57,039,737. Illinois, the second state in coal-producing importance, was second in increased production, with a gain of 9,837,042 short tons in quantity and $9,924,320 in value. West Virginia, the third in producing importance, was third in increased production, with a gain of 4,801,233 short tons in quantity and $6,794,691 in value. Ohio, fourth in rank, was fourth in amount of increased output, showing a gain of 4,410,779 short tons and $4,978,166. The total increase in the production of anthracite and bituminous coal in the United States in 1907 was about 10 per cent. larger than the total coal production in 1877, thirty years before.

"An interesting fact presented by the statistics of the production of coal in the United States is that in each decade the output has been practically doubled. Up to the close of 1865 the total production had amounted to 284,890,055 tons. In the decade from 1866 to 1875, inclusive, the production amounted to 419,425,104 tons, making the total production up to the close of 1875, 704,315,159 tons. In the following decade, from 1876 to 1885, inclusive, the production amounted to 847,760,319 tons, something more than double the total production up to the beginning of that decade. At the close of 1885 the total production amounted to 1,552,075,478 tons, and the production for the 10 years ending with 1895 was 1,586,098,641 tons, and the total production at the close of 1895 amounted to 3,138,174,119 short tons. In the decade ending December 31, 1905, the total production amounted to 2,832,402,746 short tons, and the grand total from the beginning of coal mining amounted to 5,970,576,-865 short tons. The average annual production from 1896 to 1905 was 283,240,275 short tons, compared with which the average production in 1906 and 1907 (447,260,351 short tons) shows an increase of 164,020,076 tons, or 58 per cent.

"This great increase in the production of coal, when considered with the increase in the population, furnishes some further interesting comparisons. Going back for a period of a little over 50 years, or to the middle of the last century, and comparing the statistics of coal production with the increased population, it is found that in 1850, according to the United States census for that year, the production of coal amounted to 6,445,681 tons, when the population of the country amounted to 23,191,876 persons. The per capita production of coal in that year is thus seen to have been 0.278 ton. In 1860, or 10 years later, the population was 31,443,321 persons, and the coal production amounted to 16,139,736 tons, or an average of 0.514 ton per person. At the census of 1870 the population of the United States amounted to 38,558,371; the coal production in that year amounted to 36,806,560 short tons, a per capita average of 0.96 ton. Ten years later, when the population was 50,189,209, the coal output amounted to 76,157,944 short tons, or 1.52 tons per capita. In 1890 the population had grown to 63,069,756, an increase of 25 per cent. over 1880, while the coal production had grown to 157,770,963 short tons, or a per capita output of 2.52 tons. At the taking of the Twelfth Census, in 1900, the increase in population amounted to 22 per cent., the total number of persons reported being 76,303,387, while more than 70 per cent. had been added to the coal production, with a total of 269,684,027 short tons, or an average of 3.53 tons for each inhabitant. In other words, while the population from 1850 to 1900 showed an increase of 230 per cent. the production of coal increased 4,084 per cent. The Director of the Bureau of the Census, Hon. S. N. D. North, estimates the population of the United States on June 1, 1907, at about 85,500,000 persons, making the per capita production in that year 5.6 tons; that is, in less than 60 years the per capita production of coal in this country has increased from a little more than a quarter of a ton to 5½ tons. It is true that in the earlier years the proportion of wood used for fuel was larger than it is to-day, but the actual consumption of wood at this time is little, if any, less than it was 50 years ago, and is probably greater. It must also be remembered that in addition to the great increase in the consumption of coal per head of population there has been a great increase in the use of oil for fuel purposes, while natural gas still remains an important factor in this regard.

"The total number of men employed in the coal mines of the United States in 1907 was 680,492, against 640,780 in 1906 and 626,035 in 1905. Of the total number of men who were employed in 1907, 167,234 were employed in the anthracite mines of Pennsylvania, while the bituminous and lignite mines gave employment to 513,258 men. In 1906 the anthracite mines gave employment to 162,355 men and in 1905 to 165,406 men. The bituminous workers numbered 478,425 in 1906 and 460,629 in 1905. The average number of days worked in the anthracite region in 1907 was 220, against an average of 195 in 1906 and 215 in 1905. The bituminous mines worked an average of 234 days in 1907, 213 days in 1906, and 211 days in 1905. The average production for each employee in the anthracite region of Pennsylvania in 1907

COAL PRODUCTION OF THE UNITED STATES IN 1907, BY STATES AND TERRITORIES, IN SHORT TONS

State or Territory	Loaded at Mines for Shipment	Sold to Local Trade and Used by Employees	Used at Mines for Steam and Heat	Made into Coke	Total Quantity	Total Value	Average Price per Ton	Average Number of Days Active	Average Number of Employees
Alabama	11,144,452	216,547	522,793	2,366,662	14,250,454	$18,405,468	$1.29	242	21,388
Arkansas	2,556,226	22,715	91,497	—	2,670,438	4,473,693	1.68	190	5,085
California and Alaska	14,265	6,014	3,810	—	24,089	91,813	3.81	187	76
Colorado	8,409,624	258,069	296,279	1,826,264	10,790,236	15,079,449	1.40	258	14,223
Georgia	204,890	5,780	10,700	141,031	362,401	499,686	1.38	262	808
Idaho (a)	300	7,278	10	—	7,588	31,119	4.10	121	22
Illinois	46,908,118	2,775,321	1,625,112	8,595	51,317,146	54,687,382	1.07	218	65,581
Indiana	12,887,937	755,061	342,715	—	13,985,713	15,114,300	1.08	197	21,022
Iowa	6,774,144	617,771	182,407	—	7,574,322	12,258,012	1.62	230	15,585
Kansas	6,957,953	172,859	191,637	—	7,322,449	11,159,698	1.52	225	12,439
Kentucky	9,911,715	476,739	254,679	109,991	10,753,124	11,405,038	1.06	210	16,971
Maryland	5,427,882	48,461	56,285	—	5,532,628	6,623,697	1.20	263	5,880
Michigan	1,792,598	129,434	113,826	—	2,035,858	3,660,833	1.80	234	3,982
Missouri	3,495,133	437,072	65,731	—	3,997,936	6,540,709	1.64	214	8,448
Montana	1,793,475	73,609	89,534	60,239	2,016,857	3,907,082	1.94	268	2,735
New Mexico	2,038,475	36,205	56,000	498,279	2,628,959	3,832,128	1.46	269	2,970
North Dakota	218,308	118,102	11,350	—	347,760	560,199	1.61	223	562
Ohio	29,738,788	1,859,906	542,425	1,300	32,142,419	35,324,746	1.10	199	46,833
Oklahoma (Indian Territory)	3,381,420	58,882	161,957	40,399	3,642,658	7,433,914	2.04	216	8,398
Oregon	39,095	14,840	17,046	—	70,981	166,304	2.34	231	184
Pennsylvania	110,009,673	1,941,132	3,040,183	35,152,189	150,143,177	155,664,026	1.04	255	163,295
Tennessee	5,741,988	135,000	129,653	803,602	6,810,243	8,490,334	1.25	232	12,052

Texas	1,584,576	27,118	36,375	—	1,648,069	2,778,811	1.69	244	4,227
Utah	1,287,649	22,149	65,368	572,441	1,947,607	2,959,769	1.52	258	2,203
Virginia	2,359,806	78,704	96,653	2,175,732	4,710,895	4,807,533	1.02	241	6,670
Washington	3,365,097	90,762	134,265	90,408	3,680,532	7,679,801	2.09	273	5,945
West Virginia	39,942,715	932,652	773,526	6,442,690	48,091,583	47,846,630	.99	230	59,029
Wyoming	5,881,055	74,001	297,934	—	6,252,990	9.732,668	1.56	275	6,645
Total bituminous	323,867,357	11,392,183	9,209,750	50,289,822	394,759,112	451,214,842	1.14	234	513,258
Pennsylvania anthracite	75,553,838	1,698,851	8,351,623	—	85,604,312	163,584,056	1.91	220	167,234
Grand total	399,421,195	13,091,034	17,561,373	50,289,822	480,363,424	614,798,898	1.28	231	680,492

(*a*) Includes the production of Nebraska and Nevada

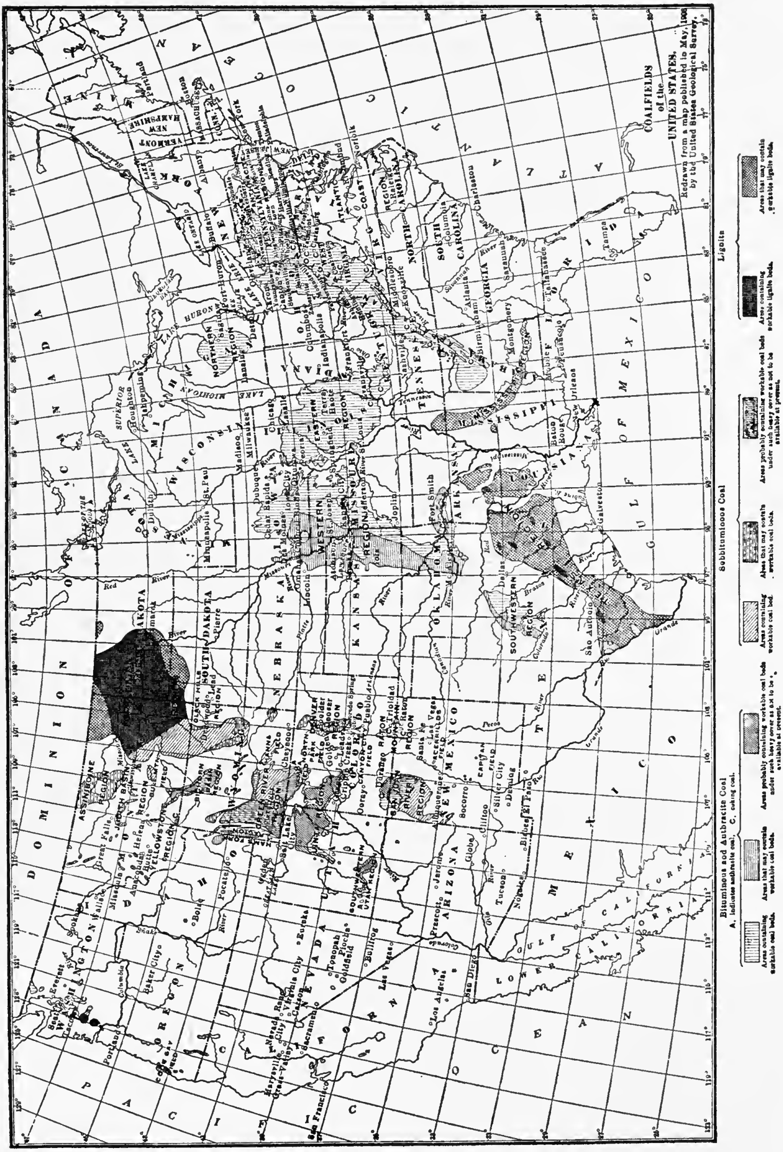

COALFIELDS
of the
UNITED STATES.
Redrawn from a map published to May, 1908
by the United States Geological Survey.
Bituminous and Anthracite Coal
A. indicates anthracite coal. C. coking coal.
Subbituminous Coal
Lignite

FIG. 2.

was 512 tons, against 439 tons in 1906 and 470 in 1905. The average production for each employee in the bituminous mines in 1907 was 769 tons, against 717 tons in 1906 and 684 tons in 1905. The average daily production per man in the anthracite region, which decreased from 2.41 tons in 1903 to 2.35 tons in 1904 and to 2.18 tons in 1905, increased to 2.25 tons in 1906 and to 2.33 tons in 1907. The average production per day by each employee in the bituminous mines, which increased steadily from 3.02 in 1903 to 3.15 in 1904 and to 3.24 in 1905 and 3.36 in 1906, fell off to 3.29 in 1907.

Total Production of Coal in the United States from 1814 to the Close of 1907, in Short Tons

	Pennsylvania	Virginia	Kentucky	Illinois	Ohio	Pennsylvania	Missouri
	Anthracite					*Bituminous*	
Total	1,931,510,321	57,229,152	122,404,574	645,868,309	492,769,358	1,846,069,253	97,618,106

	Indiana	Alabama	Tennessee	Iowa	Arkansas	North Carolina	Maryland	Washington
Total....	159,440,390	164,734,310	84,304,601	141,608,792	23,756,401	476,805	147,606,548	43,108,697

	Michigan	Georgia	California	West Virginia	Colorado	Wyoming	Kansas	Utah
Total......	13,842,943	8,123,696	5,030,945	434,198,539	112,668,336	77,818,765	91,176,204	18,837,182

	Oklahoma (Ind. T.)	Oregon	Montana	New Mexico	Texas	North Dakota	Miscellaneous [1]	Total
Total	39,845,015	1,790,392	24,739,133	22,325,432	14,444,948	2,784,258	38,966,162	6,865,097,567

The following table shows the variation in the average price of run of mine bituminous coal in the various states since 1903. For the year 1907 is added a column showing the output in tons per man per day. It will be seen that the price is roughly in inverse proportion to this output. It will be shown later that, given equivalent conditions, the labor cost is about the same throughout the country. It must be borne in mind that condi-

AVERAGE PRICE PER SHORT TON FOR COAL AT THE MINES SINCE 1903, BY STATES AND TERRITORIES

State or Territory	1903	1904	1905	1906	1907	Tons per Man per Day
Alabama	$1.22	$1.20	$1.21	$1.34	$1.29	2.75
Arkansas	1.51	1.54	1.49	1.61	1.68	2.76
California	(*a*) 2.86	(*a*) 4.74	(*a*) 4.97	(*a*)2.55	(*a*) 3.81	—
Colorado	1.23	1.31	1.22	1.26	1.40	2.94
Georgia	(*b*) 1.26	(*b*) 1.22	(*b*) 1.29	1.28	1.38	—
Idaho	3.10	(*c*) 3.95	(*c*) 3.03	(*c*) 3.93	(*d*) 4.10	—
Illinois	1.17	1.10	1.06	1.08	1.07	3.59
Indiana	1.23	1.11	1.05	1.08	1.08	3.30
Iowa	1.65	1.61	1.56	1.60	1.62	2.11
Kansas	1.52	1.52	1.46	1.49	1.52	2.62
Kentucky	1.06	1.04	.99	1.02	1.06	2.98
Maryland	1.48	1.19	1.14	1.19	1.20	3.58
Michigan	1.97	1.81	1.71	1.80	1.80	2.19
Missouri	1.61	1.63	1.58	1.63	1.64	2.21
Montana	1.64	1.61	1.72	1.77	1.94	2.75
New Mexico	1.37	1.31	1.33	1.34	1.46	3.29
North Carolina	(*e*)	(*e*)	(*e*)	—	—	—
North Dakota	1.50	1.43	1.34	1.54	1.61	—
Ohio	1.29	1.09	1.04	1.09	1.10	—
Oklahoma (Indian Territory)	1.82	1.82	1.76	1.92	2.04	2.01
Oregon	2.43	2.18	2.58	2.66	2.34	—
Pennsylvania bituminous	1.18	.96	.96	1.00	1.04	3.61
Tennessee	1.25	1.18	1.14	1.22	1.25	2.44
Texas	1.62	1.66	1.64	1.66	1.69	1.61
Utah	1.20	1.30	1.35	1.36	1.52	3.43
Virginia	.96	.86	.88	.98	1.02	2.93
Washington	1.69	1.63	1.79	1.80	2.09	2.27
West Virginia	1.17	.88	.86	.95	.99	3.64
Wyoming	1.24	1.30	1.31	1.31	1.56	3.42
Total bituminous	1.24	1.10	1.06	1.11	1.14	—
Pennsylvania anthracite	2.04	1.90	1.83	1.85	1.91	—
General average	1.41	1.26	1.21	1.24	1.28	—

(*a*) Includes Alaska. (*b*) Includes North Carolina. (*c*) Includes Nebraska. (*d*) Includes Nebraska and Nevada, (*e*) Included in Georgia.

tions that impose high costs of living will increase the labor cost. This is particularly evident in comparing the price of coal and the output per man in the Rocky Mountain states with those of the Mississippi Valley.

Coal Production in the Chief Countries of the World
(In metric tons of 2204 lbs.)

Countries	1904	1905	1906	1907
Asia:				
China	—	—	—	10,450,000
India	7,682,319	7,921,000	9,783,250	11,200,000
Japan	11,600,000	11,895,000	12,500,000	12,890,000
Australia:				
New South Wales	6,116,126	6,035,250	7,748,384	7,850,000
New Zealand	1,562,443	1,415,000	1,600,000	1,784,000
Other Australia	769,723	805,000	870,000	900,000
Europe:				
Austria Hungary (c)	40,334,681	40,725,000	37,612,000	39,876,511
Belgium	23,380,025	21,844,200	23,610,740	23,824,499
France	34,502,289	36,048,264	34,313,645	37,022,556
Germany (c)	169,448,272	173,663,774	193,533,259	205,542,688
Italy	359,456	307,500	(e) 300,000	(e) 225,000
Russia	19,318,000	17,120,000	16,990,000	17,800,000
Spain (c)	3,123,540	3,199,911	3,284,576	(e) 3,250,000
Sweden	320,984	331,500	(e) 265,000	305,000
United Kingdom	236,147,125	239,888,928	251,050,809	267,828,276
North America:				
Canada	—	—	—	—
Western	2,619,816	3,183,909	3,717,816	4,780,301
Eastern	4,194,939	4,775,802	6,196,360	5,730,060
United States	318,275,920	351,120,625	375,397,204	430,430,183
South Africa (a)	3,015,000	3,218,500	(e) 3,900,000	3,945,043
Other countries (e)	4,250,000	4,550,000	5,500,000	3,475,780
Total	867,020,658	928,049,163	988,173,043	1,089,110,496

(a) Transvaal, Natal and Cape of Good Hope. (c) Includes lignite. (e) Estimated.

AREAS, ESTIMATED TONNAGE, AND PRODUCTION OF

[A = Anthracite. B = Bituminous.

State and Field	Area in Square Miles: Containing Workable Coals	Area in Square Miles: May Contain Workable Coals	Area in Square Miles: Coal Under Heavy Cover	Kind of Coal	Estimated Original Coal Supply in Short Tons. Coal Both Easily Accessible and Accessible with Difficulty	Production in Short Tons: 1906	Production in Short Tons: Total to January 1, 1908, Including Waste
Alabama:							
Warrior and Plateau fields	7,845	—	—	B	63,513,000,000	11,301,993	—
Cahaba field	325	—	—	B	2,994,000,000	1,635,907	—
Coosa field	260	—	—	B	2,396,000,000	170,063	—
Lignite field	—	6,000	—	L	—	—	—
Total	8,430	6,000	—	—	68,903,000,000	13,107,963	247,000,000
Arizona	30	—	—	B	60,000,000	—	—
Arkansas:							
Bituminous field	1.584	—	—	B	1,797,000,000	1,934,673	—
Lignite field	100	5,900	—	L	90.000,000	—	—
Total	1,684	5,900	—	—	1,887,000,000	—	36,000,000
California	500?	—	—	S, B	1,000,000,000	25,290	7,000,000
Colorado:							
Denver region	600	3,700	—	S	13,590,000,000	1,544,776	—
Durango field	1,380	—	520	B, S	21,428,000,000	177,718	—
North Park field	20	480	—	S	453,000,000	1,300	—
Trinidad field	1,080	—	—	B	24,462,000,000	6,572,673	—
Uinta region	6,000	—	—	B, A	271,810,000,000	1,143,310	—
Yampa field	700	—	2,300	B, S, A	39,639,000,000	5,407	—
Scattered fields	350	—	—	B, S	388,000,000	666,034	—
Total	10,130	4,180	2,820	—	371,770,000,000	10,111,218	169,000,000
Georgia	167	—	—	B	933,000,000	353,548	12,000,000
Idaho	200	1,200	—	S, B	600,000,000	5,882	—
Illinois	35,600	—	—	B	240,000,000,000	38,434,363	968,000,000
Indiana	6,500	—	—	B	44,169,000,000	11,895,252	239,000,000
Iowa	12.560	5,640	—	B	29,160,000,000	6,798,609	212,000,000
Kansas	3,100	15,780	—	B	7,022,000,000	6,423,979	136,000,000
Kentucky:							
Eastern Kentucky	10,270	—	—	B	67,787,000,000	3,768,651	—
Western Kentucky	6,400	—	—	B	36,241,000,000	5,884,996	—
Total	16,670	—	—	—	104,028,000,000	9,653,647	184,000,000
Louisiana	8,800	—	—	L	—	—	—
Maryland	455	—	—	B	8,044,000,000	5,108,539	221,000,000
Michigan	11,000	—	—	B	12,000,000,000	1,473,211	21,000,000
Mississippi	7,500	—	—	L	—	—	—
Missouri	16,700	6,300	—	B	40,000,000,000	3,983,378	146,000,000
Montana:							
Fort Union region	32,300	6,100	—	L, S	279,500,000,000	—	—
Bull Mountain field	754	—	—	S	6,560,000,000	—	—
Red Lodge and Bridger fields	47	100	—	S	2,000,000,000	557,148	—
Judith Basin region	516	2,500	—	B	2,000,000,000	1,058,763	—
Assinniboine region	—	8,000	—	S	10,000,000,000	13,550	—
Yellowstone region	450	—	—	B	3,000,000,000	200,460	—
Scattered fields	—	875	—	S, L	—	—	—
Total	34,067	17,575	—	—	303,060,000,000	1,829,921	37,000,000
New Mexico:							
Raton field	1,360	—	—	B	30,805,000,000	1,292,241	—
San Juan region	11,600	—	5,000	S	131,375,000,000	604,517	—
Scattered fields	375	—	—	B, A, S	1,600,000,000	67,955	—
Total	13,335	—	5,000	—	163,780,000,000	1,964,713	33,000,000

THE VARIOUS COAL-FIELDS OF THE UNITED STATES

S = Sub-bituminous. L = Lignite]

State and Field	Area in Square Miles: Containing Workable Coals	Area in Square Miles: May Contain Workable Coals	Area in Square Miles: Coal Under Heavy Cover	Kind of Coal	Estimaed Original Coal Supply in Short Tons. Coal Both Easily Accessible and Accessible with Difficulty	Production in Short Tons: 1906	Production in Short Tons: Total to January 1, 1908. Including Waste
North Carolina	60	—	—	B	200,000,000	—	1,000,000
North Dakota:							
Western fields	31,240	3,900	—	L	500,000,000,000	317,542	—
Turtle Mountain field..	—	360	—	L	—	—	—
Total	31,240	4,260	—	—	500,000,000,000	317,542	4,000,000
Ohio	12,660	—	—	B	86,028,000,000	25,552,950	739,000,000
Oklahoma..............	10,000	—	—	B	79,278,000,000	2,924,427	60,000,0000
Oregon	230	—	—	S	1,000,000,000	109,641	2,000,000
Pennsylvania:							
Anthracite region......	480	—	—	A	21,000,000,000	71,282,411	—
Bituminous fields	14,200	—	—	B	112,574,000,000	129,293,206	—
Total	14,680	—	—	—	133,574,000,000	200,575,617	5,652,000,000
South Dakota...........	2,000	4,000	—	L	10,000,000,000	—	—
Tennessee:							
Bituminous fields......	4,400	—	—	B	25,665,000,000	5,766,690	—
Lignite fields	1,000	—	—	L	—	—	—
Total	5,400	—	—	—	25,665,000,000	5,766,690	126,000,000
Texas:							
Bituminous fields......	8,200	5,300	—	B	8,000,000,000	839,985	—
Lignite fields	2,000	53,000	—	L	23,000,000,000	472,888	—
Total	10,200	58,300	—	—	31,000,000,000	1,312,873	22,000,000
Utah:							
Uinta region	9,990	—	—	B	150,970,000,000	1,701,674	—
Southwestern Utah region	3,140	1,500	—	B, A	45,438,000,000	—	—
Scattered fields........	—	500	—	B, S	50,000,000	70,877	—
Total	13,130	2,000	—	—	196,458,000,000	1,772,551	28,000,000
Virginia:							
Southwestern fields	1,550	—	—	B	21,000,000,000	4,205,019	—
Brushy Mountain fields	200	—	—	—	900,000,000	49,860	—
Richmond fields.......	150	—	—	B	600,000,000	—	—
Total	1,900	—	—	—	22,500,000,000	4,254,879	86,000,000
Washington	1,100	—	—	B, S	20,000,000,000	2,864,926	64,000,000
West Virginia	17,000	—	—	B	231,039,000,000	87,791,580	650,000,000
Wyoming:							
Fort Union region	11,530	3,060	—	S	174,600,000,000	1,091,499	—
Bighorn Basin region ..	905	430	2,830	S	1,000,000,000	5,451	—
Hanna field	1,435	240	290	S	33,000,000,000	450,636	—
Green River region ...	4,855	1,350	20,750	B, S	199,152,000,000	2,122,253	—
Hams Fork region	1,073	960	115	B, S	16,000,000,000	2,078,772	—
Black Hills region	320	—	—	B	133,000,000	385,383	—
Scattered fields........	450	200	—	S	200,000,000	—	—
Total	20,568	6,240	23,985	—	424,085,000,000	6,133,994	116,000,000
Total for United States.......	327,596	137,375	31,805	—	3,157,243,000,000	414,157,278	10,218,000,000

CHAPTER V

COST OF MINING COAL

Importance of the business — Factors governing costs — Price of wages a result of efficiency — Price and cost of coal in various States — Estimates of cost for various places — Pittsburgh Coal Company — Capital charges — Details of cost of coking coal in Virginia — Illinois field — Coke manufacture and anthracite mining — Cost of coke — Cost of anthracite — Philadelphia and Reading Coal and Iron Company — Chance's chart of costs according to thickness — Public policy in coal mining — Causes of waste — Limitation of waste a question of the value put on coal — Desirability of extensive consolidations — Capital required for coal-mining expansion.

Modern civilization is propelled by the annual combustion of upward of 1,200,000,000 tons of coal. This vast use of power other than human or animal muscle is the basic fact in the mightiest revolution in industry, in art, and in habits that the human race ever experienced. Every time we press a button to turn on an electric light, every time we enter an elevator or a street car, we participate not only in a human revolution, but in a great geologic fact; for the mining and destruction of coal removes some of the important strata of the earth's crust.

Coal mining is the basis and dependence of other kinds of mining just as it is of other industries. And farther, since coal mining is one of the simplest and commonest of mining operations, it serves as a standard by which the complexity and cost of other kinds of mining may be appraised.

If coal were not so abundant and widespread its use could not, of course, be so extensive and fundamental. The fact of its wide distribution is the most powerful element in the conduct of the business. If coal were not cheap it could not be so extensively used; it would not, therefore, be so valuable. But because it is cheap it is often wasted; it is cheap because it can be offered in the market by innumerable competitors, whose aim is not the wise use of coal, but ready money profit from it. Hence this most valuable of mineral resources has been in considerable measure crudely and greedily exploited.

The cost of coal to the consumer depends on two elements that vary widely: (1) Mining and (2), Transportation; but since the effect of the latter is self-evident, I do not propose to discuss it.

Factors that Influence Cost of Mining

I. The cost of mining coal depends, in my judgment, upon the following factors:

(*a*) The thickness of the seam.

(*b*) The purity of the coal in the seam.

(*c*) The regularity of the seam.

(*d*) The geological attitude as regards angle of dip, occurrence of faults, etc.

(*e*) The climate, cost of living, etc.

(*f*) The depth.

(*g*) The amount of water to be pumped.

(*h*) The solidity of the roof.

(*i*) The presence of gas, dust, or other elements of danger.

(*j*) Topography of the surface.

Some other factors may influence the cost in a minor degree; such as the hardness of rock encountered in development work, hardness of coal, cost of supplies, etc.

It will be noted that I have mentioned only natural conditions, leaving out the factor that many would be inclined to place first on the list — the rate of wages. I do not believe that this is a factor at all. The price of labor is determined by the natural factors. It is an effect, not a cause, in the economy of mining. If we have two neighboring districts with the same natural advantages, but in which the rates of wages are different, that difference is apparent, not real. The difference will be equalized by the supply and demand for labor as automatically as water runs down hill. If a mine pays lower wages than its neighbor it will have poorer men; if other conditions are the same, the cost will be the same. You cannot change this natural law; it is like the force of gravity.

Labor Cost and Wages

I hope that no one will understand this dictum to mean that where natural conditions are the same, the wages will be the same, or that the cost of labor will be the same; on the contrary, these things vary a good deal. Management, scale of operations, appliances of all kinds vary, or may vary, almost without limit among various enterprises. These factors help to establish wages and labor costs; they are quite independent both of natural conditions and of labor conditions, and have to do with the success or failure of enterprises. They introduce variations in cost that are, or may be, equal to the margin of profit that there is in the business.

How Labor Costs may Differ with same Rate of Wages

To elaborate a little, let us suppose that Smith and Jones are two rival operators in neighboring coal mines in which the natural conditions are exactly the same and in which coal is salable at $1 per ton. There are only two mines in the district and each can produce twice its actual tonnage. Smith is a good operator, with sufficient capital, equipment, development and ventilation. He can mine coal for 60 cents per ton. Jones is a poor operator, and his mine is poorly opened. It costs him $1 per ton to produce coal. It is obvious that the successful and opulent Smith has the decision as to how great a difference there shall be in labor costs in that district. He can prevent Jones from making a profit, and can close him down by selling coal under $1 per ton, which is Jones's cost. It is obvious that the difference between labor costs here will be approximately as 6 is to 10. This is not due to the rate of wages; it is just the difference between Smith and Jones.

How Wages may Differ and Costs be the Same

Now let us suppose that Smith and Jones are 2000 miles apart and each sells his coal at a point midway between them with equal transportation costs. Smith can supply the market and so can Jones, and each wants to sell all he can, and can produce all he can sell. Smith can sell without loss as low as 60 cents per ton. Jones, if he pays as much wages as Smith, cannot sell for less than $1. Neither Jones nor his employees know anything of Smith's superior methods and appliances, and they have no means of living except by selling coal. Obviously under these conditions there is only one thing to do — work for less money. So Jones fixes his wages at 60 per cent. of Smith's wages and continues business. This rate is fixed by the efficiency of Jones as against Smith. His men get just what they earn. In other words, the final result is exactly the same as if each laborer were in business for himself.

Actual Costs

Returning now to the natural factors that govern the cost of coal mining, we find that their number and importance is very considerable, and if all coal were to be mined we should have enormous differences of cost. As a matter of fact, these great differences do not at present exist because the commercial conditions of the country cause the elimination of all mines except those favorable for cheap working. This results from the fact that there is in this country, according to the U. S. Geological Survey, 2,000,000,000,000 tons of coal of all kinds easily accessible. This coal is spread over an area of 500,000 sq. m., and may be attacked at many thousand favorable points. The unfavorable seams will have to await to be worked after the better ones are exhausted.

Price of Coal at Mines

According to the excellent review of the "Production of Coal" for 1907, published by the U. S. Geological Survey, the extreme variation in the price of coal at the mines in the various States is only from 99 cents in West Virginia to $4.10 in Idaho. The last figure is for only 7500 tons and doubtless represents a case where an isolated but unfavorable seam may be worked because high transportation charges prevent the introduction of coal from other places. Leaving out such abnormal cases and considering only States where the output reaches 1 per cent. of the production of the country, we find that the price of bituminous coal at the mines varies only between 99 cents for West Virginia to $1.68 for Arkansas. Pennsylvania anthracite is valued at $1.91, but I shall explain later that the cost of anthracite is radically different from that of bituminous coal and no comparison should be made except with very careful explanation.

It is probable that the figures of average price of coal at the mines give the best general idea to be had of the cost of mining throughout the country. The price, of course, exceeds the cost, but it can be confidently asserted that the difference is not over

10 to 15 cents per ton, if we consider the whole output of States. Within given fields there must be considerable variation; some mines working cheaply and with large profits, while others have no profits at all, and some, if all capital charges were correctly made against them, would be found running at a loss. But it is quite obvious that the entire industry cannot run at a loss and that the average complete cost must fall inside the average selling price. It is difficult to get specific figures that will illuminate the general subject as accurately as the broad figures published by the Survey, and I doubt if we can form a better idea of average costs than by assuming them to be 90 per cent. of the selling price. This assumption gives us the following for bituminous coal:

Selling and Cost Prices of Bituminous Coal — Run of Mine.

	1903.	1904.	1905.	1906.	1907
U. S. price	$1.24	$1.10	$1.06	$1.11	$1.14
Cost	1.11	0.99	0.95	1.00	1.00

United States average price for 5 years, $1.13; estimated cost, $1.00.

	1907 Price.		Estimated Cost.
Pennsylvania	$1.03	Appalachian field.	$0.93
West Virginia	0.99	Appalachian field.	0.90
Maryland	1.20	Appalachian field.	1.08
Virginia	1.02	Appalachian field.	0.91
Kentucky	1.06	Appalachian field.	0.95
Illinois	1.07	Illinois field.	0.96
Alabama	1.29	Southern field.	1.17
Arkansas	1.68	Ozark field.	1.50
Colorado	1.40	Rocky Mountain field.	1.26
Wyoming	1.56	Rocky Mountain field.	1.40
Utah	1.52	Rocky Mountain field.	1.37
New Mexico	1.46	Rocky Mountain field.	1.31
Washington	2.09	Puget Sound field.	1.88
Michigan	1.80	Michigan field.	1.62

These costs are intended to be complete, that is, to cover both operating and capital charges. I shall endeavor to give some reasons for believing them to be fairly accurate, but first let me disavow any intention of applying them to any particular property or district. It would be more enlightening, possibly, to take some detailed statements of costs and compare and digest them. But such statements are hard to get and I must confess that those I have been able to secure are open to grave question as to their accuracy. For instance, I have the statements of a coal company operating three different mines. Detailed statements of operating costs for each month for each mine are given for a period of years. The aggregate tonnage and total operating cost may be figured out only with great labor. To get five years' operation averaged, I should have to combine 180 different cost statements. If this were necessary to secure the facts, one might be heroic enough to do it, but, after all, it would only give the results of an insignificant fragment of a single field and a single management. But far worse than this, after making this compilation, I should still doubt its accuracy because a single glance at the balance sheet reveals the fact that in mining 1,000,000 tons of coal, $350,000 has been added to capital charges. The writing off of such charges is a matter of judgment, based on familiarity with the property itself. I cannot possibly supply either the time or the experience required to form a judgment of my own as to this rate of depreciation, and yet, in a business of narrow margin like that of bituminous coal, it is a matter of great importance whether 1 cent, or 5 cents, or 15 cents per ton must be added for depreciation.

It is interesting to note that E. V. d'Invilliers, in his article on "Estimated Costs of Mining and Coking" (*Trans.* A. I. M. E., Vol. XXXV, 1905) shares the same difficulty in arriving at true costs for coal-mining operations. He expresses himself as follows: "The cost of coal delivered to an oven, and the cost of the manufactured product, depends largely upon individual judgment or practice, and on general management. Therefore, without having access to the accounts of a number of individual mines, it is not possible to do more than approximate the average regional cost of mining coal or manufacturing coke. . . . For, though each plant in a district may be mining upon the same scale of wages, the computation of net mining costs may differ to a considerable extent in two adjoining plants, due to different methods of bookkeeping, to a difference of opinion as to what items are properly chargeable to mining account and to capital account, or to physical difference at the two mines."

Mr. d'Invilliers goes on to estimate the real cost of mining and coking at Connellsville and at Reynoldsville, Penn., the first a slope mine, largely self-draining, on a seam capable of producing 9000 gross tons (10,000 short tons) to the acre; the second a shaft mine where considerable pumping will be required and capable of producing 7200 gross tons (8000 short tons) per acre. His estimate per gross ton is as follows:

	Mining Cost.	Coal.	Royalty.	Total.
Reynoldsville	$0.66	$0.86	$0.04	$0.90
Connellsville	0.34	0.52	0.08	0.60

Reducing this to a short-ton basis we find that Mr. d'Invilliers's estimate of total cost is:

Reynoldsville	80 cents
Connellsville	53 cents

These figures are for January, 1904. I find that for that year the average price of bituminous coal in Pennsylvania is reported at 96 cents. My arbitrary estimate for cost of 90 per cent. of the price gives us 86 cents for that year. Now, since it would seem that the Reynoldsville mine represents conditions not far from average in the Pennsylvania bituminous-coal regions, it appears that the difference between my estimate and Mr. d'Invilliers's estimate is not so great, but that it might all be covered by a difference of judgment between two men in "what is chargeable to operating account."

Pittsburgh Coal Company

The reports of the Pittsburgh Coal Company, which operates sixty mines in the neighborhood of Pittsburg, so situated that they must represent nearly average conditions for the Pennsylvania bituminous field, show the following: The average number of short tons mined per acre is 7000. Net profits for eight years average 13.8 cents per ton. The total cost for all capital charges is 16.2 cents per ton. If we assume that the U. S. Geological Survey figures for the value of coal at the mines will hold good for the Pittsburgh Coal Company, we get the following, per short ton:

Average price of coal for 5 years		$1.03
Cost — Capital charges	16.2 cents	
Operating charges	73.0 cents	0.892
Profit		0.138
		$1.030

Similarly the Monongahela River Consolidated Coal and Coke Company, also operating near Pittsburg, with an extraction of 8000 tons per acre, shows the following for nine years:

Assume price of coal as before		$1.03
Cost — Capital charges	0.17 cents	
Operating charges	0.74 cents	0.91
Profit		0.12
		$1.03

Capital Charges

Without going into further tables of figures I find that in Pennsylvania the capital charges may be calculated as follows: A charge of 5 cents per ton is made arbitrarily to cover the depletion of coal lands. If the property is bonded, this 5 cents per ton is put into a sinking fund to retire the bonds.

In addition, current interest must be paid on capital or bonds. This charge will be in some proportion to the amount of unmined coal lands held for the future. Thus, if a company has a coal reserve for 100 years on its capital account, its interest charges must be greater than if its reserves are only enough for 20 years.

It appears that it requires approximately $1 per ton of annual product to equip a coal mine for operation. Thus, for an output of 1,000,000 tons per year $1,000,000 will be needed for plant and equipment. The renewal or depreciation of this plant will cost 6 per cent. per year.

In summary, then, we have:

For coal in the ground	5 cents
For interest on $1 capital	5 cents
For depreciation of same capital	6 cents
Total	16 cents

It is self-evident that the operating costs will vary more than capital costs; probably about in proportion to the total. Thus, if we find at one mine total costs of 96 cents, of which 16 cents is for capital and 80 cents for operating, we would probably find that at another mine where the total cost is only 72 cents, the cost would be 60 cents for operating and 12 cents for capital. My reason for believing this is that a mine that is cheap to work must also be cheap to open.

While I am inclined to think that under present or recent conditions, the average cost of bituminous coal in Pennsylvania is 90 cents or more, there is reason to believe that some of the most favorable mines work much cheaper.

Mr. Gary, in his recent testimony before the Ways and Means Committee on tariff revision, states that the cost of coke at the ovens, presumably at Connellsville, chiefly, was, in 1906, $1.75 per ton, on which there was 54 cents profit. This reduces the cost of coke to $1.21. If the burning of the coke costs 31 cents, we have left 90 cents for the coal, of which $1\frac{1}{2}$ tons are required per ton of coke. This figures the cost of coal at the mines of the U. S. Steel Corporation down to 60 cents per ton. Presumably this includes a sufficient allowance for depreciation. If so, the cost seems remarkably low and probably represents the cost of bituminous coal under the most favorable conditions. At any rate it agrees pretty well with Mr. d'Invilliers's figures for a representative Connellsville mine.

Certain other figures given by Mr. Gary about costs are of interest. He says that wages of all classes at coal and coke plants belonging to the U. S. Steel Corporation in 1908 averaged $2.39 per day. Now at coal mines labor is usually about 75 per cent. of the total expense; we may, therefore, calculate that the whole cost per man per day is about $3.20. If coal is mined for 60 cents per ton there must be an output of about $5\frac{1}{3}$ tons for every man. In the State of Pennsylvania at large, the output is only 3.6 tons per man. If this output is obtained at a total cost of $3.20, then the cost per ton is 89 cents. This agrees with my other figures for Pennsylvania.

Let us apply this reasoning to other coal fields and see how close it brings us to my estimate of cost at 90 per cent. of the selling price.

In Michigan the wages are undoubtedly about the same as in Pennsylvania. I have estimated the cost of Michigan coal at $1.62 per ton. The output per man per day is $2.11. If we divide $3.20 by this amount we get $1.52.

Again, in Wyoming I am informed that wages of coal miners average about $3.60 per day. If this is 75 per cent. of the whole cost per man, that cost is $4.80 per day. The output per man averaged in 1907, 3.42 tons; the cost per ton, therefore, should be $1.40. This is exactly my estimate by the 90-per cent. rule.

I have no information as to the average wages of coal miners in Colorado, but some light can be had on costs there from another source. The average value of coal at the mines in that State in 1907 is given at $1.40. My 90-per cent. rule gives a cost of $1.26. The Colorado Fuel and Iron Company mined that year about 4,500,000 tons of coal at a profit of $900,000, or 20 cents per ton. This profit was not altogether on mining since some of the coal was sold at a distance from the mines. Besides this the profits were diminished by certain fixed charges, of which the exact proportion belonging to the fuel department is not clear. At any rate it seems that the net profits on coal from mining were not over 10 cents. If, then, the U. S. Geological Survey is right in its average price of coal, the actual cost must have been about $1.30.

Following are some more detailed figures on the cost of operating a slope mine, self-draining in Virginia. The figures are complete in all respects except that of depreciation. I am in doubt whether that item is fully taken care of, but having no means of forming an individual opinion, I cannot express one. The seam averages 7 ft. thick:

Cost Sheet at a Virginia Colliery

	1905–1906. Per Ton.	1906–1907. Per Ton.
Mining	$0.246	$0.251
Timbering	0.010	0.018
Ventilation	0.008	0.010
Removing refuse and deposit	0.005	0.017
Tracks	0.030	0.031
Haulage	0.067	0.102
Dumpage	0.009	0.012
Blacksmith shop	0.006	0.007
Repairs	0.009	0.008
Supplies	0.007	0.003
Salaries — Plant	0.017	0.019
Switching	0.005	0.006
Engineering	0.003	0.005
Extraordinary expenses	0.007	0.011
Adjustment stables account	0.005	
Sinking fund	0.100	0.100
Attorneys' fees and legal expenses	0.025	0.016
General expense	0.014	0.012
Salaries — General office	0.040	0.058
Interest and discount	0.073	0 068
Taxes	0.011	0.011
Insurance	0.005	0.005
	$0.702	$0.770

Summary:		
Labor	$0.382	0.423
Supplies	0.052	0.077
Sinking fund	0.100	0.100
	$0.534	$0.600
General expense	0.056	0.070
Interest, insurance, taxes, attorneys' fees	0.112	0.100
	$0.702	$0.770
Tons mined	240,371	221,552

It is interesting to note the increased cost in 1907 over 1906, due to the unhealthy pre-panic business conditions.

The following table shows the estimated cost of coal mining in various parts of the Illinois field, according to Mr. George S. Rice. The only comment I can make is that the estimates for depreciation and amortization seem rather low.

ESTIMATE OF COST OF R. OF M. COAL IN ILLINOIS, AVERAGE CONDITIONS.

Yearly Output	Northern Ill. Longwall 150,000 Tons		Middle Ill. 250,000 Tons		Southern Ill. 250,000 Tons	
	Labor	Sup.	Labor	Sup.	Labor	Sup.
Mining (paid to miners "pick rate")	87	—	55	—	48	
Narrow work (entry driving and passing through rolls, etc.)	½	½	4	1	3	1
Care of mine (maintenance of roads, roof falls, timbering, etc.)	15	5[1]	7[1]	3[1]	6	2
Haulage	8	2	5	1	4	1
Hoisting and loading and care of mine top[2]	3	2	2	1	2	1
Steam	1	2	1	1	1	1
Mine management	2	1	1½	½	1½	½
	1.165	.125	.765	.065	.655	.065
	—	1.165	—	.765	—	.655
Total mine cost	—	1.29	—	.83	—	.72
General costs: Depreciation and amortization	—	5	—	3	—	2
General costs: Selling	—	2	—	2	—	2
General costs: Gen'l management	—	2	—	2	—	2
Grand total	—	1.38	—	.90	—	.78

[1] Chiefly timber and ties.

[2] These costs or the subdivision of care of mine top will run high unless the mine runs fairly steady.

Coke Manufacture and Anthracite Mining

The production of commercial anthracite is so different a problem from that of mining bituminous coal that its cost is nearly parallel to that of coke. Run-of-mine anthracite is worthless for fuel. It will not burn unless it is carefully sized. It will not burn if there is even a moderate mixture of slate or bone in it. The sizing and rejection of impurities necessitates careful crushing, sizing and washing. It is distinctly a process of concentration as well as of sizing, for the loss in the "breakers" will average fully one-third of the run-of-mine tonnage. The cost of concentrating, or operating the breakers, is from 30 to 50 cents per ton shipped — not cheap milling by any means, and no doubt mining men not acquainted with the fact will be surprised at it. The comparison may be tabulated as follows:

	Coke.	Anthracite.
Tons run-of-mine per ton	$1\frac{1}{2}$	$1\frac{1}{2}$
Cost of manufacture per ton ..	30 cents to 60 cents	30 cents to 50 cents

Several instances of actual figures for coke have come to my attention. Mr. d'Invilliers calculated average results at two Pennsylvania points for five years ending 1903 as follows:

Connellsville Region Plant of 500 Ovens

Coal, $1\frac{1}{2}$ tons, at 56 cents net ton	$0.840
Charging, leveling, drawing and labor	0.326
Salaries, supplies and depreciation	0.050
Total	$1.216

It will be noted that I deduce from Mr. Gary's evidence that the actual cost of coke in Connellsville to the steel company in 1906 was $1.21.

Reynoldsville Plant of 500 Ovens

Coal, 1.7 tons, at 70 cents	$1.19
Charging, leveling, drawing and labor	0.40
Salaries, supplies and depreciation	0.05
	$1.64

In neither of these cases have I used any table exactly as given by Mr. d'Invilliers. He does not give the details of his estimates for a five-year average, and I have endeavored to supply them. There seems to be some mistake in his average of Reynoldsville costs, for they do not work out in proportion as he gives them.

Another example of coke costs more in detail is from a 200-oven hand-operated plant in Virginia — in 1906:

Cost of coal, 70.2 cents per ton	1.027
Coal used in making coke	1.027
Crushing	0.023
Charging	0.033
Leveling and sealing	0.028
Drawing	0.210
Loading	0.134
Switching	0.023
Salaries at plant	0.033
Tracks	0.008
Repairs	0.021
Supplies	0.012
Extraordinary expense	0.006
Insurance	0.001
Total	1.561

In summary:

Raw material	1.027
Labor	0.459
Supplies	0.075
	1.561

The following year, 1907, the costs at the same plant were as follows:

Raw material	$1.227
Labor	0.524
Supplies	0.114
Total	$1.865

Anthracite Mining

The extraction of run-of-mine anthracite is rather more expensive than that of bituminous coal, chiefly because the anthracite seams are very much more folded. It is necessary to do vastly more development work in rock, and necessary also to use more timber in supporting gangways than is the case in flat seams. Moreover, the constantly changing dip prevents the use of uniform methods throughout the mines. On the other hand, the coal often occurs in magnificent thick seams. The actual difference in cost for run-of-mine I do not estimate at more than 10 cents per ton, 92 cents for bituminous and $1.02 for anthracite (per short ton, the long ton is used at the mines).

Below will be found consecutive statements of the costs of the Philadelphia & Reading Coal and Iron Company for a period of years. These tables in the main explain themselves, but it is worth while to make the following comments: The actual cost of mining and repairs will be seen to average about $1.80 per long ton, equivalent to about $1.60 per short ton. This is for current operating only, but it includes the cost of putting the coal through the breakers, and it is a cost based on the finished product which may be calculated to be only two-thirds the run-of-mine product. Details for cost of breaking are not given, but from inquiries made in the region, it seems that 40 cents per ton is an average. Deducting this sum we get $1.20 for mining alone, and this is for mining 1½ tons of run-of-mine coal. The actual cost, then, per ton of run-of-mine to this company seems to be some 80 cents per short ton.

The capital and general charges that follow in the statements largely explain themselves. The only item to which I wish to draw special attention is that of improvements, which is regularly charged in as an operating cost. This is entirely as it should be, and the charge is doubtless based on the theory that the annual improvements to plant are sufficient to cover the renewal of equipment. The company has charged to improvements and equipments at collieries $13,092,635. This is equivalent to about $1.30 per ton on its annual output. Some companies would have charged a much larger amount to this item. The amount has not been increased in recent years in spite of the fact that since 1902 the output has increased 50 per cent. It is usual to charge off for depreciation at coal mines 6 per cent. of the capital employed in the plant and equipment. In the case of the Reading company such a sum would have been sufficient in 1902, but would fall far short of the charges made in 1908. As costs are usually calculated, therefore, it would seem that this company is writing off somewhat more for depreciation than is strictly necessary. It would be obviously logical for the company to hold on its balance sheet a greater capital for an output of 10,000,000 tons per year than for an output of only 7,000,000 tons.

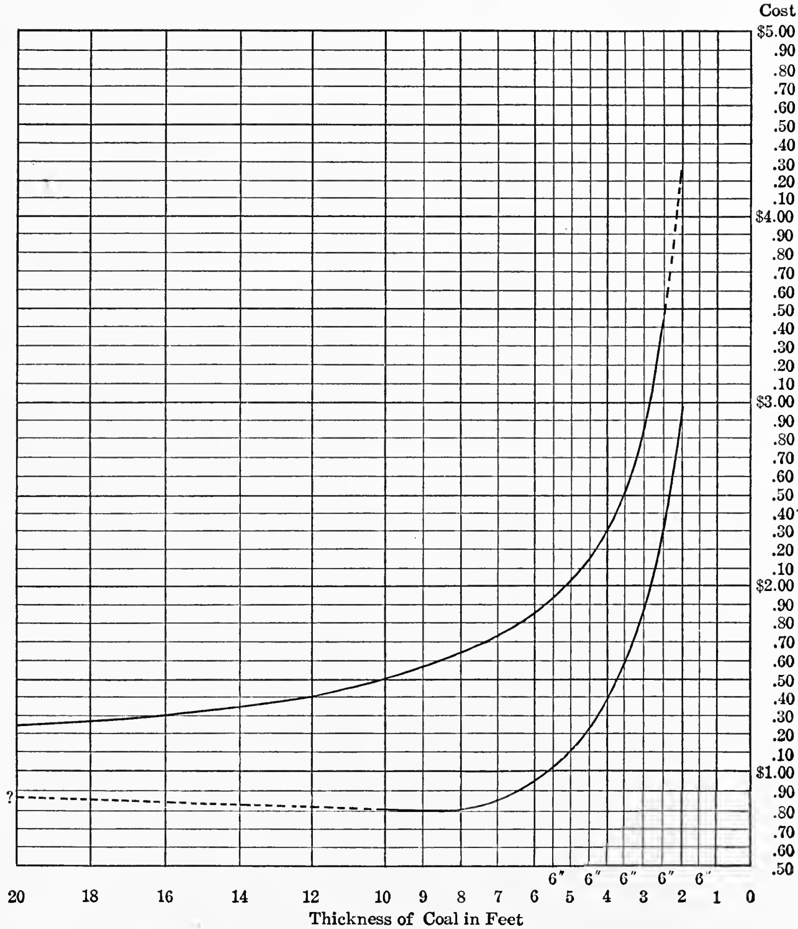
PHILADELPHIA & READING COAL AND IRON COMPANY — STATEMENT OF COSTS

	1902	1903	1904	1905	1906	1907	Per Ton	1908	Per Ton
Anthracite mined, tons	6,968,566	6,299,449	8,707,508	9,438,665	9,132,353	10,034,713		10,218,392	
Mining and repairs, 1.733	$12,076,964	$11,635,094	$16,683,568	$17,378,181	$16,904,915	$18,741,729	1.867	$19,026,334	1.865
Royalty	392,646	370,226	561,603	621,530	620,217	677,143		667,722	0.066
Taxes	253,212	255,714	239,927	305,900	296,953	296,953		339,087	0.033
Repairs of houses	17,644	15,274	22,087	57,693	37,215	53,040		49,849	0.008
Damages account dirt,	35,990	6,366	47,104	25,352	7,260	15,768	0.300	2,054	
Improvements	863,428	867,330	1,273,035	1,730,974	1,131,038	1,345,229		1,286,010	0.128
Depletion of lands	374,101	340,445	454,241	478,326	458,541	499,059		514,350	0.051
Fixed charges 0.34	419,858	377,747	317,224	104 035	118,466	115,074		117,248	0.012
	$14,433,843	$13,858,196	$19,598,789	$20,691,691	$19,583,552	$21,744,995		$22,002,654	
Total cost per ton, 2240 pounds	$2.07	$2.20	$2.25	$2.19	$2.36	$2.167		$2.153	
Cost per short ton	1.85	1.96	2.00	1.95	2.10	1.93		1.93	

In other words, I wish to express my conviction that the costs given by the Philadelphia & Reading company for anthracite mining are adequate in all respects, and that, therefore, the accompanying statement gives an excellent idea of the real cost of anthracite mining.

The following is an interesting chart by Mr. H. M. Chance, showing the relation of cost of anthracite mining to the thickness of the seam. Mr. Chance points out that the most important factor in the variation of coal-mining cost is the thickness of the seam, and nothing will show the facts in the case more plainly than the chart which I take from Mr. Chance's communication to the *Engineering and Mining Journal* of July 29, 1909.

Curves showing Cost of Mining Anthracite Coal. as
affected by thickness of the coal worked, by H.M. Chance.



Upper Curve shows Costs under Unfavorable Mining Conditions
Lower Curve " " " Favorable " "

Fig. 3

Public Policy in Coal Mining

It has often been pointed out that coal in the earth is a natural resource, the use of which is important not only to the owners of the coal lands, but to the nation at large, and that since the supply of coal is limited by nature, wisdom demands that it should be wisely handled. This is a fact that has been recognized by many governments from the earliest times, and the policy of treating mining rights as public rather than as private property has been adopted by probably the greater number of nations. These ideas have been so widely discussed that they are already known to the majority of people, and I wish to call attention only to some considerations that may have a practical value.

Causes of Waste in Coal Mining

An interesting paper[1] contributed by Mr. George S. Rice to the transactions of the American Institute of Mining Engineers at the Chattanooga meeting, October, 1908, calls attention to the fact that the percentage of yield in Illinois from the coal seams is only from 50 per cent. to 95 per cent., and that the losses are from 5 per cent. to 50 per cent. of the available coal. It would be interesting if space permitted to quote Mr. Rice's article in full, but since that is not feasible I shall call attention to some of the principal conclusions developed.

Mr. Rice summarizes the causes of mining waste as follows:

(1) Cheapness of coal "in place"; that is, in the seam.

(2) Low market prices resulting from extreme competition.

(3) Character of the seam, roof, and floor as determining the method of mining.

(4) Surface subsidence due to mining.

(5) Interlaced boundary ownerships.

(6) Carelessness in mining operations.

Mr. Rice says: "The first two factors taken together are the controlling ones in most mining operations, in influencing the choice of a mining system."

This statement is so true that too much emphasis cannot be laid upon it. It has been pointed out in Chapter II that economy may demand the sacrifice of considerable portions of low-priced mineral products in order to secure a sufficiently low mining cost; and it will be pointed out in various places in succeeding chapters that the value of the material mined is always one of the greatest factors in the cost of mining. So pre-eminent is this factor that it is almost possible to say that it is the only one of real consequence in determining percentage of waste;

[1] Mining Wastes and Mining Costs in Illinois.

for it is self-evident that were the product sufficiently valuable, a system or method would be found to prevent the loss of it. The prevention of losses, therefore, as a matter of public policy, is simply a question of dollars and cents. If the public wishes the coal to be mined cleaner, it must be willing to pay a sufficient price to make clean mining profitable to the operator.

It is also self-evident that common sense must be invoked to place a limit on efforts to secure this kind of economy. A reference to Mr. Chance's chart discloses at a glance that, as the thickness of the coal seam diminishes, the cost increases without limit — in mathematical language, approaches infinity. It is preposterous, therefore, to attempt to save all coal, because a seam one inch thick would cost $50 a ton; a seam two inches thick would cost $25 a ton; in each case at the mine. Such costs would preclude the possibility of using coal for anything like the ordinary purposes. Efforts toward the prevention of waste, therefore, must be confined strictly within limits that can easily be agreed upon as reasonable for any given district. For instance, in Illinois it might be agreed that coal seams down to a thickness of two feet should be worked. Such a decision might have far-reaching consequences in the conduct of the coal-mining business. For instance, suppose an operator had one seam 6 ft. thick and another seam 2 ft. thick. It we imagine that (1) a price is fixed that would allow the mining of a 2-ft. seam without loss and at the same time without profit, and (2) that the law requires the operator to mine his 2-ft. seam or else lose the right to mine the 6-ft. seam, it is evident that the operator would be willing to mine the coal according to all requirements; because the 6-ft. seam would be so profitable that the mining of the 2-ft. seam without profit would not be a serious inconvenience. If, however, it were a question of mining a 2-ft. seam without profit, in connection with a 3-ft. seam with a very small profit, the operator would probably feel that the returns of the enterprise would be too small and he would not undertake it.

The question of effective economy in coal mining as regards waste, therefore, is a question precisely like the productive tariff so far as its effect on the public at large is concerned. In the case of the tariff, however, the public is found to subject itself readily to loss because it is quite possible to make the majority of the voters beneficiaries of the tariff. If this is not actually the case a majority think themselves benefited, believing that it is of more consequence to them to get a higher price for the products they have to sell than to pay a higher price for the products they have to buy.

In the case of a proposal to raise the price of coal in order to prevent waste, it is not at all evident how the public could be imposed upon by such considerations. Granted that the coal miners would find such a policy an unqualified benefit, it is not clear how the public at large could be induced to pay a higher price for one of its chief necessities for no object except an altruistic regard for future generations.

It seems as if the only rational way to prevent wastes and at the same time to secure better operation all around, with a saving of human life as well as of coal, is to permit a carefully guarded monopoly in each field of the business of coal mining. Monopoly is a disagreeable word, but it is the only one that conveys the meaning in plain English. It would have to take the form either of a consolidation of ownership or of a pooling of interests under government supervision. My own conviction is that the interests both of the public at large and of the coal-mining business itself demand such an arrangement.

The business in the United States is suffering wofully from over-competition. A vast amount of capital is invested in coal mines that is put in extreme jeopardy through the failure to secure a reasonable price.

It is just as disastrous from an economic standpoint for the coal business to be over-developed as to be under-developed. The under-development of coal mines means, of course, high prices through failure of the supply and consequent loss to the public. Over-development, on the other hand, means a loss, through a part of the public's money being tied up in useless enterprises.

It does not seem unreasonable to hope that in each mining district the government might fix a price for the sale of coal, simply on the basis of an actual cost of mining down to a certain thickness. Such a regulation of the coal-mining business would not be inherently different from the regulation of freight rates by the Interstate Commerce Commission. If such an arrangement were made all that the government or state inspectors would need to do would be to look out for the clean mining of the thinnest seams; the thick ones would be well taken care of without urging.

New Capital Required in Coal Mining Operations

A glance at the figures in Chapter IV reveals the fact that in the ten years between 1897 and 1907 the production of coal rose from 200 million tons to 480 millions, equal to an average increase of 28 million tons a year. Without going into details we may assume that the equipment of the mines for this production must cost, on an average, at least $1.25 per annual ton. Under the most favorable conditions the cost of equipment and development is $1 per annual ton for flat bituminous coal seams; for the more difficult forms of mining, such as anthracite, the cost per annual ton is at least $2.50, and for coke production as much or more. The average amount of new capital going into the coal business, therefore, is at least $35,000,000 a year and $40,000,000 is a more probable figure. This is an exceedingly important fact to bear in mind in considering any possible consolidations in this business.

CHAPTER VI

COST OF MINING LAKE SUPERIOR IRON

Importance of the district — General statement of the cost problem — The United States Steel Corporation — Capital employed in mining, transportation, and blast furnaces — Working capital — Treatment of capital charges — Iron mines and royalties — Cost of mining — Old ranges and the Mesabi range — Cost of open-pit operations — Engineering and management — Taxes — Economy of consolidation — Estimate of average mining cost — Transportation — Estimates of selling cost of pig iron at Pittsburg — Statistical record of United States Steel Corporation — Its capital charges and increased capacity — Its profits — Its plants and property.

The iron ores of the Lake Superior region are the richest in the world, and it is probable that the 400,000,000 tons shipped up to the present time have averaged in metallic iron 60 per cent. of dry ore. Some cargoes have run as high as 68.5 per cent. When you remember that these ores are hematite and that pure hematite is only 70 per cent. iron, you realize that they are exceptionally pure natural concentrates, indeed purer than most artificial concentrates.

When people speak of the output of metal mines in general they mean the gross selling value of the refined metals of New York. Now the value of Lake Superior iron ores is never given in mass. You hear of the value of bessemer, or non-bessemer, old range or Mesabi ores at the mines or at Cleveland, but you do not hear of average values nor of gross values in pig iron.

Output of Various Mining Districts

To get a sense of proportion let us calculate the metal-selling value at New York of the annual output of some of the greatest mining districts for an average of five years: Cripple Creek, gold, \$12,000,000; Transvaal, gold, \$94,860,000; Butte, copper, silver, and gold, \$48,000,000; Cœur d'Alene, lead-silver, \$13,000,000;

Joplin, zinc and lead, $16,300,000; Lake Superior, pig iron, $290,000,000.

The business is profitable, one of the most profitable in the world, but it is not easy to give precise figures concerning it. Much has been written on the various problems involved, such as the caving system of mining, the systems of accounting, mining in open pits, blast-furnace practice, etc., but each of these is only a link in the chain. I have never found any comprehensive discussion of the subject as a whole. I have, therefore, endeavored to work out on an original basis a statement of the cost of operating this vast business. It may be interesting to explain the method.

General Statement

The first thing to decide is what to include in the cost. At present, it is not a matter of any particular interest to have details of the mere cost of extracting ore from some particular iron mine and dumping it on the surface, although before the absorption of most of the mines by the various steel and furnace corporations the local mining costs were indeed a subject of interest. There were then many companies which only mined the ore and sold it at the pit mouth.

At the present time by far the greater part of the ore is mined by concerns which use it to make pig iron and, in many cases, finished manufactured steel or iron products. To describe this industry in parallel terms to those used in the case of other metals it seems to me that we should find the cost of pig iron delivered at New York. It is quite true that New York is not the greatest market for pig iron, but since I have discussed other metals on the theory of their delivery there it is reasonable to follow the same plan with iron.

The reason for stopping with the production of pig iron is

Note. — In this chapter I have assumed in regard to the United States Steel Corporation that the profits on ore hauled by others will be counterbalanced by profits earned by the corporation on ore hauled for others, so that the final result with regard to this transportation will be the same as if all the ore mined by this company were transported by the company. I have also assumed that the making of pig iron at Pittsburg is representative in cost, and that pig iron can be made at Pittsburg and sold at New York for as low a price as pig iron made at other points and shipped to New York. All tons are of 2240 pounds.

simply the analogy of other metals. Pig iron is the basic commodity of iron manufacture. It bears the same relation to the making of steel rails or pocket knives as electrolytic-copper bars bear to the making of copper wire or brass door knobs, or as pig lead bears to lead pipe or buck-shot. As I shall try to show what it costs to produce from various districts copper, lead, and zinc ready for manufactures, so I shall try to show the cost of bringing Lake Superior iron to the same stage.

Complexities of the Problem

When we give this problem some attention we soon find it rather complex. The ore comes from scores of different mines, each producing its own particular grade at its own particular cost. But the cost of getting ore out of the mine is considerably less than that of transporting the ore from the mines to the furnaces, although the cost of transportation varies considerably according to the situation of the mine. We find that in some cases large royalties are paid to fee owners and in other cases the mining company owns the ground. These various factors are bewildering. Furthermore none of the companies gives its costs.

The United States Steel Corporation, however, issues very good reports. These and various isolated data published by the U. S. Geological Survey, and such information as I could get from personal observation, are the sources from which my conclusions are derived. The Steel Corporation is fully as much a manufacturing as a mining concern and even buys some of its pig iron from others. It does not stop with pig iron. It makes steel rails, sheets, wire, rods, and even spelter and cement. It is the greatest of all industrial enterprises, employing in good times more than 200,000 men. Naturally the reports of such a corporation must be condensed. As a matter of fact no operating data of any kind are given. The omission is in this case quite proper. The production, the earnings, the capital expenditures, the property holdings, are all given. This information seems at first insufficient for any definite statement of costs, but it is all that can be had. On two recent trips to the Mesabi range, I saw a good deal of the mines, but I enjoyed no confidences. My inquiries were such as any one could easily make. I make this explanation in order that no one may be under a misapprehension. The basis for the statements I am about to make is what I believe to be common sense.

Activities of the United States Steel Corporation

The operations of the Steel Corporation are undoubtedly representative of the Lake Superior iron business — far more so than those of any other concern. It mines and ships 55 per cent. of the whole product. It owns two of the three ore railroads in Minnesota and the shipments over its roads are 52 per cent. of the whole Lake Superior output. Just what proportion of the ore is transported on the lakes by the company's boats I do not know. When we come to pig iron we find that the company produces an amount equivalent to 55 per cent. of the probable content of Lake ores. It seems to have about 75 per cent. of the known ore reserves of the region. We may conclude, therefore, that this company performs about 55 per cent. of the business all along the line, and that its costs would be approximately the same if it did all the business.

One might argue that the costs of the Steel Corporation are radically different in some respects from those of the independents. For instance, an independent may have to pay 80 cents a ton for freight that costs the Steel Corporation only 40 cents. It is for this very reason that the Steel Corporation is most representative. Its business is complete; that of the others, fragmentary. Just as the independents expect a profit on the ore that they own, so they must expect to pay a profit on the transportation that they do not own. It would be next to impossible to work out the real cost of pig iron if we tried to discover and weave together the obscure and disjointed costs and profits of a chain of discordant operators.

Capital Employed at Iron Mines

For the purpose of this article the capital employed is one of the most vital elements to consider. Remembering that we are to obtain our costs on pig iron and not on finished products, we must segregate the capital used in manufacturing from that used in mining and smelting. This can be done only approximately. Probably no one could make the division with absolute certainty, for it is necessary to remember that transportation, fuel, and power facilities owned by the company are used for the joint purpose of manufacturing steel products and of producing pig iron. I am, therefore, compelled to make a division on my own judgment, and in order to enable the reader to estimate the legitimacy of this judgment, it is necessary to show the method of arriving at it.

The corporation owns in the Lake Superior region 72 iron mines of which 10 are on the Marquette range, 10 on the Menominee, 6 on the Gogebic, 6 on the Vermilion, and 40 on the Mesabi range. Neglecting the purchase price of the properties, and considering only the actual money invested in the plants for the machinery, developments, etc., I make a rough guess that the total capital employed would be somewhat as follows:

Old ranges, each $2,500,000	$10,000,000
Mesabi range	25,000,000
Invested in extensive exploration and developments in the whole Lake Superior region	15,000,000
Total investment	$50,000,000

Capital Employed in Transportation

The Duluth & Iron Range railroad and the Duluth, Missabe & Northern railroad with a total of 363 miles of main line would be indispensable to the conduct of this business, even if it did not extend beyond the production of pig iron. We may calculate the value of this property at $50,000 to the mile, or in round numbers 18,000,000. The Elgin, Joliet & Eastern railroad and various small lines near the manufacturing plants, with a total length of about 295 miles, may be estimated to belong half to the production of pig iron and half to manufacturing. I would charge, therefore, $7,000,000 in round numbers for these lines. The Bessemer & Lake Erie railroad, with 205 miles of lines, I would charge entirely to the production of pig iron, and capitalize it at $10,000,000. This figures up a total of $35,000,000 for railroad tracks. In addition to this we have the railroad equipment which I estimate at $52,500,000, out of which $40,000,000 would be necessary for the production of pig iron alone. We have then a total for railroads and their equipment of $75,000,000.

The marine equipment consists of 76 steamers and 29 barges. Many of these steamers are the largest and best upon the lakes, and some of them undoubtedly cost $700,000 or $800,000 each. I should say that the total equipment must be worth $40,000,000.

Capital Employed in Coal and Coke Properties

We have in the Connellsville and neighboring regions 62,253 acres of coal lands and 20,471 coke ovens. I believe it would be conservative to estimate the capital employed there at $30,000,000. In the Pocahontas district there is a lease on 65,947 acres on which are 2151 coke ovens. This property must have cost somewhere in the neighborhood of $10,000,000 for its development.

There are in addition 31,928 acres of steam-coal ground in Pennsylvania, West Virginia, and Ohio. I would estimate the valuation of the plants employed on these properties to be at least $5,000,000. We have then a total of $45,000,000 for coal and coke plants. Of this I should say $35,000,000 would be necessary for the conduct of the pig-iron business of the corporation.

Capital in Blast Furnaces

The corporation owns, exclusive of its properties in the South, 100 blast furnaces, many of them the largest and best in the world. This property may be estimated at $110,000,000.

For the handling and shipping of iron ore, coke, and coal, the corporation owns a large number of extensive docks, the total value of which I would guess at $20,000,000.

Capital in Inventory and Surplus

At the end of 1908, the inventory of the Steel Company was given at $143,000,000, of which nearly $66,000,000 was in ore. It seems to be a fair deduction from this, if its business were only making pig iron one-half the grand total would be necessary — say $70,000,000. At the same time the surplus was given at $133,000,000, of which, however, $78,000,000 had been invested on plant account, leaving a cash balance of something over $50,000,000. We may assume that, inasmuch as the selling price of pig iron is about one-half of that of the finished products, — one-half of this cash surplus would be required in the business of making pig iron — say $25,000,000, making a total working capital of $95,000,000.

Summary of Capital Used

We may summarize the capital as follows:

Iron mine plants and development	$50,000,000
Plants for transportation of iron ore	115,000,000
Coal, coke, and quarry plants	35,000,000
Docks and dock equipment	20,000,000
Blast furnaces	110,000,000
Total fixed capital	$330,000,000
Working capital in inventory and surplus	95,000,000
Total capital	$425,000,000

It is to be noted that this estimate does not include the purchase price of lands or good-will, but only such capital as would be required if the opportunity to conduct this business were a free gift. Capital so employed is worth in round numbers 5 per cent. interest plus a sinking fund, calculated to retire the principal in about forty years. Such a fund is equal to about 1 per cent. additional. We must calculate the use of this capital then at 6 per cent., and this is not profit. It is merely the actual value of the money employed — such a return as can be secured by an investor without burdening himself with the management of an enterprise. In the case of the Steel Corporation by far the greater portion of this capital is actually represented by 5 per cent. bonds to be retired by a sinking fund substantially on the terms indicated above. We must therefore include as an operating cost of this business an annual instalment of 6 per cent. on $330,000,000 equal to $19,800,000. On an output of 10,000 tons of pig iron a year this is $1.98 a ton.

In addition to this we must make a charge for depreciation which is usually represented by new construction. It is generally believed that depreciation on the kind of property in question will amount to some 6 per cent. per annum. But in this case the entire plant is not in use. The above investment provides capacity for nearly 15,000,000 tons of pig iron a year, but as we are calculating on a product of only 10,000,000 or two-thirds capacity it seems fair to charge depreciation only on two-thirds of the capital invested or $220,000,000. Six per cent. on this amount will make an annual instalment of $13,200,000.

The working capital should be charged with an average rate of interest — say 5 per cent. This on the $95,000,000 calculated to be the amount makes an annual instalment of $4,750,000.

The cost, then, of making pig iron should be charged with the following sums for amortization of fixed capital:

For amortization of fixed capital	$19,800,000
For depreciation	13,200,000
For interest on working capital	4,750,000
Total capital cost per annum	$37,750,000

Equal to $3.77 per ton on the assumed output.[1]

The Iron Mines

Let us return to the source of operations and consider what iron-ore resources the company owns. According to the reports of the Minnesota Tax Commission the various properties owned by the Oliver Iron Mining Company on the Mesabi range have in sight 920,000,000 tons. This, I believe, is an estimate only of those ores which are at present merchantable. The large quantities of lower-grade ores on the western portion of the Mesabi range, which depend upon concentration for their utilization, have not, I believe, been reported. The discoveries of this kind of ore are very extensive, and as experiments have gone to the point of demonstrating the practicability of concentrating them, these ores should be considered as a resource. What the total volume of such ores may be I can only guess, but I should say that it would not fall far short of 300,000,000 tons of concentrates,

[1] These figures are different from those calculated in an article on this subject of which the present chapter is substantially a reprint. In that article the total capital was estimated at $475,000,000, on which an amortization charge of 6 per cent. or $28,500,000 was made. Further investigation has revealed some inaccuracies in this calculation, principally in the items of working capital and in the value of blast-furnace property.

Furthermore, the present treatment of the subject seems more logical and more in accordance with the calculation of similar costs of our other industries, treated in other chapters.

In the article mentioned I assumed a royalty charge of 40 cents per ton. In this chapter this has been cut down to 20 cents, the estimate made by Mr. Carnegie as the actual payments made on the present arrangements by the corporation on all its ores; the change is made on the theory that the amortization of capital and the depreciation of the plants calculated for the mining properties are sufficient to cover the royalty that a company legitimately charged itself with. In other words, I am trying to account for the expenditures which it seems the company actually makes.

making a total of probable ore on the Mesabi range of 1,220,000,000 tons.

As to the ore resources on the old ranges I have no means of making an estimate. It is to be remembered that these mines extend to great depths and that the exploration of them in advance is not easy, but on the other hand many of them are exceedingly persistent and have already been worked for a great many years with no signs of exhaustion. Assuming that these mines may be counted on to produce as much in the future as they have in the past, we get an estimate of 114,000,000 tons for the old ranges, that is, outside of the Mesabi range. Therefore, I would estimate, in round numbers, the total ore resources of the Steel Corporation in Lake Superior at 1,300,000,000 tons.

It will be seen that I have estimated for the exploration and finding of these ores, outside of cost of mining plants in operation, $15,000,000. This seems to be an extremely moderate estimate of cost for putting in sight such enormous reserves, but as far as I can judge by the inquiries that I have made the sum is somewhere near the mark. Explorations on the Mesabi range have been extraordinarily fruitful, and the cost for drilling seems to be not much over 1 cent per ton developed.

Royalties

A very large proportion of the ores controlled by the Steel Corporation is not held in fee, but under leases on which the company pays a varying rate of royalty. This royalty has shown a constant tendency to increase. Many of the earlier leases provide for a royalty of only 25 cents per ton and the leases were made for periods of 20 years or more. In some cases these leases are already near termination and new leases will have to be made at an advanced royalty. Some of the latest leases provide for royalties of 85 cents per ton on standard ores with provision for still further increases.

It is probable that under present conditions the company pays an average of not over 20 cents per ton, because a good deal of its ores are mined from its own lands, but it is manifestly unfair to the Steel Corporation not to allow for its own land a royalty equal to that which it must pay to other owners. On this basis it is probable that the actual royalty allowable on the ore should be about 40 cents per ton.

On the theory that I have adopted for these articles, royalty is not wholly an operating cost, but is in a large part a profit paid to the owners of lands out of their exploitation. Accordingly I charge in this estimate only the 20 cents per ton actually paid to other owners and make up the difference to the Steel Company through the amortization of capital invested in its iron mines and explorations.

Cost of Ore from Old Ranges

At present about two-thirds of all the ore from Lake Superior comes from the Mesabi range, but in the case of the Steel Corporation the proportion is over 74 per cent. It is probable that we would not be far wrong if we adopted a proportion of 70 per cent. from the Mesabi range and 30 per cent. from all the others. By making the above division we may make a reasonably close estimate of the cost of mining in the Lake Superior ores in general.

On the old ranges the problem is essentially uniform. That is to say, there is no great difference in mining ore on the Menominee range, or on the Vermilion range. In all cases the work is done entirely underground, usually at depth between 500 and 1500 ft. Individual mines, of course, show great variations. In some cases the ore is extremely hard and in other cases extremely soft. Some mines have one large body of soft ore; others have a number of comparatively small bodies of hard ore, but these individual differences occur about equally on all the ranges.

The cost may be estimated as a function of the output per man per day. In the case of the hard-ore mines, the output per man is as low as 2½ tons per man, while in some of the most favorable soft-ore mines the output exceeds 5 tons per man. Now, the average wages in the Lake Superior region for all men employed may be calculated at $2.60 per day. We may further estimate that wages account for approximately 60 per cent. of the cost at the mines.

It is probable that the actual operating cost may be calculated at the rate of $4.25 per man employed. On this basis, if a mine gets out 2½ tons per man, its operating cost will be $1.70 per ton; if it gets out 5 tons, its cost will be 85 cents. I believe the actual figures on the average would fall about half-way between these extremes, and that the average output for the old range mines would be somewhere near 3¾ tons per man. This would give a cost of about $1.15 at the mines, exclusive of taxes.

Costs on the Mesabi Range

The cost of mining on the Mesabi range is determined almost absolutely by the depth of the surface covering. If the orebody is thin and the overlying surface deep, it is necessary to mine the ore by underground methods. In this case the cost of mining on the Mesabi will be approximately 90 cents per ton, the average output per man being 4½ tons.

Open-pit mining varies greatly in cost. This work is now done universally by means of steam shovels and the difficulty varies according to the proportion of overburden to ore, the texture of the ore, the proportion of boulders and tongues of country rock in the orebody, and the amount of water to be pumped. These various factors cause abrupt variations in the cost.

We may calculate that the removal of stripping costs 32 cents per yard. If one yard of stripping uncovers a yard of ore we will have one yard of ore containing 2½ tons mined at a cost of removing 2 yards of material, or 64 cents, making the mining cost 25.6 cents per ton of ore. To this cost, however, must be added the interest on capital invested in preliminary stripping and other costs of preliminary development of the mine, the cost of pumping and of certain general expenses that do not occur on the ground, so that when equal amounts of stripping and of ore are removed, I calculate that the cost will be decidedly over 30 cents per ton. This estimate does not include the taxes which I shall presently discuss separately.

It is evident that the proportion of stripping to the ore does not vary directly according to the relative thickness of the surface and the underlying ore; it is a function of these factors combined with several other factors. The glacial material is usually much more uniform in thickness than the orebodies underneath. The latter are usually trough-shaped with many irregularities at the sides and bottom. Furthermore, pits must have sloping sides so that in cases where the depth of the ore is equal to that of the overburden there will still be a considerably larger volume of overburden removed from the pit than there will be of ore. These considerations induce a good deal of caution on the part of operators in the question of deciding upon open-cut mining where the overburden is deep.

Open Cut *vs.* Underground Mining

When the exact proportion of stripping to ore can be worked out, it is a simple question of arithmetic to figure where it will pay to adopt underground mining instead of open pits. As the cost of underground mining is about 90 cents per ton, when open-pit operations are cheaper than that, theoretically the mining should be done by the latter method. But a good many considerations come in to interfere with carrying this method to its logical limits. Among these may be pointed out the necessity of investing a large amount of money in excavating the overburden before mining can be undertaken. In the case of companies that are financially weak this is a matter of considerable importance.

In many cases where open-pit mining would have been much cheaper, the ore has been mined underground because the mine could be opened more rapidly and a certain profit more quickly realized even though the operators knew that they were not securing the best costs. This argument does not apply to the Steel Corporation, of which the capital is abundant for undertaking operations in the most comprehensive way. As a matter of fact, it is in many cases resorting to open-pit methods at mines where formerly, under other owners, the work was done underground.

Exigencies of Open-Cut Operations

At first glance it would seem as if when a yard either of ore or of waste can be dug out by steam shovels for 32 cents, that the cost per ton would be approximately 13 cents, and that, therefore, it would be as cheap to mine almost 7 tons in an open pit as it is to mine 1 ton underground. In other words, 6 tons of stripping might be removed to secure 1 ton of ore. This would be the case were there no expense involved in mining except the actual digging. As a matter of fact, there are other expenses that amount to considerable. One of these, the interest on the money thus locked up in stripping, I have already pointed out, but a still more important cause for hesitation in adopting open-pit mining to its full apparent limit is the considerable variation in the cost of steam-shovel work in different parts of the same mine. Where the ores are soft and uniform a steam shovel will undoubtedly dig a large amount of ore. In some mines the cost of digging ore for a period may go as low as 6 or 7 cents per ton, but this may be followed by another period when the costs may be several times as high.

For instance, in 1906, at the Mountain Iron mine an output of 2,560,000 tons was obtained with a force of 500 men. The bulk of the work was done in eight months, say 200 days. At an average cost of $4.25 per man per day we get for this period a total cost of about $425,000. Supposing that for the remainder of the year one-half the force was occupied, we must increase the estimated cost by about $125,000, making a total for the year of $550,000. This equals 21 cents per ton. In 1907, with an output of 1,973,000 tons, 1200 men were employed. This indicates a cost of more than 65 cents per ton.

A part of the increase was due, no doubt, to an additional volume of the stripping undertaken, but a considerable part of the increase cannot thus be explained. In the orebody itself changes were encountered that not only diminished greatly the output per steam shovel, but also greatly increased the number of men employed per shovel. Up to 1906 the total number of men required in shops, train crews, track laborers, etc., per steam shovel never exceeded 75; since then it has been 100.

The reasons for this are: (1) The ore itself has become much harder, frequently breaking into great slabs and chunks that have to be sledged to make them suitable for reduction in the blast furnace. (2) Owing to the irregularity of the bottom of the deposit it is often impossible to provide adequate working faces for the steam shovels, so that along the bottom and sides the shovels frequently have to take shallow cuts, and sometimes the shovels suddenly run into worthless bars of rock. When the last occurs, the machine must be moved to a new working place. (3) Boulder-like masses of worthless country rock occur in the ore which must be removed as waste. In a word the excavation of ore by steam shovels, after the stripping is all done, may be much more expensive than is popularly believed.

Unwatering the Open Pits

The cost of pumping must be fully as high for open-pit as for underground mining and must be kept up just as steadily. The great pits form catchment basins, often many scores of acres in extent, and in the event of heavy rains, which are far from uncommon on the Mesabi range, the volume of water is often so great as to cause work to be suspended. Fortunately the ore is porous so that the pumping may all be done from a single shaft so located as to provide for the drainage of the entire orebody for all times. The volume of water ejected from a single orebody is frequently 5000 to 6000 gal. per minute. I estimate that when 5000 gal. per minute is pumped from a depth of 300 ft. and the output is 1,500,000 tons per year, the cost of pumping will be 7 or 8 cents per ton. I suppose this is about a maximum cost for the Mesabi.

Now, returning to the question of where open-pit work should end and underground mining should begin, we find that the conditions are about as follows: The actual cost of digging ore in a pit where the ore is hard and sorting is necessary may run up as high as 40 or 50 cents per ton. This cost will be reached when a steam shovel with a crew of 100 men at an average cost of $4.25 per day digs 20 cars, or between 800 and 1000 tons per day. The cost will not exceed 50 cents per ton, because ore can be sorted and loaded as cheaply as that by hand without any steam shovel. Let us then put 50 cents per ton as a maximum cost for digging.

The cost of administration, interest on development capital (largely stripping), and of pumping, is, of course, variable. Where 500,000 or more tons are mined in a year, all these expenses combined are not likely to exceed 15 cents. At the worst, then, we have 65 cents per ton as the cost of mining in open pits, outside of stripping. Now, as underground mining will cost 90 cents per ton, we have the difference between 90 cents and 65 cents to invest in stripping. This 25 cents will remove 2 tons of overburden.

I therefore conclude that it will pay to remove 2 tons of overburden to 1 ton of ore, under the least favorable mining conditions. Under the most favorable conditions, where both the ore and the overburden are soft and uniform, the economical proportion may rise as high as 4 or even 5 to 1.

Average Cost of Mining on the Mesabi Range

This is a point on which no one can get exact information without access to the cost statements of at least fifty different properties, but in a general way I think we can get a rough estimate that will be sufficient for practical purposes. It will appear that the actual mining cost of the ore at the mines is not, after all, one of the greatest factors in the final cost of producing pig iron.

Returning to our output per man per day as a basis for calculating costs I find that during 1907 the mines of the Steel Corporation in the Hibbing district produced approximately 9,000,000 tons of ore. This ore came largely from great open-pit properties, but some of it came from underground mines. I am informed that the total number of men employed was about 4500 with 60 steam shovels. Supposing that the whole of this force was employed for eight months, and half of it for the remaining four months of the year, and assuming that 26 working days constitute a month, we get an equivalentof 260 days with 4500 men, each costing $4.25. This gives us a total of approximately $5,000,000, or in round numbers, 55 cents per ton.

This estimate is open to doubt on several points, two of which are whether the amount of stripping that was done kept pace with or exceeded the amount of ore extracted, and whether the rough figures of labor employed are actually near the truth.

As to these facts I have no means of judging except the most general impressions, but I am satisfied that at the worst my information is not far enough astray to make the cost hopelessly inaccurate. In a general proposition of this kind no one attempts to get down to niceties, and there is no occasion for it. When I state that the average ore mined in the Hibbing district costs 55 cents per ton, I may be 15 or 20 per cent. astray this year, and next year I may be right.

The mines of Hibbing undoubtedly are the most favorable on the Mesabi range for cheap costs. They have the largest, softest, and most uniform orebodies, and are worked on the largest scale. It does not seem improper, therefore, that if we estimate the cost at 55 cents per ton at Hibbing, we should increase this to 60 cents for the whole range. I therefore estimate that the average cost of mining on the Mesabi range for both underground and surface is about 60 cents per ton, exclusive of taxes.

Taxes

The laws of Minnesota tax mining properties for what ore they have in sight. The tonnage developed is reported by the mining companies to the assessor, who puts a valuation upon it according to the quality and accessibility of the ore. For purposes of taxation, discovered ores are placed in five or six different grades with a minimum valuation of 8 cents per ton and a maximum of 33 cents. Roughly, the ore developed seems to average about 15 cents per ton in valuation. This valuation is taxed just as any other assessed property is taxed, the levy being somewhere in the neighborhood of 1½ per cent.

Since the Steel Corporation has in Minnesota on the Mesabi and Vermilion ranges about 930,000,000 tons on the assessors' lists, it would appear that the total valuation would be somewhere in the neighborhood of $140,000,000 and the taxation approximately $2,000,000. On this basis we find that the company must pay on its present output of approximately 18,000,000 tons, more than 10 cents per ton on its actual shipments.

This taxation is a recent development. I do not believe that the company has as yet actually paid so much, but on a basis of present and future conditions it does not seem like an excessive estimate. The fairness of this mode of taxation it is not my present purpose to discuss, but it is very evident that a company with large ore reserves and a small output may be taxed much more than a company with a large output and small ore reserves. For instance, if the Steel Corporation had only five years' ore in sight instead of 50 years, its taxes in its present tonnage would be only 1 cent per ton instead of 10 cents. For this reason there are probably vast differences in the tax rates of various companies in the Mesabi range, and I suppose the Steel Corporation undoubtedly pays more taxes per ton of output than any of the others.

Explorations and Maps

It may be interesting to digress for a moment to consider the value of combination in the operation of these mines. Since its organization the Steel Corporation has pursued a most complete, scientific, and satisfactory plan of exploring and mapping its ore reserves. It has employed expert geologists and engineers for this purpose. It has secured as much land as it could for exploration and has explored it to the point of determining, before any mining is done, the situation, volume, shape, and economic characteristics of the orebodies on large tracts.

In other words, the process of drilling and test-pitting has been carried on until the depth of surface, the quality of the ore, its probable admixture with boulders and tongues of barren rock, and its thickness have all been determined. This information is expressed on maps which show the contours not only of the surface of the land, but also of the surface of the orebody underlying the glacial drift and the contours of the bottom of the orebody.

The information permits the planning of the mining work in such a way that there shall be no duplication of effort. The drainage of an orebody can be provided for with a single shaft so situated that it reaches the bottom of the deposit. The problem of mining is solved beforehand. In other words, the propriety of mining in open pits or underground is predetermined. The location of pits, of dumping grounds, of railroad tracks and of all equipment is established once for all.

Drawbacks of Individual Management

Now, suppose these same orebodies were to be mined by different companies as was, or would have been, the case twenty years ago. The orebodies are sometimes a mile or even two miles in length and quite irregular in outline. The ordinary course of the longest axis of an orebody is northwest and southeast, so that it would cross the subdivisions of the land diagonally. Such an orebody would inevitably occur on several sections, quarter sections, or 40-acre tracts. The land ownership is scattered and irregular. It is seldom that any tract belonging to a single owner is larger than 160 acres and many tracts are only 40 acres in area. As a matter of fact most of the great orebodies on the Mesabi range belonged originally to five or six different companies.

In such a case it is evident that each company would have its individual management, its own problem of finance, and its own requirements in the way of output. The mine located on one particular 40-acre tract might find the surface only 20 ft.

deep, and it would plan an open pit. Since the neighboring ground was seldom thoroughly explored, the waste from this open pit might very likely be, and indeed was in many cases, dumped on ground afterward proved to be ore-bearing.

The next mine on the same orebody might find the surface to be locally 100 ft. deep, and if the operating company were poor and in a hurry for ore, it would undoubtedly open up its mine underground. The result of this would be that large sections of the surface would be caved down into the middle of the ore, thus preventing forever the successful stripping of that part of the orebody.

Economy of Large Ownership

But if this whole orebody were in the possession of the Steel Corporation, its explorations might show that the surface averaged about 50 ft. and that it might be economical to mine all the ore by an open pit. A single pump shaft would be sufficient. No waste would be dumped on neighboring ore-bearing ground. In short, a vast amount of duplicated expense would be avoided. This is where the value of such a combination comes in.

The Steel Corporation cannot get its work done any cheaper than anybody else. If it has to sink a shaft, for instance, it cannot do it any cheaper than any one of the half dozen mines that it might replace, but it could on the average sink one shaft for one-sixth the expense that it would cost other people to sink six shafts.

It is worth remarking in this connection that the Steel Corporation has been magnificently managed. It has not striven for minute and near-sighted economies. It has not tried to outdo its rivals in points of local rivalry, but it has kept in mind the broad outline of its operations and has tried to make use of its capital and opportunities in ways that every fair-minded man would recognize as legitimate. The company can do this only as long as it is well managed, but up to the present it is only fair to say that its activities have been well directed and that its economies are such as to be certainly of no disadvantage to the public at large, but on the contrary in many ways a great benefit.

Total Cost of all Lake Superior Ores

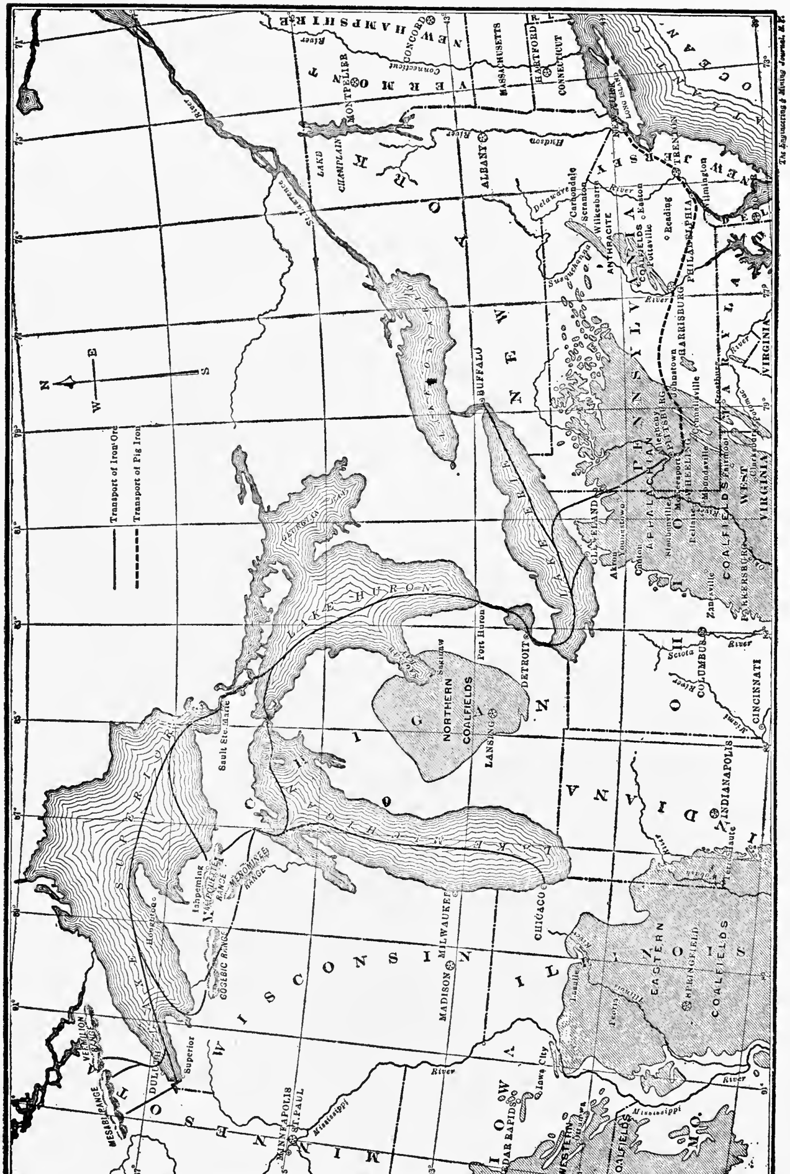
In order to keep the proportion of things in mind, even at the expense of some repetition, we may state that the cost of mining Lake Superior iron ores is for Mesabi ores, \$0.60; old range ores, \$1.15 a ton. Since the Steel Corporation mines about 7 tons of ore on the Mesabi range for over 3 tons mined on the old ranges, we may calculate that the actual cost of 10 tons would be \$7.65 or 76½ cents. To this we must add taxes which on the Mesabi range are not far short of 10 cents per ton. In order to make a round figure we may state that all Lake Superior ores would cost on the ground about 85 cents per ton, including taxation. To this we may add 20 cents per ton for royalty, making the total cost of Lake Superior iron ores at the mine, ready for shipment, \$1.05 per ton.

Transportation of Ores

The ores which are mined on both shores of Lake Superior, either in northern Wisconsin and Michigan or in Minnesota, must all be transported to the region lying south of the Great Lakes for smelting. The region of iron manufacture extends from the neighborhood of Chicago and Milwaukee at the northwest, eastward in a widening belt to Pittsburg and Buffalo and thence east to the neighborhood of New York City.

The factors which dictate the production of pig iron in this region are two, namely, the presence of coal and facilities for distribution. If we take Pittsburg as the most active and central point in iron manufacture to represent average conditions we find that the ores must be transported about 1000 miles in three sections: (1) There is the land haul from the mine to Lake Superior ports; (2) the lake haul from Lake Superior to Lake Erie; (3) the land haul from Lake Erie to Pittsburg.

The first division of the work is covered by five or six different roads — three in Minnesota and the remainder in Michigan and Wisconsin. The length of haul is variable; from Ely, Minn., on the Vermilion range to Two Harbors, the distance is about 90 miles. Most of the ore from the Mesabi range has to be hauled from 70 to 100 miles, so that I suppose an average distance for the north shore roads is perhaps 80 miles. Most of the ore on the Marquette range is less than 20 miles distant, while that on the



MAP SHOWING TRANSPORT OF LAKE SUPERIOR IRON TO SMELTING AND CONSUMING CENTERS

FIG. 4.

Menominee range is about 50, and from the Gogebic range the distance is only about 30 or 40 miles to the harbor.

The published rates on ore from mines in Minnesota to the lakes is uniformly 80 cents per ton; from the Gogebic range to Ashland, 40 cents; from the Menominee range to Escanaba 40 cents, and from the Marquette range to Marquette, 25 cents. In the case of any company other than the Steel Corporation it would be necessary to take these rates at their face value, but in this case there is reason to believe that the transportation is the most profitable part of the business.

The company does not own any railroads on the southern shore, but its two railroads on the northern shore, namely, the Duluth & Iron Range and the Duluth, Missabe & Northern, haul about 52 per cent. of the ore produced in the entire region The corporation also owns a fleet of boats on the lakes, probably sufficient to transport an equal amount. It also owns the Pittsburg, Bessemer & Lake Erie railroad, which hauls most of the ore to Pittsburg. I think we shall not be far wrong if we assume that so far as costs go the results are the same as they would be if the company transported all its own ore from the Minnesota mines to the furnaces.

While the freight on ores from the south shore to Pittsburg is undoubtedly less than that from Minnesota, it is also true that the Steel Corporation must pay on ore transported from those ranges a profit to independent railroad companies which it does not pay in the case of Minnesota ores. Its profits on Minnesota ores which it hauls for other companies probably more than counterbalance the amount it pays in profits to others on the Michigan ores.

Automatic Handling of Ore

Iron ore is about the most easily handled material in the world. Its specific gravity is high, so that the ton does not occupy much bulk, and it is absolutely uninjured by the roughest treatment. As a matter of fact, it is loaded directly into dump cars either by the steam shovels or directly from the mine shafts. It is made up in trains of apporximately 2000 tons of net freight and hauled over roads of very slight, or no adverse gradients to the lake docks. There it is dumped by gravity right into the hold of the ship and transported in large cargoes on waters that are generally tranquil, and unloaded by machinery at the lower lake ports, to be again delivered to the dump cars and carried as before to the furnaces.

I believe the operating cost of hauling such material by rail cannot exceed $\frac{1}{4}$ cent per ton per mile. On this basis transportation from the mines to Duluth would cost about 20 cents, and from Lake Erie to Pittsburg about 40 cents per ton, making a total for rail haul of 60 cents. The lake freight in all probability will cost, including unloading, an average of about 40 cents. Thus we have a total transportation cost of $1 per ton from the mines to Pittsburg. This, of course, is merely operating cost, and does not include the necessary return on the capital invested in the transportation properties, but this item I propose to consider as a lump to be added to the cost of pig iron so that I will not discuss it here.

We have, then, ore delivered at the furnaces at Pittsburg at a total cost of $2.05 per ton, distributed as follows: Mining, 85 cents; royalty, 20 cents; transportation, $1.

Cost of Coke

Without going into details, I think it would be fair to estimate the cost of Connellsville coke to the Steel Corporation at about $1.40 per ton. This is on a basis of 70 cents per ton for mining the coal and using $1\frac{1}{2}$ tons of coal per ton of coke at a coking cost of 35 cents. The freight rate from Connellsville to blast furnaces at Pittsburg is 75 cents per ton, so that we may calculate coke delivered at the furnace at $2.15.

Cost of Producing Pig Iron

It is not probable that the average Lake Superior ore of to-day will yield much over 50 per cent. in pig iron before moisture is deducted. Since the tendency is toward a gradual reduction in the grade of the ore, it does not seem far out of the way to assume that two tons will be required for each ton of pig iron. We may now calculate, when an average output of 10,000,000 tons of pig per year is made, the cost to be as follows: Use of capital, $3.77; 2 tons of iron ore at $2.05, $4.10; 1.2 tons coke at $2.15, $2.58; limestone for flux, 50 cents; labor and maintenance at furnaces, $1.40; general expense, 25 cents; total cost at Pittsburg, $12.70; freight from Pittsburg to New York, $2.60; total cost at New York, $15.30.

An interesting commentary on the correctness of these figures is the testimony of Judge Gary in the tariff hearings before the Ways and Means Committee of the House of Representatives. Mr. Gary gives costs for the year 1906 for all the furnaces of the United States Steel Corporation. His figures are those not of actual cost, but of market prices for iron ores, coke, and transportation.

The figures are as follows: Iron ore at $4.70 per ton; cost of ore used in a ton of pig iron, $8.62; coke at furnace, $3.93 per ton; coke used in making a ton of pig iron, $4.15; limestone per ton, $1.06; limestone in pig iron, 49 cents; scrap, cinder, and scale, 27 cents; labor and maintenance at furnaces, $1.37; depreciation of furnaces, 40 cents; total cost of making a ton of pig iron, $15.30.

From these figures Mr. Gary makes the following deductions for net profits: On ores in pig iron, $2.04; on coke in pig iron, 60 cents; on transportation, $1.07; total deductions, $3.71. Subtracting this amount we have by Judge Gary's estimate $11.59 per ton as the cost of pig iron at the furnaces.

There is, however, some doubt as to the exact application of the figures presented by Mr. Gary. Any one who is familiar with testimony taken at a hearing will understand why this is so. I have gone over the evidence and put together the figures in another way. I do not know which is the most accurate.

Mr. Gary's Figures in Detail

Actual cost of iron mining at all mines	$0.73
Actual cost of coke at ovens	1.21
Actual cost of iron ore at furnace	2.83
Actual cost of coke at furnace	3.39
Pig Iron:	
Iron ore per ton pig	5.50
Coke per ton pig	4.07
Limestone	0.49
Cinder and scale	0.27
Operating blast furnaces	1.38
	$11.71
Depreciation of blast furnace	0.40
	$12.11

These figures omit general expenses, which, it is explained, are kept in a separate account.

It will be noted that with this explanation the sum total of

Mr. Gary's figures are not far from my independent estimates. It is to be pointed out, however, that Mr. Gary's figures are for all the furnaces of the company, while mine are for Pittsburg alone. This fact will make a divergence in the details unavoidable. Furthermore, my figures are for general conditions as they are at present, while Mr. Gary's are exact statements for a single year. After giving the matter considerable thought I have decided to leave my estimates as originally made. They will at least serve to show something of the logic of calculating costs.

Statistical Record of the U. S. Steel Corporation

It was stated in the foregoing that the Steel Company is as much a manufacturing as a mining concern. While the principal motive of this work is to obtain figures on the cost of mining, it will be interesting, nevertheless, to give some idea of the entire business of this company, including the data upon which the above discussion is based.

The following table gives the total production of the various products since the beginning of the company; the average output per year of each commodity and the output for the years 1907 and 1908:

Products	Tenn. C. and I. not Included	
	1902 to 1907 Inclusive	Average
Iron Ore Mined:	Tons	Tons
From Marquette range	7,806,000	1,301,000
From Menominee range	11,340,000	1,890,000
From Gogebic range	9,766,000	1,628,000
From Vermilion range	10,129,000	1,188,000
From Mesabi range	64,421,000	10,736,000
Total	103,462,000	16,743,000
Coke manufactured	66,744,000	11,124,000
Coal mined, not including that used in making coke	9,786,000	1,631,000
Limestone quarried	11,126,000	1,854,000
Blast-Furnace Products:		
Pig iron	53,767,000	8,961,000
Spiegel	789,000	131, 000
Ferro-manganese and silicon	327,000	54,500
Total	54,883,000	9,146,500

TABLE — *Continued*

Products	Tenn. C. and I. not Included	
	1902 to 1907 Inclusive	Average
Steel Ingot Production:	Tons	Tons
Bessemer ingots	41,387,000	6,894,000
Open-hearth ingots	24,536,000	4,089,000
Total	65,923,000	10,983,000
Rolled and other Finished Products for Sale:		
Steel rails	10,541,000	1,757,000
Blooms, billets, slabs, sheet, and tin plate bars	5,317,000	886,000
Plates	4,068,000	678,000
Heavy structural shapes	2,370,000	395,000
Merchant steel, skelp, hoops, bands, and cotton ties	6,006,000	1,001,000
Tubing and pipe	5,277,000	879,000
Rods	1,151,000	192,000
Wire and products of wire	7,640,000	1,273,000
Sheets — Black, galvanized, and tin plate	5,390,000	898,000
Finished structural work	3,077,000	513,000
Angle and splice bars and joints	873,000	145,000
Spikes, bolts, nuts, and rivets	344,000	57,000
Axles	840,000	140,000
Sundry iron and steel products	270,000	45,000
Total	53,164,000	8,859,000
Spelter	167,000	28,000
Copperas (sulphate of iron)	111,000	18,000
	Bbls.	Bbls.
Universal Portland cement	7,611,000	1,268,000

PRODUCTION

The production of the several subsidiary properties for the year 1908, in comparison with the results for the year 1907, is shown in the subjoined table. In order to make the comparison upon relatively the same basis, the production figures of the Tennessee Coal, Iron & Railroad Company for the entire year 1907 have been included in the results shown in table on the following page for that year:

Products	1908	1907
Iron Ore Mined in Lake Superior Ore Region:	Tons	Tons
Marquette range	830,087	1,170,496
Menominee range	1,021,598	1,625,358
Gogebic range	1,078,025	1,425,457
Vermilion range	927,206	1,724,217
Mesabi range	11,272,397	16,458,273
Iron Ore Mined in Southern Ore Region:		
Tennessee coal, iron & R. R. Co's mines	1,533,402	1,576,757
Total	16,662,715	23,980,558
Coke Manufactured:		
Bee-hive ovens	7,591,062	12,716,013
By-products ovens	578,869	828,751
Total	8,169,931	13,544,764
Coal mined, not including that used in making coke	3,008,810	3,550,510
Limestone quarried	2,186,007	3,201,222
Blast-Furnace Products:		
Pig iron	6,810,831	11,234,447
Spiegel	74,716	130,554
Ferro-manganese and silicon	48,861	57,794
Total	6,934,408	11,422,795
Steel Ingot Production:		
Bessemer ingots	4,055,275	7,556,460
Open-hearth ingots	3,783,438	5,786,532
Total	7,838,713	13,342,992
Rolled and Other Finished Steel Products for Sale:		
Steel rails	1,050,389	1,879,985
Blooms, billets, slabs, sheet, and tin plate bars	551,106	761,195
Plates	312,470	894,364
Heavy structural shapes	313,733	587,954
Merchant steel, skelp, hoops, bands, and cotton ties	577,591	1,338,833
Tubing and pipe	654,428	1,174,629
Rods	93,406	126,095
Wire and products of wire	1,275,785	1,481,226
Sheets — Black, galvanized, and tin plated	770,321	1,070,752
Finished structural work	403,832	719,887
Angle and splice bars and other rail joints	84,669	195,157
Spikes, bolts, nuts, and rivets	40,252	67,991
Axles	24,057	189,006
Sundry steel and iron products	54,893	77,463
Total	6,206,932	10,564,537
Spelter	28,057	31,454
Sulphate of iron	26,411	24,540
	Bbls.	Bbls.
Universal Portland cement	4,535,300	2,129,700

The corporation has been engaged from the beginning not only in managing and operating the plants with which it began, but in adding thereto and expanding its business. The following table from the report for 1908 shows the estimate put upon the increase of capital by the officers of the company:

COMPARATIVE ANNUAL PRODUCTIVE CAPACITY
April 1, 1901, *and January* 1, 1909

	Capacity April 1, 1901	Increase Since April 1, 1901			Capacity January 1, 1909
		By Purchase of Union and Clairton Cos.	By Purchase of T. C., I. & R. R. Co.	Due to Additions and Improvements made by the Companies after their Acquirement by U. S. Steel Corpn.	
	Tons	Tons	Tons	Tons	Tons
Blast-furnace products	7,440,000	1,228,000	1,000,000	5,322,000	14,990,000
Steel ingots	9,425,000	1,258,000	500,000	5,887,000	17,070,000
Rolled and other steel and iron products for sale	7,719,000	1,103,000	400,000	3,678,000	12,900,000
	Bbls.			Bbls.	Bbls.
Cement	500,000	—	—	5,600,000	6,100,000

Regarding these increases of capacity, it will be observed that no estimate is made of the increase for the property as a whole, In blast-furnace products the increase is 100 per cent.; in steeel ingots over 80 per cent.; in finished products, 66⅔ per cent.; and in cement, 1100 per cent. Which of these is most representative of the business of the corporation? No statement is made as to the increases in natural resources. Considering the fact that the company's business as a finality resolves itself principally into the sale of finished iron and steel products, it seems most reasonable to take the increase of capacity in that particular as representing most nearly the increase in the company's whole business.

Let us assume, therefore, that the producing capacity of the properties has been increased by two-thirds since the organization.

What this increase has cost is exhibited by the following table:

"Since the organization of the corporation there have been expended for additional property and construction (exclusive of the cost at date of acquirement of Union Steel and Clairton Steel Companies, and of the stock of Tennessee Coal, Iron and Railroad Company) the following amounts:

For account of the Gary, Indiana, Plant, including the building of the city of Gary and terminal railroad work	$42,797,229.57
For account of the manufacturing properties (including expenditures by U. S. Steel Corporation)	116,155,559.41
For account of the coke and coal properties	20,056,764.27
For account of the iron ore properties	23,120,539.17
For account of the transportation properties	49,026,895.81
For account of the miscellaneous properties	4,340,999.14
Total capital expenditures	$255,497,987.37
During the same period there was expended for extraordinary replacements and betterments the sum of	92,534,952.12
Total	$348,032,939.49

"On account of the foregoing expenditures there were issued and disposed of, bonds, mortgages, and purchase obligations of subsidiary companies to the amount of $39,172,863.37, leaving a balance of expenditure of $308,860,076.12, the funds for the payment of which have been provided from the current earnings and surplus of the organization. There have also been paid off through operation of the bond sinking funds, and by discharge upon their maturity, $85,871,019.36 of bonds, mortgages, and other capital obligations which were outstanding at the time of organization of the U. S. Steel Corporation."

The statement leaves in doubt the exact meaning of the expenditures for extraordinary replacements and betterments. It seems most probable that such expenditures should be charged off to depreciation. Making this deduction, we find that the capital expenditures have been $255,498,000 plus the cost of the Union and Clairton Steel Companies and the Tennessee Coal, Iron & Railroad Company. The sum total of which appears to be in the neighborhood of $94,000,000. A round figure for all capital expenditures since the organization we may take as $350,000,000.

On the assumption that these expenditures have increased the total productive capacity of the concern by two-thirds, it is easy to deduce the conclusion that the actual capital invested in the enterprises at the beginning of the organization was $525,-000,000, and that at present the total invested capital can be calculated at $875,000,000, a sum which may be compared with the total obligation of the company in preferred stock and bonds of the corporation, which amount in par value to $958,315,000.

The cash surplus of the corporation is kept in round numbers at $50,000,000, the remainder of the surplus, which is stated to be $133,000,000, having been expended on the various plant investments. The working capital may be safely assumed to be represented by the inventories which were, at the end of 1908, $143,180,000 plus the cash, making a total sum of $193,000,000. Adding this to the foregoing estimate of fixed capital investments, we arrive at a total of $1,068,000,000 as the actual capital employed in the enterprise. This sum plus the natural enhancement of the value of its properties is what the stockholders of the corporation have to show for their money.

Analyzing this matter a little further we find that the obligations in the preferred stock and bonded indebtedness amount to $958,000,000, so that the common stock represents the equivalent of $110,000,000 invested capital plus all of the enhancement in the value of the property — a state of affairs with which the stockholders should be satisfied.

The following table shows the disposition made of the earnings of the company since the beginning:

Net Profits and Surplus of United States Steel Corporation and Subsidiary Companies at Close of each of the Periods Named

(Includes only Surplus received or earned on or subsequent to April 1, 1901)

Period	Net Profits for Period Available for Dividends	Surplus at Close of Period before Declaration of Dividends [1]	Dividends on U. S. Steel Corporation Stock for Respective Periods.	Written off Account of Capital Expenditures, for Special Funds and for Sundry Adjustments and Accounts	Balance of Surplus
Nine months ending Dec. 31,1901	$60,600,109.05	$85,600,109.05	$41,979,168.75	—	$43,620,940.30
Year ending Dec. 31, 1902	90,306,524.25	133,927,464.55	56,052,867.50	—	77,874,597.05
QUARTER ENDING					
March 31, 1093	14,891,989.64	92,766,586.69	14,012,944.25	—	78,753,642.44
June 30, 1903	23,987,950.22	102,741,592.66	12,609,770.92	—	90,131,821.74
September 30, 1903	19,684,774.49	109,816,596.23	10,006,759.90	—	99,809,836.33
December 31, 1903	2,230,775.78	102,040,612.11	6,482,260.84	$29,461,668.91	66,096,682.36
March 31, 1904	4,606,593.70	68,099,358.51	6,304,919.25	—	61,794,439.26
June 30, 1904	9,082,563.81	69,700,504,29	6,304,919.25	—	63,395,585.04
September 30, 1904	7,617,906.85	73,831,323.75	6,304,919.25	—	67,526,404.50
December 31, 1904	10,143,836.95	77,378,489.44	6,304,919.25	9,708,124,50	61,365,445.69
March 31, 1905	12,178,326.35	71,826,602.51	6,304,919.25	3,300,000.00	62,221,683.26
June 30, 1905	16,875,599.99	82,537,094.61	6,304,919.25	7,500,000.00	68,732,175.36
September 30, 1905	16,977,532.04	90,322,263.92	6,304,919,25	6,500,000.00	77,517,344.67
December 31, 1905	22,653,287.55	100,142,623.70	6,304,919.25	9,099,253.78	84,738,450.67
March 31, 1906	22,371,919.85	102,570,244.10	8,846,431.75	10,500,000.00	83,223,812.35
June 30, 1906	24,536,025.28	110,636,708.48	8,846,431.75	13,000,000.00	88,790,276.73
September 30, 1906	23,543,749.98	118,444,038.26	8,846,431.75	11,000,000.00	98,597,606.51
December 31, 1906	27,767,393.02	124,657,647.29	8,846,431.75	18,090,501.19	97,720,714.35
March 31, 1907	27,031,008.20	118,256,429.88	8,846,431.75	14,500,000.00	94,909,998.13
June 30, 1907	30,843,512.61	131,134,185.12	8,846,431.75	18,500,000.00	103,787,753.37
September 30, 1907	28,758,142.27	140,376,218.82	8,846,431.75	15,000,000.00	116,529,787.07
December 31, 1907	18,614,416.20	138,173,190.89	8,846,431.75	6,681,515.52	122,645,243.62
March 31, 1908	8,854,297.37	127,092,583.20	8,846,431.75	—	118,246,151.45
June 30, 1908	9,042,027.55	125,937,322.46	8,846,431.75	—	117,090,890.71
September 30, 1908	13,998,455.19	137,506,368.22	8,846,431.75	—	128,659,936.47
December 31, 1908	13,739,899.00	142,167,611.33	8,846,431.75	Cr. 94,034.59	133,415,214.17

[1] Includes Capital Surplus of $25,000,000 provided at date of organization, also Undivided Surplus of Subsidiary Companies representing accrued profits on Inter-Company materials on hand in inventories.

Summary — April 1, 1901, to December 31, 1908

Capital surplus provided at date of organization			$25,000,000.00
Aggregate net profits as above		$560,938,617.19	
Less, amount included therein representing accrued profits on inter-company materials on hand in inventories	$10,371,803.25		
Net charges against profits made at close of fiscal years, not applicable to particular quarters	7,119,665.15		
Reserved for fund to cover possible failure to realize advanced mining royalties	2,800,000.00		
		20,291,468.40	
Balance of profits earned			540,647,148.79
			$565,647,148.79
Dividends paid on U. S. Steel Corporation Stocks, viz.:			
Preferred, 54¼ per cent		$218,975,274.66	
Common, 15½ per cent		78,765,032.50	
			297,740,307.16
Leaving a surplus of			$267,906,841.63

Brought forward	$267,906,841.63
Of the foregoing surplus there has been appropriated for payment of construction and capital expenditures and special charges, per sixth annual report, page 8	162,827,364.16
Balance of surplus December 31, 1908, exclusive of subsidiary companies' inter-company profits in inventories	$105,079,477.47
Undivided surplus of subsidiary companies on December 31, 1908, representing profits accrued on sales of materials to other subsidiary companies and on hand in latter's inventories	28,335,736.70
Total	$133,415,214.17

It seems legitimate to make the following comments on this statement:

The actual profits were $540,647,000 derived from the sale of approximately 67,500,000 tons of finished steel products and about 12,000,000 barrels of cement. Let us figure only on the tonnage of finished iron and steel products, and there appears a profit of $8 per ton.

Of these earnings $297,740,000 has been paid in dividends or approximately $4.40 per ton. The remaining $242,000,000 has been added to plant or used to increase the cash surplus, only $25,000,000 or some 40 cents a ton being used for the latter purpose, the remainder, over $217,000,000, or $3.20 per ton, being used for the expansion of the business. Under ordinary circumstances there would be in one's mind a great doubt as to whether the sum thus expended for plant extensions should be held as an addition to capital or whether it should be written off to depreciation. But in this remarkable case there seems to be no doubt whatever that the circumstances justify the treatment of the whole amount as a true capital expenditure. It is not necessary to dwell on this point further than to point out that the expansion of the producing capacity of the concern by 66⅔ per cent. shown above is a more than sufficient justification. We are led then to believe that the profits reported by the company are really profits, namely, $8 per ton, and that this is over and above all requirements for interest on bonds and building up of sinking funds, besides depreciation. This means that the sum of nearly $70,000,000 per annum has been earned by the preferred and common stock of the corporation. The full dividends of 7 per cent. a year have been paid on the preferred stock, absorbing $219,000,000 [1] in the seven and three-quarters years.

[1] In 1903 the preferred stock was diminished by $150,000,000 by conversion into an issue of bonds. The present preferred stock amounts to $360,281,100 on which the annual dividend is $25,215,672.

Summary of Manufacturing Plants Owned by Subsidiary Companies

Name of Operating Company	Total Number of Works.	Number of Blast Furnaces	Bessemer Steel Works		Open Hearth Steel Works		Blooming Slabbing Billet and Sheet Bar Mills		Number of Rail Mills	Plate Mills		Puddling Mills			Skelp Mills		Merchant Bar, Hoop and Cotton Tie Mills	
			Number of Works	Number of Converters	Number of Works	Number of Furnaces	Number of Works	Number of Mills in Works		Number of Works	Number of Mills in Works	Number of Works	Number of Puddling Fces.	Number of Muck Rolls	Number of Works	Number of Mills in Works	Number of Works	Number of Mills in Works
Carnegie Steel Co	27	51	7	16	7	98	9	26	4	3	9	—	—	—	—	—	11	46
Illinois Steel Co	5	21	2	6	2	24	2	7	2	1	3	—	—	—	—	—	2	8
Indiana Steel Co. (Gary)	1	4	—	—	2	28	1	2	1	—	—	—	—	—	—	—	—	—
The Lorain Steel Co	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Am. Steel and Wire Co	29	12	2	4	3	17	3	5	—	1	3	—	—	—	—	—	2	6
National and other Tube Cos	13	11	3	7	—	—	3	5	1	—	—	2	76	2	10	35	1	3
Am. Sheet and Tin Plate Co	36	—	—	—	1	10	3	5	—	—	—	1	4	—	—	—	—	—
American Bridge Co	17	—	—	—	1	11	1	1	—	—	—	—	—	—	—	—	1	1
Union Steel Co	2	5	—	—	2	24	2	4	—	1	1	—	—	—	—	—	—	—
Clairton Steel Co	1	3	—	—	1	12	1	2	—	—	—	—	—	—	—	—	1	1
Tennessee C., I. & R.R. Co.	6	16	—	2	1	6	1	1	1	1	1	—	—	—	—	—	1	2
Universal Portland Cement Co	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Grand Total	142	123	14	35	20	230	26	58	9	7	17	3	80	2	10	35	19	67

OF UNITED STATES STEEL CORPORATION

Structural Shape Mills: Number of Works	Structural Shape Mills: Number of Mills in Works	Rod Mills: Number of Works	Rod Mills: Number of Rod Mills in Works	Wire Mills: Number of Works	Wire Mills: Number of Nail Factories	Wire Mills: Barbed Wire & Fence Factories	Wire Mills: Departments for Galvanizing	Wire Mills: Departments for Tinning	Sheet Mills Black Plate Mills and Tin Plate Mills: Number of Works	Sheet Mills Black Plate Mills and Tin Plate Mills: Number of Hot Mills in Works	Sheet Mills Black Plate Mills and Tin Plate Mills: Departments for Tinning	Sheet Mills Black Plate Mills and Tin Plate Mills: Departments for Galvanizing	Pipe Mills: Number of Works	Pipe Mills: Number of Fces-in Works	Number of Bridge and Structural Plants	Number of Foundries	Miscellaneous Works
3	9	—	—	—	—	—	—	—	—	—	—	—	—	—	2	3	1-Axle Works. 1-Armor Plant. 2-Bolt and Rivet Depts. 2-Car Wheel Works 1-Splice Bar Shop. 1-Warehouse and Shop. 1-Forge Dept.
1	1	1	3	—	—	—	—	—	—	—	—	—	—	—	1	2	1-Spike, Bolt and Nut Factory. 1-Paint Factory. 1-Splice Bar Shop.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	1-Frog and Switch Works.
—	—	12	17	21	12	11	16	7	—	—	—	—	—	—	—	5	7-Sulphate of Iron Plants. 1-Horse Shoe Works 3-Spring Works. 1-Electrical Works. 4-Wire Rope Works 4-Cold Rolling Depts. 1-Shafting Dept. 2-Zinc Smelting Works.
—	—	—	—	—	—	—	—	—	—	—	—	—	11	52	—	6	3-Galvanizing Works. 1-Galvanizing and Job Works. 1-Thread Protector Works.
—	—	—	—	—	—	—	—	—	35	41	17	5	—	—	—	2	1-Sulphuric Acid Plant. 1-Sulphate of Iron Plant.
1	2	—	—	—	—	—	—	—	—	—	—	—	—	—	17	6	1-Axle Works. 1-Eye Bar Works.
—	—	2	4	2	2	2	2	—	2	34	1	—	—	—	—	—	2-Sulphate of Iron Plants.
1	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4-Cement Plants.
6	14	15	24	23	14	13	18	7	37	449	18	5	11	52	20	30	51-Miscellaneous Works.

The remainder, \$321,000,000, has all gone to the benefit of the common stock and has been used to pay dividends to the amount of \$78,765,000, and the building up of equities to the amount of some \$242,000,000.

It is probably true that at the beginning the common stock represented little or nothing more than a speculative possibility. But the success of the company during the last eight years has created most substantial values for it. It must be remembered that the great constructive enterprises of the corporation have as yet yielded little return. That is for the future. If we calculate that the probabilities of the future contain nothing more than a realization on the expansion already accomplished, the earning powers of the concern seem fairly prodigious. If it has now reached a point where it can pay out as dividends the earnings on a product equal only to the average of the last eight years, without counting on any increased product, we find that the earnings available for dividends are equal to \$45,000,000 a year on the common stock, approximately 9 per cent. There are only two grounds for doubting that this will be realized, namely, that the prices and costs of the future may not be the same as in the past, and that the management may deteriorate. How far these elements may weaken the position of the corporation only the future can tell. But its record to date, and especially for the past five years, makes it a conservative statement that this concern is the greatest and promises to be one of the most profitable enterprises that the world has ever seen.

IRON ORE MINES

Developed Iron Ore Mines Owned by Subsidiary Companies, December 31, 1908

In the Lake Superior Ore Region

Marquette Range
- Hartford Mine.
- Queen Mine (¾ int.).
- Section 16 Mine (¾ int.).
- Section 21 Mine (¾ int.).
- Hard Ore Mine (¾ int.).
- Hematite Mine (¾ int.).
- Moore Mine.[1]
- Stegmiller Mine.

Marquette Range (Con't)
- Winthrop Mine.[1]
- Champion Mine.

Menominee Range
- Mansfield Mine.
- Michigan Mine.
- Riverton Mine.
- Cuff Mine.[1]

Menominee Range (Con't)
- Hilltop Mine.[1]
- Chapin Mine.
- Aragon Mine.
- Cundy Mine.[1]
- Iron Ridge Mine.[1]
- Pewabic Mine (½ int.).

[1] Inactive at present time.

IRON ORE MINES — *Continued*

Gogebic Range
Norrie Mine.
Aurora Mine.
Chicago Mine.[1]
Tilden Mine.
Atlantic Mine.
Puritan Mine.
Davis Mine.

Vermilion Range
Pioneer Mine.
Savoy Mine.
Sibley Mine.
Zenith Mine.
Soudan Mine.

Mesabi Range
Mountain Iron Mine.
Stephens Mine.[1]
Virginia Mine.

Mesabi Range (Con't)
Fayal Mine.
Auburn Mine.[1]
Genoa Mine.[1]
Chisholm Mine.
Sauntry Mine.[1]
Clark Mine.
Adams Mine.
Burt Mine.
Day Mine.[1]
Duluth Mine.
Glen Mine.
Hull Mine.
Hull-Rust Mine.
Leonard Mine.
Pillsbury Mine.
Rust Mine.
St. Clair Mine.[1]
Sellers Mine.
Winifred Mine.

Mesabi Range (Con't)
Spruce Mine.
Monroe Mine.
Tener Mine.
Myers Mine.
Morris Mine.
Donora Mine.[1]
Sharon Mine.[1]
Penobscot Mine.[1]
Higgins Mine.
Union Mine ($\frac{1}{2}$ int.).[1]
Biwabik Mine ($\frac{1}{4}$ int.).
Mahoning Mine ($\frac{1}{5}$ int.).
Hartley Mine.
Gilbert Mine.
McKinley Mine.
Canisteo Mine.
Walker Mine.
Holman Mine.
Hill Mine.

IN THE SOUTHERN ORE REGION

Red Mountain Range (Near Birmingham, Ala.).
Muscoda Group: 5 active and 1 inactive mine openings.
Fossil Group: 4 active mine openings.
Ishkooda Group: 4 active mine openings.
Green Springs: 1 inactive mine opening.

Alabama Brown Ore Pockets (At Greeley, Ala.).
Greeley Group: 3 active mine openings.
Champion Group: 1 active mine opening.

Georgia Brown Ore Pockets (At Bartow, Ga.).
Bartow Group: 2 inactive mine openings.

In addition to the foregoing mines, the subsidiary companies own in fee and hold under long term leases in the regions named, extensive acreages of mineral and timber lands, containing large quantities of ore yet unopened, and on which there are substantial tracts of standing timber designed for future use in mining operations.

[1] Inactive at present time.

Coal and Coke Properties Owned by Subsidiary Companies December 31, 1908

Northern Coal and Coke Properties	Acreage of Coal Property			Coke Plants			Coal Plants Not Connected with Coke Plants
	Coking Coal	Steam Coal	Surface	No. Plants	No. Bee-Hive Ovens	No. By Product Ovens	
Connellsville Region.							
In Westmoreland and Fayette Counties, Pa.:							
Property owned	58,513	—	21,353	64	20,696	—	2
Property leased	1,457	—	—	—	—	—	—
Pocahontas Region.							
In McDowell County, West Virginia:							
Property owned	—	—	36	8	2,151	—	4
Property leased	65,357	—	—	—	—	—	—
Steam Coal Properties.							
In Washington, Allegheny, Green, Somerset and Mercer Counties, Pa.:							
Property owned	—	25,207	793	—	—	—	4
Property leased	—	3,669	—	—	—	—	—
Sundry small coal tracts located at or near mill plants in Ohio, Pennsylvania and West Virginia:							
Property owned	—	3,168	696	—	—	—	6
Property leased	—	140	—	—	—	—	—
In Sullivan County, Indiana, and Williamson County, Illinois — Owned	—	3,831	90	—	—	—	—
By-Product Coke Plants Located at Blast Furnace Plants.							
So. Sharon, Pa	—	—	—	1	—	212	—
No. Sharon, Pa	—	—	—	1	—	25	—
Benwood, W. Va	—	—	—	1	—	120	—
Joliet, Illinois	—	—	—	1	—	280	—
Total Northern Coal and Coke Property	125,327	36,015	22,968	76	22,847	637	16

Southern Coal and Coke Property

(Tennessee Coal, Iron & R. R. Co.)

Acreage of Coal Territory, viz.:

Mineral interests only — Owned .... 151,408 acres
Mineral interests and surface — Owned ..... 176,376 acres
Surface only — Owned .... 7,912 acres

On the above property are located 6 coal mining plants operating 23 mines and producing coal for both sale and for manufacture of coke. There are in connection with these coal mining operations 11 coal washing plants and 6 coking plants, which latter embrace 2,664 bee-hive coke ovens and 240 by-product coke ovens.

Miscellaneous Properties Owned by Subsidiary Companies December 31, 1908

Water Supply Plants:

In the Connellsville coke region are located various water supply plants, consisting of eleven reservoirs and six pumping stations with a distributing system of pipe lines aggregating about 90 miles in length. These plants have a capacity of 18,000,000 gallons of water per day, furnishing water for use in manufacturing coke, and in addition, providing the water supply for three municipalities.

NATURAL GAS PROPERTY:

The Carnegie Natural Gas Company has in Pennsylvania and West Virginia extensive natural gas territory, either owning or having under lease about 180,449 acres; owning 550 miles of pipe lines, five pumping stations and 309 active wells.

Extensive natural gas territory and pipe lines are controlled and owned by the American Sheet and Tin Plate Company in Pennsylvania, it having under lease about 43,538 acres; owning one large and four smaller pumping stations and 151 active wells.

ORE DOCKS:

Large forwarding ore docks situated on Lake Superior are owned as follows:

At Two Harbors, Minn., owned by Duluth & Iron Range R.R. Company 6 docks.

At Duluth, Minn., owned by Duluth, Missabe & Northern Ry. Company, 4 docks.

Receiving ore docks are owned at the furnace plants at Chicago, Ill.; Milwaukee, Wis.; Lorain, Ohio, and Cleveland, Ohio.

Receiving and forwarding docks are owned at Lake Erie ports as follows:

At Conneaut, Ohio, by Pittsburg and Conneaut Dock Company.

At Ashtabula, Ohio, by Carnegie Steel Company.

At Fairport, Ohio, by Pennsylvania and Lake Erie Dock Company.

CHAPTER VII

OCCURRENCE AND PRODUCTION OF COPPER

Occurrence and Production of Copper

The commercial copper minerals — World's production — Growth of copper production in the United States — Various districts of the United States — Production from various kinds of ore — The plants required — Generalization on the cost of plants required for copper mining.

While it is no part of the plan of this volume to discuss the geological or mineralogical occurrence of ores, convenience seems to demand for the reader some general statement that will show where copper comes from and how it is obtained. Some reference to geological conditions will be found in following chapters illustrating the economic problems encountered at the various mines; so that no further description will be attempted here. The entire output of the mines to be discussed here is derived from the following minerals:

		Per Cent. Copper
Cupriferous pyrite		0.5 to 4
Richer copper sulphides	Chalcopyrite	34.4
	Bornite	55.58
	Chalcocite	79.7
Oxides and carbonates	Red oxide	88.8
	Black oxide	79.8
	Azurite	61.4
	Malachite	63.8
Silicate — Chrysacolla		
Native copper		100

These various ores are apt to be found derived from an original mineralization of cupriferous pyrite which is simply iron sulphide containing a small proportion of copper. The effects of the circulation of surface waters on such ores has resulted in an extensive and often profound rearrangement of the minerals. In general terms this is the origin of most commercially valuable copper deposits. There are, however, some very important exceptions. The native copper ores of Lake Superior have not been proved to have any connection with any original sulphide. The new porphyry deposits of Utah, Nevada, Arizona, and Mexico have no defined connection with solid masses of pyrite, although they are undoubtedly secondary sulphides. Except in the case of cupriferous pyrite, which sometimes occurs in very large homogenous masses with little admixture of foreign substances, commercial copper is invariably a mixture of the true ore with a large proportion of country rock or other minerals, technically known as "gangue."

World's Production

The smelter production of copper in the world was 1,589,-809,300 lb. in 1907; in 1906 the production was 1,596,973,700 lb., and in 1905 it was about 1,545,137,000 lb. In 1907 the smelter output of the United States was 54.66 per cent. of the world's total production, in 1906 it was 57.47 per cent., and in 1905 it was about 57.52 per cent.

If we add the production of Canada and Mexico, where the mines have almost invariably some connection with those in the United States, we get the total output of North America; which was, for 1906, 69.8 per cent., and in 1907, 66.4 per cent., of the world's product.

World's Production (Smelter Output) of Copper in 1906 and 1907, in Pounds

	1906	1907
Algeria	985,600	156,800
Argentina	235,200	492,800
Australasia	81,200,000	92,400,000
Austria	2,744,000	2,060,800
Bolivia	5,600,000	5,600,000
Canada	57,030,400	57,377,600
Cape Colony	8,825,600	9,475,200
Chile	57,668,800	59,774,400
England	1,120,000	1,568,000
Germany	45,561,600	45,897,600
Hungary	470,400	280,000
Italy	6,417,600	7,392,000
Japan	95,737,600	109,614,400
Mexico	135,800,000	126,705,600
Namaqualand	5,824,000	5,600,000
Newfoundland	5,140,800	3,875,200
Norway	13,708,800	16,702,400
Peru	19,051,200	23,688,000
Russia	23,497,600	33,600,000

World's Production (Smelter Output) of Copper in 1906 and 1907, in Pounds — *Continued*

	1906	1907
Spain	105,055,200	111,272,000
Portugal	5,421,600	4,480,000
Sweden	1,120,000	
Turkey	952,000	2,800,000
United States	917,805,700	868,996,500
Total	1,596,973,700	1,589,809,300

The following table shows the growth of the American copper industry from its beginning to the end of 1908:

Magnitude and Growth of Copper Production in the United States from 1845 to 1908, Inclusive

Year	Production	Increase		Average Annual Increase by Decades	
	Pounds	Pounds	Per Cent.	Pounds	Per Cent.
1845	224,000	—	—	—	—
1846	336,000	112,000	50.0		
1847	672,000	336,000	100.0		
1848	1,122,000	450,000	67.0	242,400	50.0
1849	1,568,000	426,000	40.0		
1850	1,456,000	(*a*) 112,000	(*a*) 7.1		
1851	2,016,000	560,000	23.1		
1852	2,464,000	448,000	22.2		
1853	4,480,000	2,016,000	81.8		
1854	4,990,000	510,000	12.5		
1855	6,720,000	1,730,000	33.3		
1856	8,960,000	2,240,000	33.3	1,467,200	27.0
1857	10,752,000	1,792,000	20.0		
1858	12,320,000	1,568,000	14.6		
1859	14,112,000	1,792,000	14.5		
1860	16,128,000	2,016,000	14.3		
1861	16,800,000	672,000	4.1		
1862	21,160,000	4,360,000	20.0		
1863	19,040,000	(*a*) 2,120,000	(*a*) 5.5		
1864	17,920,000	(*a*) 1,120,000	(*a*) 5.9		
1865	19,040,000	1,120,000	6.3		
1866	19,936,000	896,000	4.7	1,209,600	6.1
1867	22,400,000	2,464,000	12.3		
1868	25,984,000	3,584,000	16.0		
1869	28,000,000	2,016,000	7.7		
1870	28,224,000	224,000	1.0		

(*a*) Decrease.

Magnitude and Growth of Copper Production in the United States from 1845 to 1908, Inclusive — *Continued*

Year	Production	Increase		Average Annual Increase by Decades	
	Pounds	Pounds	Per Cent.	Pounds	Per Cent.
1871	29,120,000	896,000	3.2	3,225,600	7.2
1872	28,000,000	(*a*) 1,120,000	(*a*) 3.8		
1873	34,720,000	6,720,000	24.0		
1874	39,200,000	4,480,000	12.9		
1875	40,320,000	1,120,000	2.9		
1876	42,560,000	2,240,000	5.6		
1877	47,040,000	4,480,000	10.5		
1878	48,160,000	1,120,000	2.4		
1879	51,520,000	3,360,000	7.0		
1880	60,480,000	8,960,000	17.4		
1881	71,680,000	11,200,000	18.6	18,930,349	14.8
1882	90,646,232	8,966,232	12.5		
1883	115,526,053	24,886,221	27.4		
1884	144,946,653	29,420,600	25.5		
1885	165,875,766	20,929,113	14 4		
1886	156,735,381	(*a*) 9,140,385	(*a*) 5.5		
1887	180,920,524	24,185,143	15.4		
1888	226,361,466	45,440,942	25.1		
1889	226,775,962	414,496	.2		
1890	259,763,092	32,987,130	14.5		
1891	284,121,764	24,358,672	9.4	34,635,407	9.1
1892	344,998,679	60,876,915	21.5		
1893	329,354,398	(*a*) 15,644,281	(*a*) 4.8		
1894	354,188,374	24,833,976	7.5		
1895	380,613,404	26,425,030	7.4		
1896	460,061,430	79,448,026	20.9		
1897	494,078,274	34,016,844	7.4		
1898	526,512,987	32,434,713	6.6		
1899	568,666,921	42,153,934	8.0		
1900	606,117,166	37,450,245	6.6		
1901	602,072,519	(*a*) 4,044,647	(*a*) .7	37,554,189	7
1902	659,508,644	57,436,125	9.5		
1903	698,044,517	38,535,873	5.8		
1904	812,537,267	114,492,750	16.4		
1905	888,784,267	76,247,000	9.4		
1906	917,805,682	29,021,415	3.3		
1907	868,996,491	(*a*) 48,809,191	(*a*) 5.3		
1908	948,196,490	80,800,000	8.5		

(*a*) Decrease.

SUMMARY

Years	Total Production	Average Annual Increase	
		Quantity	Per Cent.
	Pounds	*Pounds*	
1845–1907	12,163,637,913	—	—
1846–1907	—	13,880,213	15.0
1846–1881	—	2,034,333	17.2
1882–1907	—	30,282,201	9.9

In the following table is given for 1907 the production of all districts in the United States whose output yielded, on smelting, 2,000,000 lb. or more:

COPPER PRODUCTION OF PRINCIPAL DISTRICTS IN 1907, IN POUNDS

District or Region	State	Approximate Smelter Output	Percentage of Total Production	Rank
Butte	Montana	222,000,000	25.55	1
Lake Superior	Michigan	219,000,000	25.20	2
Bisbee	Arizona	110,000,000	12.66	3
Morenci	Arizona	63,000,000	7.25	4
Bingham	Utah	47,000,000	5.41	5
Globe	Arizona	35,000,000	4.03	6
Jerome	Arizona	33,000,000	3.80	7
Shasta County	California	28,000,000	3.22	8
Ducktown	Tennessee	19,500,000	2.24	9
Tintic	Utah	7,800,000	.90	10
Cœur d'Alene	Idaho	6,600,000	.76	11
Leadville	Colorado	5,700,000	.66	12
Silverbell	Arizona	5,600,000	.64	13
Southeastern Alaska	Alaska	5,400,000	.62	14
Santa Rita	New Mexico	5,000,000	.58	15
Frisco	Utah	4,900,000	.56	16
Calaveras County	California	4,500,000	.52	17
Encampment	Wyoming	2,900,000	.33	18
White Knob	Idaho	2,800,000	.32	19
San Juan	Colorado	2,600,000	.30	20
Lucin	Utah	2,200,000	.25	21
Burro Mountain	New Mexico	2,100,000	.24	22
Total		834,600,000	96.04	—
All others		34,400,000	3.96	—
Grand Total		869,000,000	—	—

In the following chapters something will be found regarding the conditions and results in Butte, Lake Superior, Bisbee, Morenci, Bingham, Globe, Shasta County, and Ducktown districts that account for 86 per cent. of production in the United States.

An interesting view of the broad features of the copper mining business may be had from the following table, which shows that of all the ores treated in the United States one-quarter are smelted direct and three-quarters concentrated. The concentrated ores are reduced to 12.4 per cent. of their volume before smelting. Adding this to the amount smelted crude we find the total percentage smelted to be 34.7 per cent. The average copper yield of all ores mined was 41.2 lb. per ton or 2.06 per cent. The yield from ores smelted direct was 80.1 lb. per ton or 4.05 per cent. The yield per ton of concentrating ore was 28.2 lb. per ton or 1.41 per cent.; while the resulting concentrates yielded 247 lb. per ton or 12.35 per cent.

A rough estimate of the plants required to perform the processes indicated is as follows:

Mining, milling, and smelting plants with transportation facilities between mines, mills, and smelters, at $4.50 per ton of annual capacity for 15,000,000 tons of concentrating ore	$67,500,000
Mining and smelting plants for 5,000,000 tons smelting ore at $7 per ton of annual capacity	$35,000,000
Total plant required	$102,500,000

This estimate is intended to cover only such transportation lines as are owned by mining companies, not the longer lines owned by railroad companies that are used to carry ores, concentrates, matte, or bullion for great distances.

The various refineries will probably bring up the capital in plants by an additional $7,500,000, making a total plant employed in the copper-mining business of at least $110,000,000. This estimate refers only to the successful and active plants. The addition of failures and discarded plants would undoubtedly show a largely increased figure. Computing the future life of the average mine at fifteen years, the amortization of capital is 10 per cent. To this we must add 6 per cent. for annual depreciation, so that a total charge of 16 per cent. must be made for the use of capital. On $110,000,000 this annual charge is $17,600,000, or a little over 2 cents a pound on the output of 1907.

If the average operating cost of production is 10 cents, the addition of plant charges will therefore bring the total cost up to 12 cents a pound.

TONNAGE OF DOMESTIC COPPER-BEARING MATERIAL TREATED IN 1907, IN SHORT TONS

Source	Tonnage Smelted Yielding Copper		Copper-bearing Ore Sold or Treated by the Mines		Pounds Copper per Ton All Ore Mined
	Crude Smelting Ore	Concentrates	Copper Ore	Copper-lead and Copper-lead-zinc Ore	
Alaska	90,849	—	98,927	—	71.2 Alaska
Arizona	1,768,256	247,073	3,191,125	1,608	80.5 Arizona
California	417,005	273	339,152	40	84.1 California
Colorado	263,314	65,547	22,619	7,841	258. Colorado
Idaho	83,801	683	136,327	—	80. Idaho
Michigan	—	172,000	9,892,214	—	22. Michigan
Montana	590,827	1,246,160	3,719,600	28,295	60. Montana
Nevada	83,750	291	11,100	31,077	— Nevada
New Mexico	81,013	4,250	164,849	—	66 New Mexico
North Carolina	7,865	328	11,261	—	— North Carolina
Oregon	6,518	298	7,060	—	— Oregon
Tennessee	557,950	—	558,487	—	35.7 Tennessee
Utah	1,061,708	121,042	1,793,084	2,920	36. Utah
Washington	17,317	7	14,691	—	
Wyoming	(a)17,000	(a) 1,000	(a) 26,071	—	90 Wyoming
Alabama, Georgia, Maryland, Missouri, Vermont, Virginia, and unapportioned	4,369	2,720	52,917	—	
Total	5,107,542	1,862,665	20,039,484	71,781	41.2 Average
Grand Total	6,970,207		20,111,265		

(a) Partly estimated.

Figuring on costs per ton in a general way, assuming the cost per pound to be 12 cents complete, we have:

For smelting ores $80.1 \times 12 = \$9.61$ per ton.

For concentrating ores $28.2 \times 12 = 3.38$ per ton.

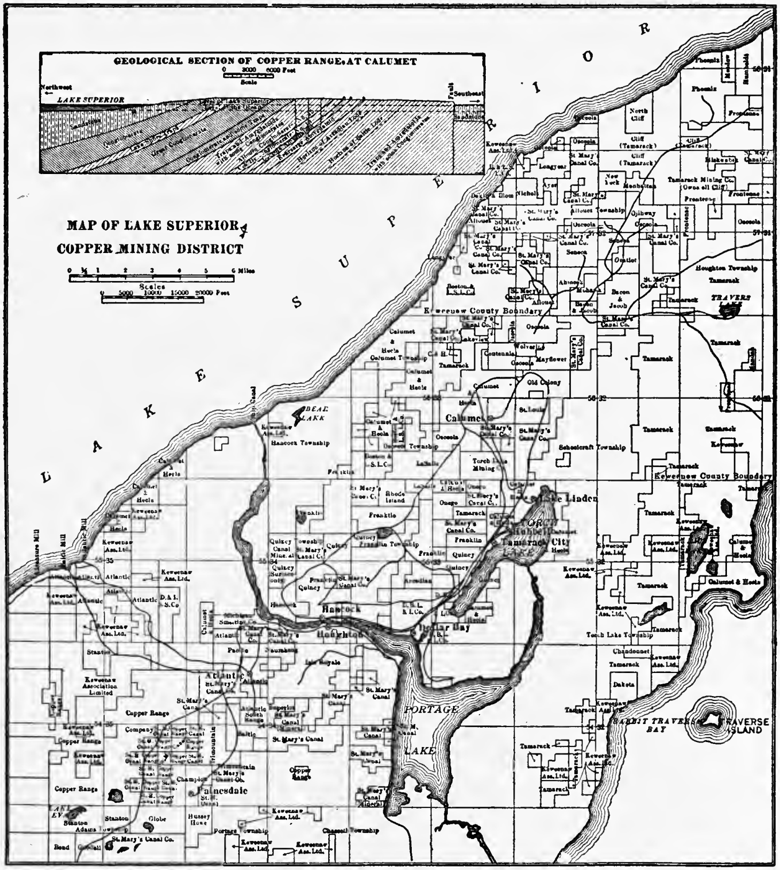
CHAPTER VIII

LAKE SUPERIOR AMYGDALOID COPPER MINES

General working conditions in the region — Plants required and their cost — Milling, transportation, and smelting — Cost of smelting — Nature of the deposits — Wolverine mine — Mohawk mine — Atlantic mine — Osceola Consolidated — Quincy Mining Company — Baltic Lode — Sorting and filling at Copper Range — Baltic mine — Trimountain mine — Champion mine.

THE Lake Superior copper mines work deposits of native metal occurring either in beds of conglomerate or in amygdaloids, which mark the upward surface of ancient lava flows. The deposits in these beds form immense ore shoots of dimensions in one case as great as three miles in length and over a mile in width in the plane of the vein, covering many hundred acres. Such a lateral extent, combined with a thickness of from 6 to 30 ft., gives a volume of many million tons of workable material.

The persistence and extent of the deposits have long established that the controlling factor in the successful exploitation of these mines is the provision of machinery for handling large quantities of material for long periods of time. The practice of the last ten years has fixed a cost of about $1,500,000 as necessary for the preliminary development and equipment of a property on a scale commensurate with economy. The actual working of the deposits is simple. The mines are dry and safe; the ores of each deposit are uniform in character and can be concentrated easily and cheaply; the smelting operations are reduced to a minimum, the concentrates to be smelted ranging from 1 to 4½ per cent. of the ore milled. Wages are very moderate, being about 25 cents an hour; supplies of all kinds are cheap; the country in the neighborhood of the mines is well watered and well timbered; transportation to and from markets is done mainly by water, and is very cheap. The population is vigorous and intelligent, although at least 95 per cent. of the men employed in the mines are of foreign birth, the greater number being Finns, Englishmen, Austrians, and Italians.



Redrawn from Map by R. M. Edwards, Houghton, Michigan.

FIG. 5

It may be said, therefore, that not a single factor in the working of the mines is unfavorable. The inclination of the deposits is from 35° to 70°, so that in following the ore shoots the shafts become enormously deep, several of them being in the neighborhood of a mile vertically below the surface. This means, of course, an unusual expense for hoisting and increasing difficulty in working as compared with mining at ordinary depths, but it indicates the extremely favorable conditions prevailing in this district by showing the remarkable persistence of the orebodies. Under present conditions the total cost of mining these ores and marketing the copper is from $2 to $3 per ton.

The ore hoisted at the various mines is shipped to mills on the shore of Lake Superior or its bays. The distance is usually from 10 to 20 miles. The mills concentrate the copper into "mineral" containing about 70 per cent. metal. This mineral is then smelted at plants situated along the shores of Portage lake, an inlet of Lake Superior. The smelting and refining are done by a single process; and ingot copper is produced that needs no further refining, the copper being exceptionally pure and commanding a higher price than any other in the market.

Plants Required and their Cost

To elaborate a little on the business aspects of the process of obtaining the copper we may group the plants required as follows:

1. *The mining plants for hoisting, pumping, compressing air, crushing, etc.* — These plants are always owned by the mining companies themselves. Unfortunately I am not able to get the cost of these plants, segregated from other plant charges, in a single instance.

2. *The transportation of ore to the mills.* — This is invariably done by railroad. The Copper Range Company had to provide this equipment for three mines which in 1906 had reached an output of 1,828,000 tons and are likely to average 2,000,000 tons a year. The cost of the Copper Range Railroad was, including working capital and equipment, $6,500,000. This road serves a number of other mines and a considerable territory outside the Copper Range group. Nevertheless it seems fair to charge half of it to those mines, so that we may figure $1.60 per annual ton for their transportation capital.

3. *The concentrating mills.* — The cost of these is invariably bound up with that of the mine equipment and development. We may as well stop to consider 1 and 3 together:

The Copper Range Mines had to raise the following sums for development and mine and mill equipment before they became self-sustaining.

Baltic	$800,000
Trimountain	1,200,000
Champion	1,475,000
Total	$3,475,000

for an annual output of say 2,000,000 tons, equal to a plant charge of $1.75 per ton of ore stamped annually.

The Wolverine Mine paid for its mining and milling plants and development, if I understand the report correctly, $780,000; providing capacity for mining and milling 350,000 tons a year, equal to $2.20 per annual ton.

The Mohawk Mining Company spent $1,350,000 to provide itself with mining milling facilities for an output of 675,000 tons, equal to $2.00 per annual ton. Its Traverse Bay Railroad went in with the mine itself, apparently, at a valuation of $450,000, or about 70 cents per annual ton.

Returning to the Copper Range and adding together the initial cost of railroad and mining plants we get a total of $6,800,000 or $3.40 per annual ton.

4. *The smelting plants for converting the concentrates or mineral into ingot copper.* — These plants are usually owned by groups of mines in common. The Michigan Smelting Company, with works capable of turning out 90,000,000 lb. refined copper a year, which represents the yield of about 4,500,000 tons of ore from the mines, is capitalized at $500,000, probably its cost. This is equal to only 11 cents per ton of rock mined.

Companies that have complete mining, milling, transportation, and smelting facilities of their own are the Quincy and Calumet & Hecla. The former states that its total cost for plant, including railroads, warehouses, real estate, smelting, mining, and milling plants is $6,300,000. The annual tonnage stamped is not given, but is approximately $1,100,000, giving a total plant cost of nearly $6 per annual ton. The Calumet & Hecla gives the complete cost of all its plants at between fifteen and sixteen million dollars, with an annual output of 2,500,000 tons, equal to $6 + per annual ton.

In round numbers, I think we may say that the minimum plant cost per annual ton is $3 for the most favorably situated amygdaloid mine and $6 for a conglomerate mine. In each case the working is conducted on a grand scale.

While the Michigan mines are all remarkably long lived it does not seem proper to reckon on anything less than a 7 per cent. annual instalment to cover the amortization of capital so invested. The corollary is that the use of capital is worth from 21 to 42 cents per ton of output, or at the very least 1 cent per pound of copper.

Cost of Smelting

Professor L. S. Austin reports (*Mining and Scientific Press*, April 24, 1909) the costs of the Lake Superior Smelting Company for 1906 as follows:

41,177 tons "mineral" (concentrates) producing 55,526,088 pounds fine copper.

		Per Ton Concentrates
Reverberatory operating	$195,144	$4.741
Miscellaneous	43,409	1.055
Construction	15,665	0.380
Blast-furnace operating	32,623	0.790
Miscellaneous	13,461	0.327
Total	$300,302	$7.293

Dividing the total cost by the pounds of copper we get 0.541 cents as the cost of smelting per pound.

It appears that to this must be added about ½ cent per pound for freight for market and marketing expense, so that the total cost for smelting, refining, and marketing is a little over 1 cent per pound refined copper.

Nature of the Deposits

While in a broad sense the conditions are rather uniform throughout the district, there are three fairly well marked types of deposits whose characteristics impose certain differences of method and cost. One is the conglomerate, of which the only commercially valuable deposit is the great ore shoot worked by the Calumet & Hecla and the Tamarack mines. This has already produced in the neighborhood of 1,100,000 tons of fine copper from more than 40,000,000 tons of ore, and there remains in sight probably 20,000,000 tons more. This magnificent orebody is about 14 feet thick; it dips at an angle of 37°, and is a hard compact bed of conglomerate overlaid by a trap hanging wall of such a character that it requires timbering.

The amygdaloid deposits are rather numerous and have much in common. There is, however, an important distinction between that of the Copper Range Consolidated Company and the other amygdaloid mines. The ordinary amygdaloids (represented by the Wolverine on the Kearsarge lode and by the Quincy mine) either are, or are assumed to be, homogenous, in that all of the vein stuff is sent to the mill with a very moderate amount of sorting at the surface. These deposits have yielded from a minimum of 12 lb. to a maximum of 50 lb. of copper to the ton. The rock is softer than the conglomerate, and is more easily milled. The hanging wall is generally firm, so that in most cases mining can be done without any timbering.

The amygdaloid of the Copper Range Consolidated Company on the Baltic lode is somewhat different. The rock is harder than the ordinary and the copper is very apt to be attached to numerous small fissures that traverse the bed. The result of this distribution of value has been the development of an entirely distinct type of underground mining, based on a system of sorting waste out of the vein itself and leaving this waste in the stopes for filling.

The Wolverine Mine

Of these various types the simplest is the kind of amygdaloid mine represented by the Wolverine. This property in common with all others of the Stanton group is very well managed and issues clear and excellent reports. The entire process of mining and realizing copper at this mine is simple. The vein averages about 15 ft. thick. It dips at an angle of about 37°; no timbering whatever is required, but a few small pillars are left. The shafts are sunk mainly in the vein itself, but partly in the footwall a few feet back from the vein. Levels are run at distances of 100 ft. and are opened by what are called "stope drifts," these being a complete section of the vein 25 ft. wide along the plane of the footwall. The cost of running these drifts is $5.68 per foot in excess of the cost of stoping an equivalent amount of ground.

In the stopes themselves, nothing is done except to break the ore with machines. Once broken the ore is caught on a low platform built at the bottom of the stope from which the ore is partly rolled and partly shoveled into the cars. This completes the mining process. The cost of the underground work is less than $1 a ton; 7 cents a ton is added for crushing and sorting in the rock house at the suface. Transportation to the mill costs about 16 cents a ton and concentration about 22 cents. General expenses such as superintendence, taxes, and insurance, etc., amount to about 22 cents more; and smelting, refining, and marketing about 29 cents, making a total of operating expenses of $1.84. Construction work for the last four years has averaged 8 cents, and the total expenses with construction for the same period have averaged $1.92.

It is to be noticed that in this mine the exploration work is reduced nearly to zero. The whole operation is a straight, uncomplicated matter of handling so much material; and to the handling of it nature has interposed as few obstacles as can be found in any underground mine. There is very little water to pump; there are no complex vein systems to work out, no faults to interrupt the vein, and no geological relations to be understood. There is always abundant room to work, good ventilation, comparatively soft ground, and no timbering. While it cannot be denied that the Wolverine is a well-managed property which has kept notably clear from extravagant impractical projects of all kinds, it seems fair to say that the low costs obtained by it are not in any way extraordinary, but merely the inevitable result of common-sense methods applied to a favorable set of conditions.

The accompanying table gives such details as are published of the cost of mining in the Wolverine. It is to be noticed that the Wolverine is at present the richest of all amygdaloid mines and that for this reason the cost for smelting is higher than that of any of the other mines of its class.

Working Expenses at the Wolverine Mine, Year Ending June 30, 1907

Underground Expenses (Rock Stamped 344,062 Tons) —		Per Ton
Sinking 450 ft. at $17.88	$8,046.00	
Drifting 4,993 ft. at $5.68	28,385.80	
Stoping 23,175 fathoms at $7.69	178,269.70	
Labor	1,546.55	
	$216,248.05	
Timbering	5,286.60	
Tramming	71,603.15	
Mining captains and labor	29,151.80	
Mechanics	7,833.15	
Hoisting and pumping	22,092.51	
Carried forward	$352,215.26	

Working Expenses at the Wolverine Mine, Year Ending June 30, 1907 — *Continued*

			Per Ton
Brought forward		$352,215.26	
Compressor		29,774.52	
Teaming, etc.		1,095.95	
Supplies and fuel		19,107.47	
Electric light		291.88	
		$402,584.98	
Less profit on supplies furnished contractors		65,416.00	
		$337,168.98	$0.98
Rock House —			
Labor	$13,371.85		
Machinists	1,166.28		
Fuel	2,160.00		
Supplies	3,621.29		
Teaming, etc.	808.30		
Electric light	1,167.12		
		22,294.84	0.065
Stamp Mill —			
Transportation	$55,053.35		
Supplies and electric light	9,918.72		
Machinists	4,318.90		
Fuel and teaming	26,816.00		
Labor	27,632.80		
Pumping	7,599.78		
		131,339.55	0.38
Surface and Incidental Expenses —			
Superintendence and labor	$20,309.57		
Supplies	9,523.51		
Telephone, telegrams, and sundries	495.28		
Taxes and insurance	48,938.14		
Freight on mineral, etc	5,948.28		
	$85,215.18		
Less amounts received for rents	6,547.90		
		78,667.28	0.223
		$569,470.65	$1.648
Construction average of four years			0.08
Amortization of $780,000 at 5 per cent. interest and 3 per cent. annual amortization			0.20
Smelting, refining, and marketing			0.284
Total			$2.212

Average cost of copper in New York, 7.93 cents per pound.

The amortization in this case includes the purchase price of the property. This item is not distinguished from the capital invested in equipment.

STATEMENT OF RECEIPTS AND EXPENDITURES OF THE WOLVERINE COPPER MINING COMPANY FROM DATE OF ORGANIZATION TO JUNE 30, 1908

Receipts

From capital stock (60,000 shares at $10 per share), paid in at organization		$600,000.00	
From assessments		180,000.00	
From proceeds of copper (87,146,014 lbs.)		12,534,015.91	
From interest		80,916.41	
		$13,394,932.32	

Expenditures

			Cost per Pound
For real estate, land, buildings, machinery, dwellings, etc., at organization	$550,000.00		$0.65
For lands since purchased	181,819.23		0.2
For mining and surface labor, improvements, costs of smelting and marketing copper, and all incidental expenses	7,051,483.87		8.05
		7,783,303.10	= 8.9 cents.
Receipts over expenditures		$5,611,629.22	
Deduct dividends paid, Nos. 1 to 20 inclusive		4,800,000.00	
Balance of receipts over expenditures		$811,629.22	

STATEMENT OF WORKING EXPENSES AT THE WOLVERINE MINE FOR YEAR ENDING JUNE 30, 1908

Underground Expenses		Cost per Ton Stamped
Sinking 414 feet at $18.20	$7,536.50	
Drifting 4,841.1 feet at $5.58	27,024.20	
Stoping 23,817.3 fathoms at $7.76	184,951.75	
Labor	887.40	
	$220,399.85	
Timbering	6,935.15	
Tramming	65,016.55	
Mining captains and labor	30,354.10	
Mechanics	8,689.43	
Hoisting and pumping	32,312.98	
Compressor	30,278.69	
Teaming, etc.	2,561.90	
Supplies and fuel	20,559.38	
Electric light	437.87	
	$417,545.90	
Less profit on supplies furnished contractors	66,621.00	
Carried forward	$350,924.90	$1.01

Statement of Working Expenses at the Wolverine Mine for Year Ending June 30, 1908 — *Continued*

			Cost per Ton Stamped
Rock House			
Brought forward		$350,924.90	$1.00
Labor	$13,293.55		
Machinists	1,564.44		
Fuel	2,343.00		
Supplies	1,654.25		
Teaming, etc	952.18		
Electric light	1,321.16		
		21.128.58	.06
Stamp Mill			
Transportation	$52,923.45		
Supplies and electric light	11,372.06		
Machinists	7,555.47		
Fuel and teaming	30,199.81		
Labor	30,669.90		
Pumping	9,261.29		
		141,981.98	.40
Surface and Incidental Expenses			
Superintendence, and labor	$21,606.41		
Supplies	8,300.22		
Telephones, telegrams, and sundries	505.87		
Taxes and insurance	53,794.59		
Freight on mineral, etc.	5,454.14		
	$89,661.23		
Less amount received for rents	6,790.50		
		82,870.73	.24
Total working expenses		$596,906.19	$1.71

Summary of Results, 1908

Rock hoisted	367,795 tons
Rock stamped	348,860 tons
Product of mineral	12,117,000 pounds
Product of refined copper	9,356,123 pounds
Yield of rock 26.82 lb. per ton treated	1.341 per cent.
Cost per ton of rock hoisted	$1.62
Cost per ton of rock stamped	1.71
Cost per pound of refined copper at mine	6.379 cents
Cost of smelting, freight, and marketing product, including New York office expenses	.942 cents
Total cost per pound of refined copper	7.321 cents

The Mohawk Mining Company

This is one of the newer and lower grade amygdaloid mines. It is situated northeast of Calumet on the Kearsarge lode, the same one on which the Wolverine is situated. This lode is one of the longest and most persistent veins in the world. It is considered to be payable for a length of ten miles. The values, however, are not evenly distributed through it. Certain portions are quite unpayable while others are very good. The poor spots are believed to form irregular patches, alternating irregularly with the richer portions. This fact makes necessary a large amount of preliminary development to open up enough ground to insure a steady output of pay rock.

The Mohawk, like the Wolverine, is under the Stanton management, and the reports to stockholders are all that can be desired. The essential facts will, I believe, all appear from the following statements:

Current Costs, Mohawk Mining Company, 1906

Rock hoisted	703,771 tons
Rock stamped	618,543 tons
Product refined copper	9,352,252 lb.
Yield per ton stamped	15.12 lb.

Costs per Ton Stamped —		Per Ton
Underground expense	$578,817	$0.93
Surface expense	56,463	0.09
Rock house expense	45,327	0.07
Transportation to mill	83,952	0.14
Stamping	120,152	0.19
Total	$884,712	$1.42

Smelting refining, and marketing 17.65 lb. per ton	0.18
Construction, average four years (charged to additional output of 5,000,000 tons in 20 years), 5 per cent. interest, 3 per cent. amortization charged on output of 10,000,000 tons	0.10
Amortization of $1,350,000 invested in plant on 10,000,000 tons to be mined in 26 years, 5 per cent. interest, 2 per cent. amortization	0.25
Total cost of mining 10,000,000 tons	$1.95

Cost of refined copper in New York 11.05 cents per pound.

MOHAWK MINE — STATEMENT OF RECEIPTS AND EXPENDITURES FROM DATE OF ORGANIZATION TO DECEMBER 31, 1908

Receipts

Capital Stock issued for purchase of Mine	$450,000.00
Capital Stock issued for cash	300,000.00
On account of Assessment No. 1 — $2.50 per share	250,000.00
On account of Assessment No. 2 — $3.00 per share	300,000.00
On account of Assessment No. 3 — $3.00 per share	299,994.00
On account of Assessment No. 4 — $2.00 per share	199,996.00
Sales of "Mohawkite"	116,407.79
Sales of copper, 226,824 lb. at 11.65 cents (1902)	26,425.91
Sales of copper, 6,284,327 lb. at 13.11 cents (1903)	823,940.81
Sales of copper, 8,149,515 lb. at 12.99 cents (1904)	1,058,382.25
Sales of copper, 9,387,614 lb. at 15.53 cents (1905)	1,457,588.20
Sales of copper, 9,352,252 lb. at 19.60 cents (1906)	1,832,765.96
Sales of copper, 10,107,266 lb. at 15.66 cents (1907)	1,583,083.66
Sales of copper, 10,295,881 lb. at 13.43 cents (1908)	1,382,731.05
Balance of interest account	18,160.68
Total copper, 53,803,669	$10,099,476.31

Expenditures

		Cost per Pound
Real estate (Mine location and Traverse Bay R. R.)	$450,000.00	0.9 cents
Real estate (land since purchased)	30,251.92	
Net expenditure for mining operations, equipment, taxes, and incidentals	7,384,624.51	13.7
	$7,864,876.43	14.6 cents

Dividends

January 10, 1906	$200,000.00		
July 10, 1906	300,000.00		
January 10, 1907	400,000.00		
July 10, 1907	500,000.00		
July 10, 1908	250,000.00		
		1,650,000.00	
			9,514,876.43
Balance of receipts over expenditures			$584,599.88

Statement of Working Expenses at the Mohawk Mine for the Year 1908

			Cost per Ton Stamped
Underground Expense			
Mining contracts	$302,659.43		
Mining on company account	65,606.30		
Timbering, tramming, and labor	170,453.00		
Hoisting and pumping	32,998.36		
Power drills	52,653.11		
Supplies and electric light	36,222.98		
		$660,593.18	$0.96
Surface Expense			
Superintendence and labor, less sundry credit items	$27,627.13		
Supplies and materials	9,073.99		
Sundry expenses	2,281.22		
Freight on mineral, barrels, etc	5,641.74		
Fire insurance	6,800.26		
Taxes	24,434.95		
Legal expenses	300.00		
Telegrams and telephone	203.74		
	$76,363.03		
Less amount received for rents	13,524.15		
		62,838.88	0.09
Rock House Expense			
Labor	$38,019.68		
Supplies and teaming	6,988.62		
Fuel	3,000.00		
Electric light	1,080.00		
		49,088.30	0.07
Transportation Expense			
Freight on rock	$78,869.75		
Labor	3,312.84		
Supplies, etc.	550.00		
		82,732.59	0.12
Carried forward		$855,252.95	$1.24

STATEMENT OF WORKING EXPENSES AT THE MOHAWK MINE FOR THE YEAR 1908 — *Continued*

Stamping Expense			Cost per Ton Stamped
Brought forward		$855,252.95	$1.24
Labor	$57,562.93		
Fuel	44,660.80		
Pumping cost	19,862.75		
Electric light and teaming	2,316.59		
Supplies	19,346.86		
	$143,749.93		
Less received for custom work	10,037.25		
		133,712.68	0.20
Total working expenses		$988,965.63	
Construction		21,796.11	0.03
Total expense at mine		$1,010,761.74	$1.47

Summary of Results

Rock hoisted		789,694 tons
Rock stamped		685,823 tons
Product of mineral		13,310,820 lb.
Product of refined copper		10,295,881 lb.
Yield of rock treated, 15.01 lb. per ton, or		.7505 per cent.
Cost per ton of rock hoisted		$1.252
Cost per ton of rock stamped		$1.442
Cost per pound of refined copper at mine	9.605 cents	
Cost of smelting, freight, and marketing product, including office expenses	.938 cents	
Total cost per pound of refined copper	10.543 cents	
Total cost per pound of refined copper, including construction,		10.755 cents

ATLANTIC MINE

This property has frequently been referred to as the best example of close management and low costs in the Lake Superior copper district. The original amygdaloid mine seems to have been finally abandoned as probably unpayable, but the company has other property of prospective value. The last year for which reports in the characteristic manner were issued, and which shows the results obtained by the property to that date, is for 1904. The following is the summary. It is a model of what a report to stockholders ought to be:

Summary of Receipts and Expenditures of Atlantic Mining Company, from Date of Organization to December 31, 1904

Receipts

Capital Stock paid by consolidation	$700,000.00	
Capital Stock paid by assessments	280,000.00	
		$980,000.00
Sales of copper		15,512,930.86
Other sources		853.15
		$16,493,784.01

Expenditures

Real estate ("South Pewabic" and "Adams" mines, buildings, railroad, stamps, etc., as valued at consolidation)	$659.642.11	
Real estate (land since purchased)	20,349.66	
	$679,991.77	
Net expenditure for additional equipment, mining operations, smelting and marketing copper, taxes, and incidentals............	14,523,445.03	
		15,203,436.80
Balance of receipts, being net profits to date		$1,290,347.21
Deduct dividends paid		940,000.00
Net surplus, December 31, 1904		$350,347.21

Statement of Working Expenses by the Atlantic Mine for the Year Ending December 31, 1904

Underground Expenses			Cost per Ton Stamped
Sinking shafts 182 feet, average $22.74 net.	$4,138.89		
Sinking forks 6 feet, average $21.87 net ..	131.24		
Drifting (8′x10′) 4,910 ft., average $7.86 net	39,073.22		
Stoping 22,009 fathoms, average $4.42 net.	97,332.82		
Timbering, tramming, and labor	118,592.96		
Timber, materials, and supplies	27,423.43		
Pumping and operating air compressors:			
Labor	12,916.58		
Fuel..............................	14,868.00		
Supplies and materials	3,981.10		
Carried forward..............................		$318,458.24	$0.82

STATEMENT OF WORKING EXPENSES BY THE ATLANTIC MINE FOR THE YEAR ENDING DECEMBER 31, 1904 — *Continued*

			Cost per Ton Stamped
Surface Expenses			
Brought forward		$318.458.24	$0.82
Superintendence and labor of all kinds, less sundry credit items	$35,487.61		
Supplies and materials	15,867.64		
Fuel	22,937.71		
Fire insurance	558.75		
Taxes	6,592.02		
Expenses and sundry repairs	5,022.25		
Electric lighting and wiring	2,590,31		
	$89,056.29		
Less amount received for rents	8,410.45		
		80,645.84	0.21
Railroad Expenses			
Labor	$24,270.95		
Fuel	9,020.00		
Supplies	6,496.83		
	$39,787.78		
Less amount received for freight	9,637.30		
		30,150.48	0.08
Stamp Mill Expenses			
Labor	$40,766.74		
Fuel	54,913.81		
Supplies	16,909.19		
Fire insurance	2,047.31		
Transporting mineral, etc.	3,674.57		
	$118,311.62		
Less received for custom work	14,292.60		
		104,019.02	0.26
Total working expenses		$533,273.58	
Construction Account			
AT MILL.			
1 "Huntington" mill	$3,549.66		
1 Engine for dynamo	1,679.34		
		5,229.00	0.01
Total expenditure at mine		$538,502.58	$1.38

Summary of Results

Ground broken in openings and stoped	24,165 fathoms
Rock stamped	390,526 tons
Product of mineral	7,149,640 lb.
Product of refined copper	5,321,859 lb.
Yield of refined copper per cubic fathom of ground broken	220 lb.
Yield of rock treated, 13.63 lb. per ton, or	0.681 per cent.
Gross value of product, per ton of rock treated	$1.8185
Cost per ton of mining, selecting, and breaking, and all surface expenses, including taxes	1.0220
Cost per ton of transportation to mill	.0772
Cost per ton of stamping and separating	.2663
Cost per ton of working expenses at mine	1.3655
Cost per ton of freight, smelting, and marketing product, including New York office expenses	.1684
Cost per ton of running expenses	1.5339
Total expenditure (including construction) per ton of rock treated	1.5484

The Osceola Cons. Mining Company works some large amygdaloid mines near the Calumet & Hecla.

Abstract of the Reports of the Osceola Mining Co.

The following table gives the comparative results for 1906, 1907 and 1908.

	1906	1907	1908
Tons rock stamped	1,016,240	811,603	1,241,400
Pounds mineral obtained	24,227,281	18,607,747	26,912,944
Percentage refined copper in mineral	76.725	75.962	78.961
Pounds refined copper per ton of rock stamped	18.3	17.4	17.1
Product fine copper	18,588,451 lb.	14,134,753 lb.	21,250,794 lb.
Cost per pound at mine, excluding construction	8.73 cents	10.59 cents	8.74 cents
Cost per pound construction	0.84 cents	0.60 cents	0.69 cents
Cost per pound of smelting, freights, eastern expenses, commissions, and all other charges	1.32 cents	1.25 cents	1.10 cents
Total cost per pound of refined copper	10.89 cents	12.44 cents	10.53 cents
Cost of mining and stamping per ton of rock stamped	$1.60	$1.84	$1.50
Gross cost of stamping per ton	16.39 cents	17.47 cents	15.78 cents
Net cost of stamping per ton after deducting profit on custom rock	13.83 cents	11.71 cents	13.34 cents

From the above, it appears that the total costs per ton for 1908 were $1.80 as compared with $2.16 in 1907, and $1.99 in 1906. This rise and fall of cost was an experience the company shared with nearly all other mining companies during this period.

The reports state that the old Osceola mine shows large reserves of copper towards the south end, the northerly shafts being more nearly worked out. At the North Kearsarge mine No. 1 shaft was damaged by fire in September, 1906, and repaired at a cost of $36,950. This was charged to operating expenses. The report contains little additional information of interest.

The total dividends to date are $7,612,550. Dividends since the beginning of 1901 have been $3,942,150 from an output of 136,584,911 lb., equal to a trifle less than 3 cents a pound. Lake copper in the same period averaged 15.57 cents in price. It appears from this that the copper has averaged some 12.5 cents in cost, including everything.

The company has been absorbed by the Calumet & Hecla.

Quincy Mining Company

Next to the Calumet & Hecla the Quincy mine with its record of $18,450,000 paid in dividends, from a total capital investment of $2,150,000, has been the best copper mine in the Lake region. Its career is tersely expressed in the following statement issued annually in its report to the stockholders.

In 1908 its record was as follows:

		Per Pound
Refined copper, 20,600,361 pounds		
Cost of mining and milling	$1,980,867	9.61 cents.
Smelting, transportation, etc	175,081	.85
Taxes	47,909	.24
Construction	104,604	.51
Total	$2,308,461	11.21 cents.

The Quincy is an amygdaloid mine. It works a vein some 10 to 15 ft. thick. In persistence and general character it is a fine example of that kind of deposit. It is now about 5,300 feet deep on the incline. The yield per ton is not given, but is probably about 20 lb.

General Summary of Receipts and Expenditures of the Quincy Mining Company
From its Organization to December 31, 1908

Expenditures		Receipts	
For Expenditure on Location previous to 1856..	$42,097.98	From Capital Stock paid in	$200,000.00
" " " Quincy vein, 1858, not now worked	55,000.00	" " " (Scrip)	1,250,000.00
" Openings and Explorations on 3,800 feet, Pewabic vein, extending to Portage Lake, preparatory to future work............	11,500.00	" " " 10,000 shares increase	700,000.00
" Real Estate and permanent improvements.	6,300,535.28	" Proceeds of Copper and Silver (412,874,406 lb. Copper)	62,159,878.06
" Mining, smelting and marketing copper, and all incidental costs	39,185,794.43	" Interest	383,185.16
Balance carried down................	19,441,364.25	" Profit on sale P. L. & R. Improvement Company Stock, and other investments	79,637.16
		" Sales Real Estate, Hancock, Mich........	263,591.56
	$65,036,291.94		$65,036,291.94
Average cost............................	11 cents per pound	Balance brought down, being receipts over expenditures................................	$19,441,364.25
" profit	4 cents " "	Deduct dividends declared, Nos. 1 to 86 inclusive	18,450,000.00
Cost of plant and equipment per pound of copper .....1.52 cents			
Operating cost per pound of copper ....9.50 cents		Makes balance as per statement on preceding page	$991,364.25

Baltic Lode

The second type of amygdaloid deposits, represented by the Baltic, Trimountain, and Champion mines of the Copper Range Consolidated Company, presents a more difficult problem in operating. The Baltic lode has a dip of about 70°. Its hanging wall is insecure, so that it will not stand for any considerable area without support. Moreover, the vein is wide, sometimes as much as 50 ft., and the vein stuff has more the appearance of trap than the ordinary amygdaloid. The great width of the vein would in many cases make the leaving of pillars to support the hanging wall a very expensive and doubtful expedient.

Mining on this lode by the ordinary methods used for amygdaloid deposits was a failure. The whole vein had to be mined in order to find the copper which was scattered somewhat irregularly through the mass; but the whole vein proved to be too low grade to pay. It would yield only about 14 lb. copper to the ton. F. W. Denton solved the problem approximately as follows: The vein as a whole yielded in the mill 14 lb. copper and probably contained six additional pounds of copper that were lost in the milling process. By picking out waste or low-grade ore in the mine it was found that 40 per cent. that would run no better than the mill tailings could be rejected. This selection yielded the following results: 100 tons mined contained 2000 lb. copper; 40 tons were rejected containing 240 lb.; this left 60 tons of material containing 1760 lb. of copper or 29 lb. to the ton. This when sent to the mill and treated with a loss of 7 lb. in the tailings yielded 22 lb. per ton milled as against 14 lb. obtained before.

Logically, this process means additional expense as follows: 100 tons of rock would have to be broken and only 60 tons realized. If to break the whole vein cost 40 cents a ton, the breaking of the 60 tons recovered must cost 67 cents per ton. This represents about the measure of additional expense involved in the selection process. The coarse waste picked out underground can be piled back as easily as it can be shoveled into cars by the ordinary process and taken to the shaft. Indeed, it is possible that an actual saving is effected in tramming by the use of this system because it is easier to get the rock into a chute than it is to shovel it into a car, and the tramming of the rock from the chute to the shaft is practically as cheap as it would be to push the cars to the shaft after they were loaded by hand.

Peculiarities of Sorting and Filling Method

This method of filling the stopes by rock sorted from the vein itself is a novelty in Lake Superior though not in the mines of the West. Since it was developed independently by Mr. Denton, it resulted in one or two points of practice different from that employed anywhere else.

The rock sorted from the vein is hard and rough, and this fact has been taken advantage of in building up stone walls on the levels instead of using timbered drifts. These stone walls are covered with large timbers and lagging and then the whole thing is covered with the waste filling. It is found that stone walls resist the pressure of the accumulating filling very much better than any timber, and in fact maintain themselves in perfect condition as long as they are required. The mill holes leading through the waste to the working faces at the top instead of being built of wooden cribbing are circular wells laid in stone. In building the walls on the main levels and in the mill holes, advantage has been taken of the presence of Italian and Austrian miners who usually have had experience in laying stone walls in their own country. The total result is a very pretty adaptation of methods to the natural conditions.

The results in dollars and cents obtained by this method are all, and rather more, than could be expected. As compared with the Wolverine we find that in 1905 the underground costs at the Baltic were $1.04 a ton, and in 1906, $1.06 a ton, against $0.93 and $0.98, respectively, at the Wolverine, a difference of about 10 cents a ton as against the 27 cents increase that we might have expected. The Copper Range mines are, however, less than 1000 ft. deep, while the Wolverine will average more than 2000 ft.; so that the former gets some advantage in costs on this account.

There are certain advantages in the sorting and filling system over and above mere availability. These are: (1) The security of the mine; (2) the fact that no pillars need be left for any reason, unless, indeed, the shafts are sunk in the vein, in which case it is always necessary to leave some ground on each side of the shaft; (3) the system completely solves the question of exploring the vein for its copper contents; enough ground can always be taken to expose stringers and bunches running into the walls.

Costs at Copper Range Mines

Outside of the operations in the mine itself, the Copper Range Company does its business much as other amygdaloid mines do; whatever further economies it achieves are entirely due to mechanical reasons and the volume of material handled and not to differences in the method. The accompanying table gives the results obtained in recent years.

Costs of Mines of the Copper Range Consolidated Company, 1906

	Baltic	Champion	Trimountain
Tons stamped	649,932	671,785	506,942
	Per Ton	Per Ton	Per Ton
Superintendence and labor	$0.79	$0.86	$1.05
Rock house	0.07	0.10	0.08
Hoisting	0.06	0.05	0.09
Power drills	0.06	0.07	0.07
Timber and supplies	0.15	0.16	0.14
Surface costs	0.06	0.08	0.07
Transportation to mill	0.17	0.14	0.11
Stamping	0.18	0.22	0.21
Smelting, refining, and marketing	0.25	0.32	0.23
Total operating	1.79	2.00	2.05
Taxes	0.07	0.09	0.08
Construction, estimated average	0.10	0.10	0.10
Average current costs	1.96	2.19	2.23
10,000,000 tons to be mined in 26 years from time of investment at 5 per cent. interest and 2 per cent. amortization	0.15	0.27	0.22
	$2.11	$2.46	$2.45
Recent yield copper per ton	22 lb.	25 lb.	19 lb.
Current cost copper per lb.	9 cents	$8\frac{3}{4}$ cents	11.7 cents
Cost of copper, per pound, complete	$9\frac{1}{2}$ cents	$9\frac{3}{4}$ cents	$12\frac{7}{8}$ cents

The following statements from the excellent reports of the Copper Range Company show the statistical history of these mines to date and full details of the operations for 1908. The record seems to warrant the belief that these mines can produce copper more cheaply than any other amygdaloid mines in the Lake Superior region, except the Wolverine.

BALTIC MINING COMPANY — STATEMENTS OF RECEIPTS AND EXPENDITURES FROM DATE OF ORGANIZATION TO DECEMBER 31, 1908

Receipts

Capital stock issued for purchase of mine	$1,000,000.00
Assessment No. 1, January 12, 1898	100,000.00
Assessment No. 2, October 27, 1898	100,000.00
Assessment No. 3, September 18, 1899	300,000.00
Assessment No. 4, April 3, 1901	300,000.00
From sale of copper (1898) 25,000 lb. at 12.33 cents	3,082.50
From sale of copper (1899) 621,336 lb. at 16.93 cents	105,240.58
From sale of copper (1900) 1,735,060 lb. at 16.49 cents	286,046.85
From sale of copper (1901) 2,641,432 lb. at 16.43 cents	433,947.78
From sale of copper (1902) 6,285,819 lb. at 11.87 cents	746,276.02
From sale of copper (1903) 10,580,997 lb. at 13.43 cents	1,421,211.36
From sale of copper (1904) 12,177,729 lb. at 12.98 cents	1,581,640.67
From sale of copper (1905) 14,384,684 lb. at 15.62 cents	2,246,912.48
From sale of copper (1906) 14,397,557 lb. at 19.05 cents	2,742,402.69
From sale of copper (1907) 16,704,688 lb. at 17.28 cents	2,886,057.65
From sale of copper (1908) 17,724,854 lb. at 13.39 cents	2,372,849.47
Balance of interest account	29,442.90
	$16,655,110.95

Expenditures

Real estate(Baltic Mine location)	$1,000,000.00	
Real estate (lands since purchased)	14,751.00	
	$1,014,751.00	
Net expenditure for construction and equipment, mining operations, smelting and marketing copper, taxes, and incidentals.	10,472,448.09	
		11,487,199.09
Less dividends paid in 1905	$1,250,000.00	$5,167,911.86
Less dividends paid in 1906	1,400,000.00	
Less dividends paid in 1907	1,000,000.00	
Less dividends paid in 1908	900,000.00	
		4,550,000.00
Excess of receipts over expenditures		
Total copper	97,279,329	$617,911.86
Total cost copper to date for plant and operating		10.77 cents

BALTIC MINING COMPANY — STATEMENT OF WORKING EXPENSES AT THE BALTIC MINE FOR THE YEAR ENDING DECEMBER 31, 1908

			Per Ton
Mining Costs			
Superintendence and labor	$605,426.20		
Rock house expense	48,961.36		
Hoisting expense	51,530.05		
Power drill expense	42,999.24		
Timber and supplies	127,595.86		
		$876,512.71	$1.15
Surface Expenses			
Superintendence and labor	$24,468.23		
Supplies	4,282.34		
Insurance	8,829.73		
Purchasing department	2,157.43		
Legal and general expenses	1,814.11		
		41,551.84	0.05
Transportation of rock to mill		108,838.77	0.14
Stamp mill expenses		132,330.45	0.17
		$1,159,233.77	
Less rents received		6,061.72	
Net running expenses		$1,153,172.05	$1.51

Summary of Results

Rock stamped	764,117 tons
Product of mineral	25,282,145 lb.
Product of refined copper	17,724,854 lb.
Yield of rock treated	23.197 lb. per ton, or 1.16 per cent.
Cost per ton of working expenses	$1.509
Cost per ton of working expenses, including taxes	1.56
Cost per pound of copper delivered, including taxes	.0772
Total cost at mine	$1.51

Construction

AT MINE

No. 3 rock house	$19,486.12
New change house	13,131.68
Underground electric pumps	8,539.73
Dwellings	8,453.44
Clearing lands and grading	1,390.89
Barns and fences	629.52
	$51,631.38
Less amount received from sale of second-hand crusher	783.25
Carried forward	$50,848.13

Brought forward		$50,848.13	$1.51
AT MILL			
Addition to mill	$47,133.41		
Dwellings	1,054.44		
		48,187.85	
Total cost of construction		$99,035.98	0.13
Smelting, refining, and marketing		$179,754.60	0.24
Taxes		$38,313.10	0.05
Total cost per ton			1.93
Cost per pound copper			8.32 cents.

Champion Copper Company — Statement of Receipts and Expenditures from Date of Organization to December 31, 1908

Receipts

Capital stock issued for purchase of mine	$1,025,000.00
Assessment No. 1, November 15, 1899	100,000.00
Assessment No. 2, March 6, 1900	100,000.00
Assessment No. 3, June 25, 1900	25,000.00
Assessment No. 4, September 15, 1900	50,000.00
Assessment No. 5, November 20, 1900	50,000.00
Assessment No. 6, January 16, 1901	50,000.00
Assessment No. 7, April 22, 1901	100,000.00
Assessment No. 8, June 10, 1901	100,000.00
Assessment No. 9, August 21, 1901	100,000.00
Assessment No. 10, October 7, 1901	100,000.00
Assessment No. 11, November 25, 1901	100,000.00
Assessment No. 12, January 15, 1902	100,000.00
Assessment No. 13, February 12, 1902	100,000.00
Assessment No. 14, May 5, 1902	100,000.00
Assessment No. 15, June 5, 1902	100,000.00
Assessment No. 16, September 2, 1902	100,000.00
Assessment No. 17, September 29, 1902	100,000.00
From sale of copper (1902) 4,165,784 lb. at 11.82 cents	492,553.36
From sale of copper (1903) 10,564,147 lb. at 13.37 cents	1,412,711.43
From sale of copper (1904) 12,212,954 lb. at 13.02 cents	1,591,109.71
From sale of copper (1905) 15,707,426 lb. at 15.56 cents	2,444,554.91
From sale of copper (1906) 16,954,986 lb. at 19.06 cents	3,231,328.71
From sale of copper (1907) 16,498,436 lb. at 17.28 cents	2,848,838.41
From sale of copper (1908) 17,786,763 lb. at 13.39 cents	2,381,137.30
	$16,902,233.83

Expenditures

Real estate (Champion mine location)	$1,025,000.00	
Real estate (lands since purchased)	14,095.28	
Carried forward	$1,039,095.28	$16,902,233,83

Champion Copper Company — Statement of Receipts and Expenditures from Date of Organization to December 31, 1908 — *Continued*

Brought forward	$1,039,095.28	$16,902,233.83
Net expenditure for construction and equipment mining operations, smelting and marketing copper, taxes and incidentals	10,881,313.30	
		11,920,408.58
Net balance of receipts		$4,981,825.25
Dividends paid in 1903	$300,000.00	
Dividends paid in 1904	200,000.00	
Dividends paid in 1905	1,000,000.00	
Dividends paid in 1906	1,200,000.00	
Dividends paid in 1907	1,000,000.00	
Dividends paid in 1908	500,000.00	
		4,200,000.00
Excess of receipts over expenditures		$781,825.25
Total output		93,881,496 pounds
Cost per pound to date for plant and operating		11.5 cents

Champion Copper Company — Statement of Working Expenses at the Champion Mine for the Year Ending December 31, 1908

			Per Ton
Mining Costs			
Superintendence and labor	$666,794.70		
Rock house expense	46,140.18		
Hoisting expense	44,499.52		
Power drill expense	54,662.92		
Timber and supplies	136,107.50	$948,204.82	$1.19
Surface Expenses			
Superintendence and labor	$20,882.36		
Supplies	6,080.78		
Teaming	1,614.12		
Insurance	9,934.00		
Electric lights and telephones	834.22		
Legal and general expense	2,940.78		
Library maintenance	1,750.00		
Purchasing department	3,217.71	47,253.97	.06
Transportation of rock to mill		109,066.70	.14
Stamp mill expense		140,699.50	.18
		$1,245,224.99	
Less rents received		12,687.51	.02
Net running expense		$1,232,537.48	$1.55

Summary of Results

Rock stamped	794,703 tons
Product of mineral	26,579,795 lb.
Product of refined copper	17,786,763 lb.
Yield of rock treated	22.381 lb. per ton, or 1.119 per cent.
Cost per ton of working expenses	$1.5509
Cost per ton of working expenses, including taxes	1.6203
Cost per lb. of copper delivered, including taxes	.0834

Total cost at mine			$1.55

Construction

AT MINE

"D" coal adit		$4,048.81	
Heating plant		3,078.30	
Shaft houses, changes and alterations		13,093.61	
"B" hoist and pulley stands		5,733.19	
Dwelling houses		10,425.07	
"C" hoist and pulley stands		15,159.60	
Automatic telephones		439.66	
Barns and fences		1,880.21	
Underground electric pump		9,661.68	
"B" coal trestle		4,038.62	
Grading streets "B" location		434.04	
		$67,992.79	
AT MILL			
Completing installation of new stamps	$13,629.05		
New tables and settling tanks	27,250.84		
Coal trestle	11,768.08		
		52,647.97	
		$120,640.76	.15
Smelting, refining, and marketing		$189,675.36	.24
Taxes and interest		$55,624.65	.07
Total cost			2.01
Cost per pound			9 cents

TRIMOUNTAIN MINING COMPANY — STATEMENT OF RECEIPTS AND EXPENDITURES FROM DATE OF ORGANIZATION TO DECEMBER 31, 1908

Receipts

Capital stock issued for purchase of mine	$800,000.00	
Capital stock issued for cash	400,000.00	$1,200,000.00
Assessment No. 1, December 12, 1900	$300,000.00	
Assessment No. 1, April 12, 1901	200,000.00	500,000.00
Carried forward		$1,700,000.00

Trimountain Mining Company — Statement of Receipts and Expenditures from Date of Organization to December 31, 1908 — *Continued*

Brought forward			$1,700,000.00
Assessment No. 2, January 10,1902		$200,000.00	
Assessment No. 2, March 10, 1902		100,000.00	300,000.00
From sale of copper (1902)	5,730,633 lb.		712,959.76
From sale of copper (1903)	9,237,051 lb.		1,186,547.57
From sale of copper (1904)	10,211,230 lb.		1,396,188.30
From sale of copper (1905)	10,476,462 lb.		1,620,893.76
From sale of copper (1906)	9,507,933 lb.		1,791,714.68
From sale of copper (1907)	8,190,711 lb.		1,415,088.48
From sale of copper (1908)	6,034,908 lb.		807,901.07
Balance of interest account			67,572.67
Total copper	59,388,928 lb.		$10,998,866.29

Expenditures

Real estate (Trimountain mine location)	$800,000.00	
Real estate (land since purchased)	3,000.00	
	$803,000.00	
Net expenditure for construction and equipment, mining operations, smelting and marketing copper, taxes and incidentals	8,767,724.10	
		9,570,724.10
Net balance of receipts		$1,428,142.19
Dividends paid in 1903	$300,000.00	
Dividends paid in 1908	500,000.00	
		800,000.00
Excess of receipts over expenditures		$628,142.19
Cost per pound, plant and operating		14.76 cents

Trimountain Mining Company — Statement of Working Expenses at the Trimountain Mine for the Year Ending December 31, 1908

Mining Costs			Per Ton
Superintendence and labor	$343,270.54		
Rock house expense	24,204.46		
Hoisting expense	48,008.23		
Power drill expense	29,461.16		
Timber and supplies	68,639.85	$513,584.24	$1.53
Carried forward		$513,584.24	$1.53

Brought forward		$513,584.24	$1.53

Surface Expenses

Superintendence and labor	$21,940.35		
Supplies	3,275.25		
Insurance	6,363.72		
Purchasing department	1,203.13		
Legal and general expenses	1,091.50	33,873.95	.10
Transportation of rock to mill		37,866.46	.11
Stamp mill expense		73,016.00	.22
		$658,340.65	
Less rents received		10,110.38	
Net running expenses		$648,230.27	$1.96

Summary of Results

Rock stamped	334,929 tons.
Product of mineral	9,634,979 lb.
Product of refined copper	6,034,908 lb.
Yield of rock treated	18 lb. per ton, or 0.9 per cent.
Cost per ton of working expenses	$1.935
Cost per ton of working expenses, including taxes	2.048
Cost per pound of copper delivered, including taxes	.125
Total cost at mine	$1.94

Construction

AT MINE

Steam laundry		$317.76	
Underground electric pumps		3,651.77	
		$3,969.53	

AT MILL

Crushing rolls	$1,133.34		
New store building	6,469.55		
		7,602.89	
Total cost of construction		$11,572.42	0.03
Smelting, refining, and marketing		$71,207.27	0.21
Taxes		$37,903.40	0.11
Total cost			$2.29
Cost per pound			12.61 cents

The above figures exhibit the operations of this group in sufficient detail. It remains to compute, without detail, the entire cost for the Copper Range properties over a period of four years, 1905 to 1908 inclusive, for operating, construction, taxes, and all expenditures.

	Pounds	Cost	Per Pound Cents
Baltic	63,211,963	$5,808,000	9.19
Champion	66,938,611	6,512,000	9.74
Trimountain	34,210,014	4,172,000	12.2
	164,360,588	$16,492,000	10.00

It seems proper to say that 10 cents per pound is the true dividend cost. Figuring on averages these mines would appear to be able to produce 41,000,000 lb. a year at a profit of 5.5 cents. The Copper Range Company owns one-half the stock of the Champion and practically all the stock of the other mines, together with the Copper Range Railroad. The railroad does not earn much. We may estimate the total average earnings of the company at 15½ cents copper at $1,750,000 per year, equal to some $4.55 per share. Conceding that this average can be maintained for twenty years we may estimate a value of $57 a share.

CHAPTER IX

CONGLOMERATE COPPER MINES OF LAKE SUPERIOR

Tamarack and Calumet & Hecla

Tamarack and Calumet & Hecla — Results of Tamarack — Comparison of factors affecting costs at Calumet & Hecla conglomerate with amygdaloid deposits — Record and costs of Calumet & Hecla.

The third type of Lake Superior copper mines is represented by the Tamarack and the Calumet & Hecla. The record of these properties shows very clearly that the conglomerate is a more difficult and expensive problem than the amygdaloid. The deposit has the advantages of remarkable uniformity and continuity; but as compared with the amygdaloid, the conglomerate has three features that substantially increase the cost of working: (1) The richness of the ore has averaged 2½ times as great as that of the characteristic amygdaloid; consequently the cost for smelting has been 2½ times as great, and this fact has meant an increased cost of not far from 50 cents a ton. (2) The conglomerate is much harder, tougher, and more difficult to handle. It breaks in rough, ugly chunks which wear out the tram cars, bin linings, and stamp shoes very rapidly. Its greater hardness is reflected by the fact that the mills will handle 40 per cent. more amygdaloid than of conglomerate. This characteristic in itself is probably sufficient to add in the neighborhood of 20 cents a ton to the cost of handling, breaking, tramming, crushing, and milling this ore. (3) The hanging wall is loose and the mines need constant and expensive timbering. This item has added from 25 to 75 cents a ton to the cost.

The total of these increased costs may be reckoned at, in round numbers, $1.20 a ton. The above figures have reference to the average conglomerate ore as mined to date which has contained not less than 55 lb. copper to the ton. At present[1] the Calumet & Hecla is yielding only 42 lb. a ton while the Tamarack is yielding only 23 lb. On the present basis, therefore,

[1] January, 1898. The yield has since fallen below 35 lbs.

the smelting costs are somewhat lower than they would be for an average of this class.

Results and Costs at the Tamarack

Up to July 1, 1893, the Tamarack mine had produced 84,000-000 lb. copper from 1,400,000 tons of rock, an average of 60 lb. per ton. The cost for operating was $5,816,083, or $4.15 a ton. Construction on the original mine from which this ore came was 68 cents a ton additional. The total cost had, therefore, averaged $4.80 per ton or 8 cents per pound copper. In 1892–3, 345,925 tons were stamped, yielding 46.43 lb. per ton. The costs were:

Underground mining	$1.69
Rock house, surface and stamping	0.77
Smelting	0.82
Total operating	$3.28
Construction on old mine	0.04
Construction on new shafts	2.14
Total	$5.46

By 1899 the costs were:

Total operating	$3.50
Construction	0.63
Total	$4.13

By 1904 the costs had become:

Mining and stamping	$2.42
Smelting and general	0.61
Total	$3.03

Of late years a good deal of amygdaloid has been mined.

Since 1904 the operations on the Tamarack have been very much interfered with by a serious underground fire and other difficulties and delays. It is probable that the above figures give a fair idea of the results obtained. The item of construction has been very heavy indeed. It is accounted for by the sinking and equipping of five very deep and expensive shafts. It appears that up to 1899 the output of the Tamarack had been about 4,400,000 tons, produced at a total cost of $17,600,000, or $4 a ton. The resulting product was 195,000,000 lb. copper, or an average of about 44.3 lb. to the ton, the cost of fine copper being about 9 cents a pound.

Calumet & Hecla

The Calumet & Hecla has been a rich mine and its costs may have been somewhat higher than were strictly necessary. For the last ten years it seems that the costs have averaged a little over $4 a ton, but since the company issues no detailed reports, it is possible to make only an approximation. This cost does not appear at a disadvantage compared with the Tamarack, for while the Tamarack ores averaged about 44 lb. copper per ton, those of the Calumet & Hecla have averaged 50 lb.; and while it is true that the Tamarack has expended large sums on new construction and development, it must not be forgotten that the Calumet & Hecla has done the same thing during the same period. At present the Calumet & Hecla is mining an increasing proportion of amygdaloid from the neighboring Osceola and Kearsarge lodes to the eastward of the conglomerate.

It appears that the conglomerate workings as compared with a representative amygdaloid mine like the Wolverine would appear somewhat as follows:

Underground factors making for increased cost are: the very great depth, averaging more than 4000 ft. vertically; the considerable heat, averaging about 80°; the necessity of timbering, which in itself accounts for at least 30 cents a ton; the hard angular character of the ore which renders shoveling, tramming, and handling more difficult and expensive; and finally, the difficulty of maintaining the deep inclined shafts under a weak hanging wall.

It does not seem unreasonable to appraise these factors at 50 cents a ton, at least, excess cost over that of the amygdaloid mine of moderate depth. The cost of milling the ore should be approximately 15 cents a ton greater; while the cost of smelting 42 lb. fine copper per ton as against 22 lb. should be 25 cents more. To sum up it appears that mining costs representing the two types should compare about as follows:

	Amygdaloid	Conglomerate
Underground expense and rock house	$1.10	$1.60
Transportation and milling	0.40	0.55
General expense	0.22	0.22
Smelting, refining and marketing	0.25	0.50
Total	$1.97	$2.87

The above costs omit the item of construction which has always been a very large item with these mines. It is safe to say that the Calumet & Hecla has spent 40 cents a ton throughout its career on its plant for construction.

The costs of Calumet & Hecla on Osceola amygdaloid for 1906 are reported as follows:

Mining	$0.9993	
Hoisting	0.101	$1.2039
Rock house	0.1336	
Transportation	0.0844	
Milling	0.2631	0.3655
Other	0.018	
Total	$1.5694	$1.5694
Assuming that the output is 18 lb. copper per ton, we must add for smelting, refining, and marketing		0.22
Add also general expense, same as for Wolverine		0.22
Total		$2.0094

Calumet & Hecla Records

Until 1908 this great company had been extremely guarded in giving out information about its operating results. In order to form an idea of its costs it was necessary to compile such scraps of information as could be gleaned from a series of reports and make such deductions as seemed warranted. This state of affairs now seems partly to be a thing of the past. A legal controversy over the right of the Calumet & Hecla to control and manage the Osceola Consolidated Mining Company resulted in the disclosure of most of the essential facts regarding the former company's business condition. In the report for 1908 President Agassiz frankly gives these facts and it is to be presumed that more will be forthcoming in succeeding reports. The following summary shows the facts that may be had from the reports in the past eleven years:

Year	Tons Fine Copper	Price Cts. Per Lb.	Dividends	Spent in Purchase New Property	Balance of Quick Assets
1897–8...	41,960	—	$4,000,000	—	$6,558,456
1898–9...	43,879	—	7,000,000	—	4,398,544
1899–00..	44,548	—	8,000,000	—	4,260,858
1900–01..	37,933	—	6,500,000	—	2,168,130 fire
1901–02..	42,462	—	4,000,000	—	3,592,779
1902–03..	42,216	—	2,000,000	—	6,557,023
1903–04..	41,612	—	4,000,000	—	6,583,038
1904–05..	43,090	—	4,500,000	42,000 acres timber land	7,144,000
1905–06..	43,652	—	5,000,000	$184.859	10,629,819
1906–07..	46,297	—	7,500,000	9,223,395	7,028,942
1907–08..	43,264	—	5,000,000	—	4,700,755
–	470,913	15.2	$57,500,000	$9,408,254	1,857,701 decrease
–			1,857,701		
Total cash earnings......			55,642,299		
Add investments, partial only			9,408,252		
			65,050,551		

1888.......Milled 814,000 tons for 50,295,721 lb. copper — 61½ lb. per ton.
1897–8.....Cost $4.05 per ton milled.
1899–00....Pounds copper per ton 59.93, 1,464,697 tons milled.
1902.......Pounds copper per ton 52.44.
1904–5.....Milled 74,235 tons Osceola amygdaloid 22 lb. per ton.
1906.......Milled in March 27,018 Osceola amygdaloid.
1905–6.....Milled 1,900,000 tons for 87,304,000 lb. — 45.9 lbs. per ton.
1906–7.....Milled 1,900,000 tons Calumet conglomerate.
350,000 tons Osceola amygdaloid for 6,892,548 lb.

2,250,000 altogether for 92,584,000 lb. = 41 lb. per ton.
1907–8.....Milled 1,894,176 tons conglomerate averaging 39.68 lb. per ton.
603,891 tons Osceola amygdaloid yielding 11,145,220 lb., or 18.4 lb. per ton.

In the year ending April 30, 1908, the "Product" of refined copper is stated at 78,980,466 lb. There is some reason to believe that this means "Product sold." It is also reported that the company was constantly in the market, selling copper during the declining prices of 1907. If this is so, it must have realized practically the quotational average for the period, or 16.6 cents. On this basis the receipts for the year were about $13,100,000. The dividends were $5,000,000, leaving a balance of $8,100,000.

There is no mention made of any considerable outside investments made during the year except the purchase of 50,100 shares in the Gratiot Mining Company. What the price was is not stated. Some explorations were also carried on in various places. Under these circumstances an estimate of the cost of mining is nothing but a guess. However, I will venture the guess. In 1907 the dividends were $7,500,000. In addition $9,223,000 were expended in the purchase of property, but in so doing the balance of assets was diminished $3,600,000, leaving a net expenditure of about $5,600,000 from the proceeds of that year's business. The total profits then must have been about $13,100,000. The revenue from copper sales for that year was approximately $20,400,000. Deducting the profits we have left the costs, about $7,300,000. In that year 350,000 tons of Osceola amygdaloid was mined at an expense of $700,000. Deducting this we have $6,600,000 as the cost of mining 1,900,000 tons of conglomerate, $3.47 a ton.

In the following year a cut of 10 per cent. was made in wages, but not until the latter part of the fiscal year. The effect of this probably was to diminish costs by 5 per cent. for the whole fiscal year.

For 1908, then, I place the cost of mining the conglomerate at $3.30 and for the Osceola amygdaloid at $1.90. The total cost then would be:

Conglomerate, 1,894,176 tons at $3.30	$6,230,000
Amygdaloid, 603,891 tons at $1.80	1,150,000
Total	$7,380,000
Estimated cost of outside work and investments	720,000
	$8,100,000

These figures should be read in the light of the following remarks by President Agassiz in the report for 1908:

"In several of the previous annual reports the attention of the stockholders has been called to the unsatisfactory character of the conglomerate below the 57th level in the northern part of the mine. In 1900, the year before Mr. McNaughton became General Manager of the Company, the conglomerate yielded about 59.93 lb. of copper to the ton. I regret to state that since then this percentage has annually been diminishing. In 1902 it had fallen to 52.44 lb. to the ton. For the past fiscal year its yield was 39.68 lb. To maintain our product we have stamped an additional amount of conglomerate rock in addition to the amygdaloid rock mined from the Osceola lode, which has been increased from 74,235 tons in 1905 to 603,891 tons in 1907–08. The amount of conglomerate stamped has gradually increased from 1,464,697 tons in 1900 to 1,894,176 tons in 1907–08. Thus in 1907–08 eating into the available conglomerate at a rate far in excess of that we had been accustomed to consider the normal output plainly shows that your Directors did not seek too soon for an additional source of copper supply to replace that obtained from the waning conglomerate lode. We anticipate a still further reduction in the percentage. During the last five years the cost per ton of rock has been greatly reduced, partially offsetting the decrease in the copper contents of the rock."

It will be seen, by a study of the table given above, that the average cost of copper for eleven years must have been 8.16 cents a pound. Ten years ago it probably was 7 cents for a safe average and is now about 9 cents.

CHAPTER X

COPPER MINES ON FISSURE VEINS IN MONTANA, AUSTRALIA, AND ARIZONA

Copper Mines of Butte, Montana

General conditions at Butte — External and internal factors — Method of treatment — Mining cost factors compared with those of Lake Superior — Records of Butte mines — Wallaroo and Moonta mines in Australia — Old Dominion Copper Mining and Smelting Company.

The external factors of mining cost in the Butte district are unfavorable. The district is situated on a semi-arid plateau at great distances from the important industrial centers of North America; in a region containing, it is true, supplies of fuel, timber, and water for power purposes, but these supplies are in every case situated at considerable distances from the mines and under conditions not favorable for cheap delivery. Most of the mining supplies and all of the copper product must be shipped long distances overland on railroads operating in sparsely populated districts with high gradients and high operating costs. The freight by rail, for instance, on copper from Butte to New York is at least six times as great as the rate by water from Lake Superior to New York.

The labor employed in the Butte mines is vigorous, intelligent, and, under normal conditions, abundant; but on the other hand, the wages are the highest paid in the United States, if not in the world, for any considerable volume of labor. Up to 1901 the average wages paid were 37 cents an hour. Since 1901 they have averaged 47 cents an hour, these figures being compared with 25 cents an hour for Lake Superior. It is indeed probable that the Butte miners are better and more effective than those of Lake Superior, but hardly to the extent required to make up this great difference. Under present conditions, wages in Butte are nearly 100 per cent. higher than in Lake Superior. It seems unreasonable to estimate that more than half of this difference can be made up by superior efficiency in Butte, so that in round numbers we shall have to estimate labor costs in Butte as at least 50 per cent. higher than in Lake Superior.

One unfavorable factor which may be classed as external is the location of claims under the apex law. This has meant the parceling out of the surface in small, irregular, and conflicting fragments, and this fact has interposed a serious obstacle to the comprehensive development and working of the mines. In this respect Butte does not perhaps suffer by comparison with other mining districts in the Rocky Mountain region; but as compared with Lake Superior, this feature must be classed as a pronounced disadvantage.

Internal Factors

The internal factors of the Butte mines are not unfavorable for fissure vein deposits, but they present certain characteristics which make for increased costs as compared with Lake Superior. The ores all come from an area of about two square miles, and from this area the output of copper and silver has been simply prodigious. This is a favorable feature.

The veins, according to H. V. Winchell, belong to three different systems. Of these the first and oldest, called the Anaconda system, strikes east and west and dips to the south. The filling of these veins is quartz and pyrites in which the original proportion of copper was probably small. These veins are intersected by mineralized fault fissures striking northeast and southwest, and both these systems are intersected and faulted by a third system of mineralized fissures running northwest and southeast. In addition to these veins, still later barren faults of considerable displacement intersect all the orebodies.

The result is a great complexity of vein structure which has proved a serious problem to unravel. As might be expected the various faults are accompanied by considerable zones of crushing and alteration which add considerably to the difficulty of mining. An additional complexity is brought in by the influence of a pronounced reconcentration of values due to surface oxidation and leaching and subsequent deposition at greater depths. While it is true that in a great measure the orebodies owe their commercial value to this reconcentration, it is also true that it has resulted in an uneven distribution of the ore which imposes a necessity of sorting and is a factor of additional cost. The upper 200 or 300 ft. of the veins is absolutely barren.

The oxidation of the large bodies of pyrites and the decomposition of vast quantities of timber in these mines has resulted in the generation of an unpleasant degree of heat. The temperature must be kept down by very thorough ventilation. Here we have a factor that makes for additional cost.

Method of Treatment

The process of mining in Butte is conducted about as follows: The ore is hoisted from the mine and dumped directly into large bins from which it is drawn into railroad cars and transported to combined concentrating and smelting plants. A small proportion goes to plants in the vicinity of Butte itself, and not more than two or three miles from the mines, but by far the greater portion is taken to Anaconda 26 miles away, or to Great Falls 100 miles away. At the smelters all ores containing less than 6 per cent. copper are concentrated. The higher-grade ores are smelted in blast furnaces and the concentrates in reverberatory furnaces collecting the metals into a matte which is bessemerized on the ground into blister copper. A portion of this blister copper is refined at the Great Falls plant, but by far the greater portion is shipped to the Atlantic seaboard in the neighborhood of New York and there refined. Nearly all the copper output of Butte is sold through the agency of the United Metals Selling Company.

The most pronounced factor making for high costs in the Butte ores is the large percentage that must be smelted. This can be estimated roughly at 40 per cent. as against 4 per cent. for the richest copper ores in Lake Superior.

The concentrating and smelting are largely done in two immense plants owned by the Amalgamated Copper Company, one at Anaconda, and the other at Great Falls. It is believed that these plants are equipped and operated as well as any in the world, no pains having been spared in capital expenditure to secure the greatest economy. But it is manifestly a physical impossibility to smelt 15 to 30 tons of ore at Butte for anything like the cost required to smelt one ton of concentrates in Lake Superior. Furthermore, the Butte copper must stand not only a very heavy transportation expense to the seaboard, but must further undergo the expensive process of electrolytic refining. The logical result of these conditions is that in Butte $4 a ton for concentrating, smelting, and refining may be considered as an absolute minimum as against a cost of from 60 cents to $1 in Lake Superior.

Mining in the Butte District

It is not my intention to go into the details of mining practice further than to point out the general characteristics that determine the costs, but it may be pertinent to mention in a general way the methods in use underground. The Butte ore is all opened by vertical shafts which at present have attained depths of from 1800 to 2800 ft. Levels are run out at intervals of 100 to 200 ft. A large amount of work is necessary to discover and develop the ores and many thousand feet of exploring drifts and crosscuts must be run through country rock in pursuit of the various ore shoots. Here is an item estimated at 30 cents a ton for exploration work that is quite absent from the prominent Lake Superior copper mines.

In stoping, the walls are found to be soft enough to require constant timbering, usually by square sets. In many places the effect of the faults above mentioned has been to produce rock so soft as to make the timbering especially difficult and expensive. As a rule the stopes require, in addition to the timbering, a rock filling for safety. This filling is obtained mainly out of exploring drifts and to some extent from the surface, but also in some cases it has been found necessary to make rooms in the country rock for the mere purpose of securing waste filling. It does not appear that a great deal of waste is sorted for filling out of the vein itself, although it suggests itself to the casual visitor that this is a point that might be gone into rather seriously. Since the cost of transportation, concentrating, smelting, refining, and marketing amounts to at least $4 a ton, it would seem as if the point at which ore already broken would better be left in the mine than treated is about $1\frac{1}{4}$ to $1\frac{1}{2}$ per cent. copper.

All the mines of Butte are run on the same principle; when you describe one you describe them all. I select the Anaconda mine as a basis for comparison with the Calumet & Hecla in Lake Superior, not for the purpose of drawing any invidious comparisons of management, but for the purpose of calling attention to the factors which I believe establish the costs per ton. In such a comparison it is, of course, absurd to lay claim to accuracy, but since the object of this discussion is to find out why costs are different in different places, it seems proper to enumerate what reasons one may see.

Appraisement of Cost Factors at Anaconda and at Calumet & Hecla

	Calumet & Hecla	Anaconda	Difference against Anaconda
Costs at Mine —			
Stoping labor	$1.10	$1.65	$0.56
Exploration	—	0.30	0.30
Supplies including timber	0.50	0.90	0.40
General expense	0.22	0.50	0.28
Total	$1.82	$3.35	—
Construction and amortization	0.40	0.40	—
	$2.22	$3.75	+$1.53
Outside Costs —			
Freight to mill	$0.15	$0.15	—
Cost concentrating	0.55	—	—
Cost smelting	—	2.90	+ 2.35
Cost of refining and marketing	.50	1.21	+ .71
Total cost	$3.27	$7.86	+$4.59

Percentage milled, Calumet & Hecla mine, 100; Anaconda 90.
Percentage smelted, Calumet & Hecla mine 3; Anaconda mine, 45.
Pounds copper to ton, Calumet & Hecla mine, 42; Anaconda mine, 63.

The accompanying table shows the reported costs for the various mines at Butte since the year 1903. Two facts are worth noting: First, that the cost for mining proper has tended to rise, probably on account of an increased proportion of development work undertaken in recent years; second, that the cost of reduction and also of refining and marketing have come down notably. This reduction is probably due to the great metallurgical improvements that have been effected by reason of the liberal policy of the Amalgamated Copper Company in its expenditures to provide better smelting facilities and also its good management. A further reason for diminishing costs in smelting, refining, and marketing is a diminution in the metallic contents of the ore, a greater amount being concentrated and a less amount being smelted and refined per ton. In the case of the Boston & Montana a considerable saving has also been effected in transportation costs.

Costs at Montana Copper Mines

ANACONDA COPPER COMPANY

(Transportation to Anaconda 26 miles)

	Tons	Mining per Ton	Freight to Smelter per Ton	Reduction per Ton	Refining—Marketing per Ton	Total Cost per Ton
1903	1,392,835	$3.49	$0.15	$3.39	$2.30	$9.33
1904	983,001	3.73	0.15	3.82	1.96	9.66
1905	1,473,644	3.56	0.15	3.00	1.11	7.82
1906	1,521,310	3.63	0.15	2.27	1.08	7.13
1907	1,401,948	4.47	0.16	2.52	0.93	8.08
BOSTON & MONTANA (Transportation to Great Falls)						
1903	907,227	$2.61	$1.00	$3.05	$2.90	$9.54
1904	988,866	2.89	1.00	2.53	1.81	8.23
1905	1,138,307	2.91	1.00	2.21	1.69	7.81
1906	1,209,805	3.45	0.93	2.45	0.90	7.73
1907	1,156,785	3.93	0.76	2.67	0.92	8.28
BUTTE & BOSTON (Transportation to Anaconda)						
1903	245,333	$3.27	$0.16	$2.44	$1.12	$6.99
1904	202,286	3.42	0.17	2.67	1.05	7.31
1905	260,433	3.31	0.19	2.45	0.79	6.74
1906	246,593	3.51	0.20	2.06	1.25	7.02
1907	331,629	3.79	0.21	2.27	0.85	7.22
BUTTE COALITION						
1906	149,101	$3.94	$0.60	$3.94	$1.50	$9.98
1907	412,169	5.49	0.29	2.29	—	—
NORTH BUTTE						
1906	259,650	$4.47	$0.20	$4.84	—	$9.51
1907	374,632	4.53	0.20	4.04	—	8.77

It is to be noted that the Butte & Boston ores have cost less than the others. This is undoubtedly due to their lower grade, the proportionate cost for smelting, refining, and marketing being less. On the other hand, the North Butte has cost more on account of its higher grade, and Butte Coalition has cost more than the average on account of the large expenditures for improvements.

Wallaroo and Moonta

An example of mine conditions and costs similar to those of Butte is furnished on the other side of the world by the Wallaroo and Moonta mines of South Australia. These mines have not been described with the definiteness one would like; but in a general way the first is a group of fissure veins in metamorphic schist and the second a similar group of fissures in porphyry. The production of the district has not been so large as that of Butte, and the mineralization is less intense. The mining costs are somewhat higher because exploration is more expensive, but in other respects the parallel with the great Montana camp is close and interesting.

These mines are described by the general manager, H. Lipson Hancock (son of the inventor of the Hancock jig) in a pamphlet issued at Wallaroo, in November, 1907. The mines were discovered in 1860. In forty-seven years these mines have raised and extracted as follows:

Dressed ore and concentrates	1,670,360 tons.
Copper, averaging 15 per cent. in ore	248,993 tons.
Total value	£13,944,445
Total cost	£11,285,809
Total dividends	£2,018,254
Average cost per ton of concentrates	£6 15s. 2d.

"The dressed ore of Wallaroo," says Mr. Hancock, "has throughout recent times averaged about 11 per cent.; that of the Moonta about 20 per cent. of copper, excepting that in later years it has been 2 or 3 per cent. lower. For a long time the vein stuff as raised to surface at both properties has contained on the average from 3 to 4 per cent. copper."

Port Wallaroo, the smelting point, is situated on the west side of the York peninsula. The Moonta mines are twelve miles south and the Wallaroo mines six miles east of the port. The ore comes from about ten different veins in all. At the Wallaroo mines there are three large veins and several smaller ones in metamorphic mica schist supposed to be of Cambrian age.

Most of the work has been confined to one lode along which were occurrences of copper near the surface for a length of 10,000 ft., but at the depth of 2000 ft. the length of workable ground has contracted to 2500 ft. On the other veins the ores did not prove remunerative below the 1000-ft. level. At Moonta there are five veins of which only one is holding out below the 2000-ft. level. In both groups the copper is largely in the form of chalcopyrite mixed with iron pyrite. The ore occurs in rather short shoots, often where the vein is intersected by cross-courses.

The high cost for mining is easily explained. There are more than eighty miles of development openings, including shafts, drifts, etc. This work would probably cost at least $12 a foot, or $5,000,000. This accounts for $3 per ton of dressed ore, or approximately 75 cents per ton of vein stuff hoisted. The actual stoping, including hoisting, pumping, etc., costs about $3.50 per ton. The ground is soft like that of Butte, probably softer, requiring close timbering as well as close filling. The granulated slag from the smelter is used for filling.

Sorting and milling in 1903 cost 75 cents at the Wallaroo and $1.25 at the Moonta. These costs seem high, but the work is done with extreme care.

In terms of short tons and American money I find that the average cost of mining, concentrating, and smelting a ton of concentrates for the whole life of the mine has been $32.90. In recent years the cost has exceeded this by about $2 per ton. The increased cost is to be explained by the increased depth and a certain deterioration of the mines.

The accompanying table gives the cost of the complete operations for six out of the last ten years. The reports are excellent.

Costs of Operation at Wallaroo and Moonta for Six Years

			1,176,000 Tons Crude	292,889 Tons Concentrates
General expense...	Interest and discount	$0.07	$0.58	$2.33
	Adelaide office	0.07		
	Special funds for employees	0.04		
	Depreciation and redemption	0.40		
Mining and milling..	Wages and contracts	4.20	$5.68	$22.81
	Machinery and materials	0.55		
	Fuel	0.44		
	Buildings	0.04		
	Water supply	0.04		
	General and miscellaneous	0.41		

Costs of Operation at Wallaroo and Moonta for Six Years — *Continued*

		1,176,000 Tons Crude	292,889 Tons Concentrates
Smelting ..	Freight on concentrates	$2.37	$0.52
	Wages		3.73
	Machinery and supplies		1.33
	Fuel and flux		3.02
	Buildings and improvements		0.15
	General and miscellaneous		0.28
	Shipping copper		0.49
Total		$8.63	$34.66

Old Dominion Copper Mining and Smelting Company

This famous property has been working for many years on a fault fissure of rather complex geological relations in the Globe copper district of Arizona. It has not published any detailed reports that have come to my attention prior to the one for the year 1908, which gives some information about the two preceding years. The information is exceedingly interesting for the additional light it throws on the problem of copper mining on fissure veins. It belongs to the same class of mines as those of Butte and the Wallaroo and Moonta.

Production of Copper

In 1905	15,103,955
1906	16,653,225
1907	23,377,841
1908	30,308,223
Four years	85,443,244

The silver and gold with the ore are so small in amount as to equal in value less than 2 per cent. of the copper.

The production in tons is given only for 1908, but we can figure for the two preceding years by calculating back from the percentage of copper extracted, which is given for those years.

1906	....16,653,225 dry tons at	2.83 per cent.	= 294,070 dry tons
1907	23,377,841	3.88 per cent.	= 301,260
1908	30,308,223	5.15 per cent.	= 225,227
			820.557

Three years, 820,557 tons, producing 70,339,289 lb. copper equal to 85.8 lb. per ton. If we add 2 per cent. for silver and gold the copper equivalent is 87.5 lb. The latter figure is apparently an average, because the copper content is shown to be variable and it does not appear safe to take the figure for the final year as representative. It is plain that the increased yield in 1908 from a less amount of ore means increased selection of ore on account of lower prices.

Development Work

For three years 1734 ft. of shaft sinking and 55,261 ft. of drifts, winzes, and raises, a total of 56,995 ft., were done on the property. It is not stated that the ore reserves were greatly increased by this work, so that we are led to calculate that each foot of development opens up a little over 14 tons of ore and about 1230 lb. copper. The cost of development per foot can be inferred. It is $15.70 per foot. The cost of shaft sinking must be high, owing to the considerable amount of water. If the drifts, raises, and winzes average $12 a foot, the shafts would cost about $125 a foot. The development costs $1.09 per ton mined and 1¼ cents per pound copper.

Mining Costs

	1905	1906	1907	1908
Development	$0.8792	$1.1436	$0.9853	$1.1571
Pumping	.5354	.5470	.4331	.6356
Mining (from stopes to surface)	4.2514	4.4929	4.9152	4.5449
Total	$5.666	$6.1335	$6.3336	$6.3336

Concentrating

In 1908 about half the ore was concentrated. This ore ran 3.036 per cent. copper and 3.019 tons were put into 1 with an extraction of 82.5 per cent. Hence we may conclude that the concentrates ran 7.5 per cent. copper.

Total Operating Results

It appears that in 1908 the total cost at Globe for mining, concentrating, and smelting, deducting profit from custom ores, was $3,108,351. The tonnage mined is given at 225,227 tons dry. I am at a loss to understand how this amount of ore could have produced 30,900,000 lb. of copper, or its equivalent, with a yield of only 105 lb. per ton. This ore would only yield

23,600,000 lb. The explanation must be that a lot of ore was smelted that had been mined previously. If this explains the discrepancy we shall have to estimate that some 31 per cent. more ore was smelted than mined. On this basis we get the following:

225,227 tons mined at		6.3336	=	$1,427,383.83
294,750 tons	Concentrated and smelted at	5.703	=	1,680,968.
	Refined and marketed at	1.590	=	471,597.
	Total cost per ton	$13.6266	=	$3,579,948.

These are the best costs I can make out of this report. If I am wrong, the report is simply unintelligible. If the ore only contains 105 lb. copper equivalent per ton, then the cost per pound is 13 cents. If the copper in the ore will only average 87.5 lb., as would seem to be much more probable, the cost per pound will be 15.57 cents.

The report, however, states that the cost is 11.55 cents. Now if this is so we must calculate that the output coming from 225,227 tons of ore was mined and treated at a cost of $3,579,948, which equals $15.90 a ton. If we divide this by 11.55 we get 128 lb. per ton. But the report distinctly states that the ore only yielded 103 lb., to which I add 2 lb. to get the equivalent in copper alone, making it 105. There is a serious error in the report somewhere. If my interpretation of the costs is correct, the mine is not making any money.

CHAPTER XI

VARIOUS COPPER MINES OF ARIZONA AND MEXICO

Clifton — Morenci district — Arizona Copper Company — Shannon Copper Company — Detroit Copper Company — Miami Copper Company in Globe district — Bisbee district — Copper Queen — Calumet & Arizona — Superior & Pittsburg — Greene Consolidated — Moctezuma Copper Company.

In 1907 Arizona became the leading producer of copper in the United States. Unlike Michigan and Montana, each of which has but a single district, Arizona contains the four important and distinct districts of Bisbee, Globe, Clifton, and Jerome, all differing markedly in character and, therefore, in costs.

The external factors are uniform and unfavorable. The situation of the mines in an arid plateau poorly supplied with water, fuel, timber, and population, with freight rates inevitably high, makes for high costs. Wages of white miners are $3.50 a shift of eight hours; Mexicans are paid $2.50 a shift. The summer heats are debilitating and the energy of the men is somewhat less than it would be farther north. This is true particularly in regard to metallurgical work.

The internal factors vary with each district. These will be described separately.

Clifton–Morenci District

The Clifton-Morenci district produces prophyry ore in which chalcocite is disseminated. In this respect the orebodies resemble the deposits of Bingham, Utah, and of Ely, Nev. The ores form large irregular bodies at depths of from 100 to 300 ft. below the surface. In this respect the ore is easy to mine. But there is a certain irregularity, not only in the orebodies as a whole, but also in their internal make-up. A certain amount of sorting may be done to advantage in the mines. The ore is fairly hard and firm and is taken out by square-setting. Mexican miners with white bosses are employed.

Costs are not generally stated in detail, but the reports of the Shannon and Arizona copper companies make plain the following facts:

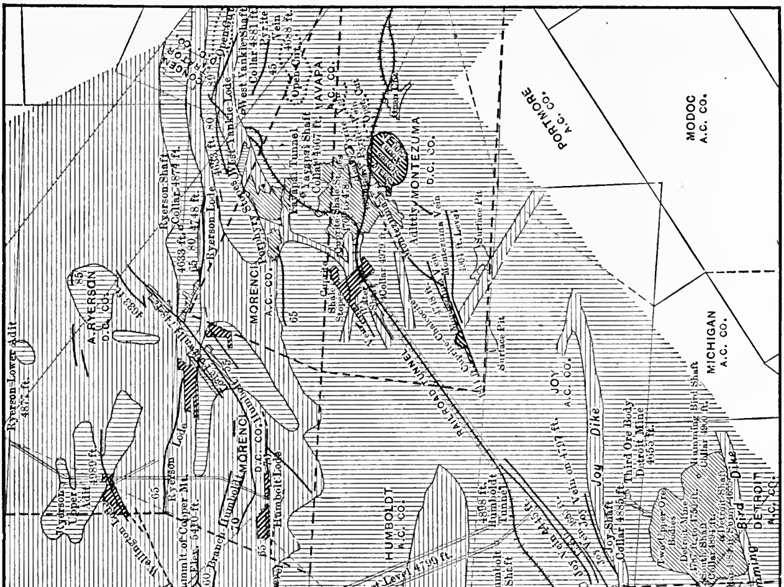


FIG. 6.—Arrangement of ore bodies in Clifton-Morenci district, Arizona.

About 1 ft. of opening work is necessary to find and develop 15 tons of ore. The cost of this work is stated to be 21 to 33 cents a ton (Shannon). Stoping costs are about $2 to $2.80 a ton. Details for one year are shown in an accompanying table.

The Arizona Copper Company gives its costs for mining, including deadwork, ores purchased, and leaching, as follows: 1904, \$2.81; 1905, \$2.46; 1906, \$2.50. It seems fair to assume from this that the underground costs are substantially the same as the Shannon. The same may be said of the Detroit Copper Company.

Assuming that the cost of mining, including development, is \$2.25 to \$2.50 a ton, and that out of this cost about 50 cents is due to timbering, it seems fair to say that the excess over Lake Superior costs is due to the external factors.

The internal factors that govern the cost of treatment are the losses due to concentrating, the proportion of concentrates to the crude ore and the smelting qualities of the ore.

(1) The Shannon Copper Company reports for 1904 a saving of 75 per cent. on ore averaging 4.16 per cent.; in 1905, 73 per cent. on ore running 3.77 per cent., and in 1906, 69 per cent. on ore averaging 3.36 per cent. This saving is for both smelting and concentrating.

(2) The Shannon Copper Company smelted in 1905, 44 per cent. of its total output; in 1906, 44½ per cent.; in 1907, 56 per cent. The Arizona Copper Company smelted in 1904, 22 per cent. of its total output; in 1905, 20 per cent.; in 1906, 20 per cent.

The costs for concentrating, smelting, refining, and marketing are not given in detail, but in the case of the Arizona Copper Company these costs lumped together were, in 1904, \$1.90; in 1905, \$1.93; in 1906, \$2.06, the costs being based on the entire tonnage sent from the mine. If the cost of concentrating is 75 cents a ton, including transportation from the mines, the cost for smelting, refining, and marketing would appear to be about \$6 per ton smelted. On this basis the cost to the Shannon company, on account of the larger proportion smelted, should be \$1.80 higher than to the Arizona company. This seems to be approximately the case.

(3) Certain difficulties have been experienced in smelting on account of a deficiency of sulphur for matting purposes. This is particularly the case with the first-class ores. In the earlier days this difficulty added more to the cost than it does at present.

Summary of Operations, Arizona Copper Company

	1904		1905		1906	
Total ore (tons)	491,600		547,000		610,000	
Total copper (lb.)	28,732,800		30,080,000		29,756,000	
First-class ore (tons)	31,695		26,000		31,378	
Concentrating ore (tons)	460,000		521,000		578,517	
Copper per ton (lb.)	57.5		56.3		48.8	
Tons smelted	102,893		108,000		121,507	
Tons leached	80,100		90,000		80,000	
Copper from leaching (lb.)	2,824,000		2,470,000		2,126,000	
Copper per ton from leaching (lb.)	35.3		26.3		26.7	
		Per Ton		Per Ton		Per Ton
Cost working mines (deadwork, ores purchased, leaching, etc.)	£285,056	$2.81	£276,326	$2.46	£373,560	$2.50
Smelting, refining, and marketing	£194,077	1.90	£215,846	1.93	£258,506	2.06
General	£14,286	0.14	£14,430	0.13	£15,579	0.14
Interest and amortization	£49,162	0.49	£58,965	0.52	£88,765	0.70
		$5.34		$5.04		$5.40
Cost per lb. at New York	9.3 cents		8.93 cents		11.07 cents	

Summary of Operations, Shannon Copper Company

	1903–4	1904–5	1905–6	1906–7
Smelting ore (tons)	66,005	53,340	69,342	—
Mill ore (tons)	91,311	135,503	140,683	—
Total	157,316	188,843	210,025	209,654
Per cent. copper, smelted ore	5.28	4.70	4.37	—
Per cent. copper, mill	3.34	3.41	2.86	—
Per cent. copper, average	4.16	3.77	3.36	—
Copper, lb. saved per ton	62.34	55.03	46.41	47.6
Per cent. saving	75.0	73.0	69.0	—
Feet development	—	11,931	14,740	14,610

SUMMARY OF OPERATIONS, SHANNON COPPER COMPANY — *Continued*

	Cost per Ton	Cost per Ton	Cost per Ton
Operating mines, mills, and smelters	$6.04	$6.91	$6.20
Exploration and development	0.21	0.30	0.33
Freight, refining, etc.	0.90	0.70	0.65
General expense	0.39	0.28	0.30
	$7.54	$8.19	$7.48
Outside developments, etc.	1.08	0.75	0.70
Total	$8.62	$8.94	$8.18
Cost per lb. at New York	13.7 cents	17.6 cents	15.7 cents
Stoping cost per ton $1.92.			

SHANNON COPPER COMPANY, MINING COSTS, 1904–5

	Total Cost	Cost per Ton
Assaying and sampling	$6,226.70	$0.048
Executive and office expense	10,519.33	0.055
Taxes, insurance and hospital	3,251.33	0.017
Incline	6,099.33	0.032
Extraction	176,124.71	0.932
Timbering and framing	94,769.75	0.501
Filling	10,749.47	0.056
Tramming	21,234.72	0.112
Tracklaying	9,193.13	0.048
Handling supplies	8,411.72	0.044
Miscellaneous	13,032.10	0.069
Total operating expense	$362,662.29	$1.92
Development	23,600.68	0.124
Exploration	17,609.68	0.093
Total mining cost	$403,872.65	$2.138
Ore received, 188,856 tons.		

Shannon Copper Company — Reported Costs of Copper per Pound

	1906		1907		1908	
	Expense for 11,017,000 Pounds Copper	Cost of Copper Per Pound	Expense for 13,593,000 Pounds Copper	Cost of Copper Per Pound	Expense for 16,408,000 Pounds Copper	Cost of Copper Per Pound
Operation	$1,431,513	$.1299	$2,115,192	$.1556	$1,953,251	$.1129
Development and exploration	60,188	.0055	67,491	.0050	31,120	.0018
Freight, refining, etc.	147,704	.0134	179,462	.0132	216,050	.0132
Interest and taxes	39,052	.0035	42,534	.0031	29,627	.0018
General expense	17,204	.0015	19,675	.0014	27,115	.0016
Total	1,695,661	.1539	2,424,354	.1783	2,257,163	.1375
Deduct gold and silver profits	—	0028	—	.0067	—	.0064
Net cost	—	.1511	—	.1716	—	.1311

Average net cost during last three years, 15.13 cents.

The above costs contain no estimate of depreciation or amortization, therefore the selling cost must be a good deal higher than those given, but I have not attempted to compute them. It is to be noted further that these costs do not correspond to those in the table above, because they do not include exactly the same items.

Miami Copper Company

The following prospectus was issued in March, 1908:

"The property of the Miami Copper Company consists of about 300 acres, 200 of which is mineral land, located six miles west of the city of Globe, Arizona, at which city are the mines and works of the well-known Old Dominion Company.

"Development which is still being carried on shows to date 2,000,000 tons of concentrating ore containing 3 per cent. of copper. Ore was struck at a depth of 220 ft., and the bottom of the shaft, at a depth of 500 ft., is still in ore, and the area shown of the ore body is 300 ft. by 350 ft., without having as yet reached the limits, so that the prospects are that an enormous body of concentrating ore will be developed as indicated by surface conditions.

"The Gila Valley Globe & Northern Railway ends at Globe, six miles distant, and surveys past the Miami have been made and right of way secured; this extension will pass within a quarter of a mile of the mine. There is abundant water available for concentration purposes.

"It is proposed to erect the first unit of a reduction works, which unit will have a daily capacity of 1,000 tons. This will give an annual production of 14,000,000 lb. of copper, based on 350 days running time and a yield from the 3 per cent. ore of 2 per cent., or 40 lb. of copper to the ton.

Concentrating tests have shown that the ore can be readily concentrated 10 into 1 and the resulting concentrate smelted with the above yield in fine copper. It is estimated that the cost of electrolytic copper sold in New York will be 9 cents per pound. On this basis the profits at 12 cents copper will be $420,000 per annum, and at 15 cents copper $840,000 per annum. As developments advance a second unit of 1,000 tons daily capacity will be built which will double the above figures of profit.

"It is estimated that it will require $750,000 to erect the necessary first unit of the reduction works and that $250,000 additional will be required for mine plant, shops, buildings, etc.

"The ore deposit of the Miami Copper Company is in nature similar to those of the Arizona Copper Company, the Nevada Consolidated Copper Company, the Utah Copper Company, and the Boston Consoldiated Mining Company; that is, large masses of ore in which the copper as a sulphide mineral is disseminated through the rock and which readily yields a high-grade concentrate by water treatment, which can be easily smelted.

"The mining is simple and cheap and when found these deposits are the most valuable as copper producers. The Miami ore, running 3 per cent. in copper as it does, is higher in grade than any of the above-mentioned properties and it will without doubt prove a large producer and dividend payer."

During the year which has elapsed since this was issued all hopes have been far exceeded. There are now 13,300,000 tons of ore in sight and the company is erecting a plant of 2,000 tons daily capacity which is twice the original plan. It is hoped that this plant will begin operations in the summer of 1910.

Bisbee District

In the Bisbee, or Warren, district, the internal conditions are essentially different from those of Clifton. This fact is sufficiently reflected by the mining costs which are at Bisbee $6 a ton against $2.50 or less at Clifton. Dr. James Douglas describes the Copper Queen mine in a paper in Vol. XXIX, 1899, *Transactions* of the A. I. M. E. The ore yielded, "about 7 per cent. copper after a rough selection in the stopes where about one-half the total material broken is rejected. To supplement the deficiency in filling the stopes, barren ledge matter from explora-

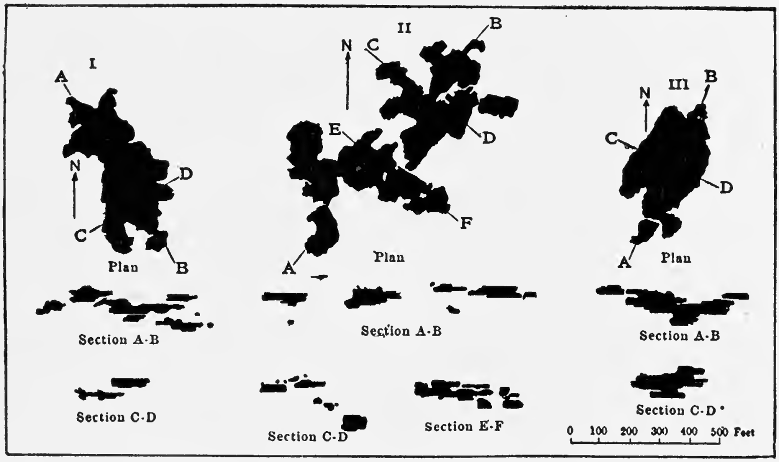


Fig. 7. — Sketch showing arrangement of orebodies, in Bisbee, Arizona where 1 foot of development work opens 11 tons of ore.

tory drifts is used. Though the timbering of worked-out portions of the mine is thus enforced, so violent is the movement of the ground that the timbers are dislocated or crushed to chips. About 30 ft. board measure of timber (from Puget Sound) is buried in the mine to the ton of ore extracted." This is a terrific cost for timber. At an average price of $24 per M. delivered at the mine, we have on this basis 75 cents a ton for timber alone. From 7 to 10 tons of ore are extracted per foot of opening work. A large part of the exploratory openings have to be closely timbered, and the cost for this work is high.

The reason for the conditions described will appear very plainly from a consideration of the structural relations of the orebodies. Dr. Douglas says: "With regard to ledge matter and the oxidized ore, my own opinion is that they are the product of replacement and local concentration; that where there is ledge matter to-day there was, originally, more or less compact iron pyrites carrying a small percentage of copper; and that during the process of alteration not only did the ferruginous solutions of alumina replace the pyrites, but the copper, by a process of segregation akin to crystallization, was concentrated and collected into areas of limited size, thus constituting the comparatively small bodies of oxidized ores which are disseminated irregularly through the very large masses of ledge matter. As the outline of the masses of ledge matter has never been traced, it is impossible to determine their actual size, but approximately there has been exposed above the 400-ft. level not less than 10,000,000 tons of ledge matter." Since at the time this was written not much over 1,000,000 tons of ore had been mined above the 400-ft. level, it is probable that Dr. Douglas believes that the ores now occupy approximately one-tenth of their original volume; the remaining nine-tenths being now "ledge matter," mainly ferruginous clay.

Nothing could be clearer than the above description as an explanation of the cost factors. All the altered residual masses must be explored; this means that the mine development, in addition to the shafts and drifts necessary to reach the ore, must search through 10 cu. ft. of difficult mining ground for every cubic foot to be extracted.

At various places in the mines large masses, like kernels, of original pyrites, still exist, surrounded on all sides by the "ledge matter." Although workable ore is found along the periphery of these masses, the pyrite itself is not payable. No concentrating ore has yet been found in the district. All the ore raised from the mines must be smelted, consequently it must be selected as much as possible.

To sum up — there are in these mines three powerful factors that make for high costs: (1) A very large proportion of development work; (2) soft ground, requiring slow, cautious working and heavy timbering; (3) careful selection imposed by the necessity of smelting the whole product, thus imposing a high subsequent metallurgical cost. This is the most imperative factor of all, for it can be shown that in this case lower costs at the expense of having to smelt lower grade ores might result in frightful losses of profits. To mine 4 per cent. ore for $3 a ton against 7 per cent. ore at $6 a ton, smelting costs remaining the same, would increase the cost of copper about 0.82 cents a pound, or $16.40 a ton.

The Copper Queen mine, unfortunately, does not publish its reports, and the Calumet & Arizona, the only other important mine at Bisbee, does not give details. The figures from the Calumet & Arizona reports in an accompanying table throw some light on the subject:

SUMMARY OF OPERATIONS OF CALUMET & ARIZONA FOR FIVE YEARS

Year	Copper Lb.	Price	Value Copper	Gold and Silver	Total Value	Tons
1904	31,638,660	12.562	3,974,448	$195,926	$4,170,374	205,807
1905	31,772,896	14.923	4,741,484	178,843	4,920,327	202,952
1906	37,470,284	17.96	6,729,612	238,464	6,968,076	215,671
1907	30,689,448	18.103	5,554,781	210,846	5,765,627	232,460
1908	28,048,329	12.948	3,631,655	234,358	3,866,013	265,344
Total & Av.	159,619,617		24,631,978		$25,690,417	1,122,234

Year	Devel. Ft.	Div.	Excess of Assets	No. of Men Mining	Estimated Cost of Mining Per Ton
1904	19,955	1,300,000	1,823,992	583	$6.15
1905	21,737	1,700,000	—	629	6.68
1906	14,818	2,600,000	—	597	6.00
1907	23,016	3,300,000	—	621	5.70
1908	30,680	800,000	3,423,269	567	4.60
	100,206	9,700,000			

Copper equivalent .... 166,500,000 lb.
Copper equivalent per ton .... 148 lb.
Approximate earnings $10,900,000
Approximate cost $14,790,000
Cost per ton $13.18
Cost per lb. copper .... 8.9 cents
Tons per ft., development work 11

The first report that gives actual operating figures to any extent is that for the year 1908. The comparison, with the five-year period is interesting. The amount smelted was 265,344 tons containing the equivalent of 113 lb. per ton, against 148 for the five years.

		Per Ton
Operating mines and smelters	$2,089,158	$7.87
Current construction	195,408	.74
Salaries and general expense	32,011	.12
Refining and marketing	368,529	1.39
Ore purchases	22,964	.08
Total	$2,708,070	$10.20

The cost per pound copper is 9 cents.

There is nothing to indicate the comparative cost of mining and of smelting except the number of men employed in each. The total number at the mines averaged 567, and at the smelter, 484. It seems probable that the total cost of mining will equal $6 a day per man employed, this being estimated on the theory that the labor cost is 60 per cent. of the total, which would indicate a mining cost, including development and everything, of $4.60 a ton. This cost is good for Bisbee and I believe below the average at this mine. Smelting would cost, on this basis, $3.18 per ton, which seems very good.

Superior and Pittsburgh

This property is a consolidation of several others which undertook a bold and expensive exploration of a tract of 1388 acres lying in the trend of the assumed extension of the copper Queen orebodies. The venture has been successful as far as finding ore is concerned, but has not yet become profitable. It is heavily capitalized, the stock issued being 1,500,000 shares at $10 par value. That the outcome is viewed with confidence by the stockholders, or by the public, is proved by the present market value (April, 1909) for the stock of $13 a share.

Operations have been carried on since the consolidation at a loss of $1,031,284 in three years. The output and results have been as follows:

19—	Dry Tons Smelted	Feet Development	Copper	Gold and Silver	Total Value
1906	95,779	40,019	9,044,875	$21,941	$1,645,339
1907	111,710	23,332	9,691,905	33,401	1,787,544
1908	214,847	29,572	21,924,259	121,296	2,839,000
	422,336	92,923	40,660,539	176,638	$6,271,883

The equivalent of copper per ton is 100 lb. The cost per ton averages $17.30, and the cost per pound copper 17.3 cents. Tons per foot development, $4\frac{1}{2}$.

A great improvement over these averages is shown by the report for 1908. The copper equivalent in the ore for that year is 108 lb., nearly equal to Calumet & Arizona for the same year. Here is the record:

		Per Ton
Tons smelted dry	214,847	
Mining and smelting..............................	$2,490,857	$11.60
Current construction	30,938	.14
Salaries and general	36,648	.17
Refining and marketing	264,869	1.23
Interest...	84,719	.40
	$2,908,031	$13.54

The cost per pound was 12.54 cents.

Phelps, Dodge and Company

A prospectus issued in December, 1908, announcing the incorporation of the various properties owned by this concern, contains all the official information issued to the public about them, and is given in following pages verbatim, so far as it relates to the copper mines. The prospectus interrupts to some extent the policy of secrecy heretofore maintained concerning the mines, but it gives no operating details. It is not possible, therefore, to calculate the costs with assurance. It is only possible to make some comments on the data furnished in order to apply to some extent the argument developed throughout this volume, as to the relation of capital charges to operating charges and profits.

Statement by Comptroller

COPPER QUEEN CONSOLIDATED MINING COMPANY

"This property consists of one hundred and thirty-five (135) mining claims in the Warren mining district, Cochise County, near the town of Bisbee, Arizona, a large smelting plant at Douglas, of a capacity of 3000 tons a day, which treats the product of the mines of the Copper Queen Company, and for the time being the ores of the Moctezuma Copper Company, and does general custom work. The company conducts a mercantile business, and has large stores and warehouses in Bisbee and Douglas, and a branch store in Waco, Arizona, as well as other pieces of real estate. It also owns mining interests in other localities.

"For five years past the production of the mines has been as follows:

1903	37,257,470 lb.
1904	50,151,552 lb.
1905	64,625,955 lb.
1906	79,219,655 lb.
1907	63,341,055 lb.
Total	294,595,687 lb.

"The output of the Douglas Reduction Works, including purchased and custom ores, for five years past has been 363,121,911 lbs.

"The earnings of the company during the five years past have been as follows:

1903	$2,201,640.40
1904	2,960,659.70
1905	5,609,486.30
1906	7,625,854.76
1907	4,471,137.08
Total	$22,868,778.24

"The difference between earnings and dividends is represented by expenditure on increased plant facilities, and undistributed assets, consisting of the larger stock of coke and fuel necessitated by increased operations; and the accumulated stock of ores at the works, amounting in value to over $1,000,000, as well as by increased cash and increased reserves.

"A large portion of the company's mining property has as yet been undeveloped, though situated within the recognized mineral zone of the district, and, owing to the difficulty of holding up the soft, shifting ground in which the ore occurs, it has always been found impossible to block out ore reserves as large as mines of such capacity elsewhere have usually maintained, as nominally in sight. There is, however, at the present time as much ore in sight as at any other period of the mine's history.

"The valuation of the company's property as of November 1, 1908, exclusive of the mines, is as follows:

Invested in plant	$4,974,866.77
Other assets	10,915,492.97
Liabilities	1,275,573.40

MOCTEZUMA COPPER COMPANY

"This property consists of about 2500 acres of mineral ground in the State of Sonora, Mexico, on which has been opened the Pilares mine. This is in a mineralized body, oval in shape, and which retains approximately its dimensions between surface and the seven hundred foot level. It is about 1700 ft. in diameter from north to south, and 1200 ft. in diameter from east to west, and contains a large area of profitable ore. A narrow gage steam railroad five miles in length connects the mine through the Pilares Tunnel with the concentrating mill at the town of Nacozari. The tunnel itself, with its branches, is over a mile in length, and is large enough to allow of the railroad cars reaching through it the different sections of the mines, and receiving their charge from large bins excavated out of the ore. These bins are of a capacity of several thousand tons each, and are fed through chutes extending to the surface levels, the chutes also being excavated from the mineralized ground.

"The quantity of what may be considered ore depends entirely upon the grade which it is profitable at a given price for copper to work, but the mine is at present opened up for an extraction of 1500 to 2000 tons a day of ore of an average grade of three per cent. The daily capacity of the concentrating mill just completed at Nacozari is 2000 tons. At Nacozari is a well-designed power plant, equipped with Curtis turbines of over 4000 horse-power, for transmitting high voltage current to both the mill and the mine. For the time being it is found to be more profitable to convey the concentrates and rich ores by the Nacozari Railroad to Douglas, Arizona, seventy miles distant, than to smelt them on the spot, the ores being treated at Douglas at the same profit to the Copper Queen Company as though they were custom ores supplied by an unallied customer. This feature of the company's operations explains the comparatively small quantity of supplies carried by the Moctezuma Copper Company as compared with the other companies.

"The old concentrating mill, which is still intact, with its very efficient gas engine and gas-generating plant, which up to within a few months treated 600 tons of ore a day, is now out of commission, though it can be started at short notice as a supplemental plant to the new mill, should this course be desirable.

"The production for the five years past has been as follows:

1903	10,281,970 lb.
1904	11,061,649 lb.
1905	10,160,016 lb.
1906	12,714,726 lb.
1907	9,640,390 lb.
Total	53,858,751 lb.

"The increased capacity of both the mine and the concentrating mill, owing to recent improvements, is indicated by the fact that in May, 1908, the production was 784,892 lb. of metallic copper, whereas by the month of October it had reached 2,300,000 lb. of copper, contained in 9500 tons of $12\frac{1}{2}$ per cent. concentrates. A production of approximately two million pounds of copper a month can now be maintained; and, if the market demanded it, this production could be increased to three million pounds per month.

"The net earnings for the five years past, while the mine was still in a stage of development and the works were contracted, were as follows:

1903	$456,524.55
1904	598,992.36
1905	533,117.66
1906	1,195,424.18
1907	833,236.25
Total	$3,617,295.00

"The company has built and owns the whole town of Nacozari, and has provided it with a well-furnished library and amusement hall, a thoroughly equipped hospital, hotel, boarding houses, and schools. At the Pilares mine the company has provided its workmen with comfortable houses and supports a school. At both Nacozari and Pilares the company has large stores and warehouses, and conducts a profitable mercantile business.

"The valuation of the company's property as of November 1, 1908, exclusive of the mines, is as follows:

Invested in plant	$3,046,384.32
Other assets	944,663.08
Liabilities	347,221.22

THE DETROIT COPPER MINING COMPANY OF ARIZONA

"The mines of this company are situated in the Clifton district, Arizona, in the same beds of felspathic rock which at the present time are yielding the product of the Arizona Copper Company, the Shannon Copper Company, and certain less prominent organizations. The property owned by the company consists of one hundred and forty-five (145) mining claims, and the ore now extracted amounts to about 36,000 tons per month, yielding about three per cent. of copper. The bulk of the ore is concentrated mechanically to a grade of about fifteen per cent., and smelted at Morenci in the company's own smelting works.

"The company's production for the five years past has been as follows:

1903	16,869,300 lb.
1904	16,424,394 lb.
1905	14,632,117 lb.
1906	20,347,497 lb.
1907	17,974,581 lb.
Total	86,247,889 lb.

"The production for the eleven months of the present year has increased to 21,500,000, owing in great measure to improved facilities for treatment. The future production with the present equipment can be maintained at approximately two million pounds of copper per month.

"The earnings during the past five years have been as follows:

1903	$543,456.00
1904	603,340.00
1905	532,684.28
1906	973,456.42
1907	814,874.11
Total	$3,467,810.81

"The company runs a large store and hotel, and owns considerable other property in the town of Morenci, besides a powerful pumping plant on the San Francisco River seven miles distant.

"The valuation of the company's property as of November 1, 1908, exclusive of the mines, is as follows:

Invested in plant	$2,158,106.00
Other assets	2,934,465.97
Liabilities	149,878.48

"The ores from the Copper Queen mines carry about twice the quantity of copper contained in those of the Nacozari and Morenci districts, but this advantage is offset by the higher cost of mining the Queen ore, owing to the character of the deposits in which they occur. Moreover, as the Queen ores cannot be subjected to preliminary mechanical concentration, which raises the smelting grade of the Nacozari and Morenci ores, they must be subjected to furnace treatment as they come from the mines; hence the cost of smelting a ton of Queen ore is higher than the cost calculated on a ton of crude Nacozari or Morenci ore, as it comes from the mine previous to mechanical concentration."

Referring to the Copper Queen and confining attention to the output from the company's own mines we get the following:

Year	Output Pounds	Operating Profits Dollars	Profits per Pound Cents	Average Price Cents	Cost Cents
1903	37,257,470	2,201,640	5.9	12.6	6.7
1904	50,151,552	2,960,659	5.9	12.562	6.962
1905	64,625,955	5,609,486	8.7	14.923	6.223
1906	79,219,655	7,625,854	9.63	17.96	8.33
1907	63,341,055	4,471,137	7.	18.103	11.103
Five years	294,595,687	22,868,778	7.76	15.7	8

The amount invested in plant is given at $4,974,866. Since it is stated above with reference to the Bisbee district, by Dr. Douglas that the ores of the Copper Queen average about 140 lb. copper per ton, an approximation that is borne out by the record of the neighboring Calumet & Arizona mine, it does not seem rash to say that the mining plant is equal to a capacity of 600,000 tons a year, and the smelting plant to 900,000 tons a year. Averaging the two we might say the plant is such that an output of at least 750,000 tons a year can be taken care of. The cost of mining and smelting plants may, therefore, be approximated at $7 per ton of annual capacity. Taking into consideration the character of the orebodies exhibited by the remarks in the prospectus, it seems fair to calculate the amortization of plant in a period not exceeding fifteen years from the beginning of the term in question. This requires an annual instalment of 10 per cent. To this should be added depreciation at 6 per cent. to cover the current construction. Applying these figures, not the whole period, but to the maximum capacity reached at the end, we get

For amortization	$0.70 per ton
For depreciation	.42 per ton
Total	$1.12 per ton

Dividing this by 140 lb., the average amount of copper realized per ton, we get 0.8 cents per pound as the amount that should be added to operating charges for plant account. I am disposed to regard this as a minimum figure and prefer to believe that at least 1 cent per pound should be added for these charges. This would mean only $2,940,000 in five years for the use of capital already invested and for current construction. It is to be presumed that the company made some profit on treating custom ores, but as these ores must have come largely from other mines owned by the same group, it is not likely that such profits would be sufficient to alter the calculation materially. My estimate of costs, then, for the Copper Queen is as follows:

	Operating Costs Cents	Capital Costs Cents	Total Cents
1903	6.7	1	7.7
1904	6.96	1	7.96
1905	6.22	1	7.22
1906	8.33	1	9.33
1907	11.1	1	12.1
Average	8	1	9

It will be noted that the average is exceedingly close to that figured for Calumet & Arizona; and, further, that a considerable rise was incident to the boom period of 1906–07.

Moctezuma Copper Company

The figures on this property are very interesting in view of the light they throw on the probable results to be obtained from the Miami, Ray, and other new properties of approximately the same grade and type.

Year	Output Pounds	Operating Profits	Profits per Pound	Average Price	Operating Cost
1903	10,281,970	456,524	4.44	12.6	8.16
1904	11,061,641	598,992	5.44	12.562	7.178
1905	10,160,016	533,117	5.25	14.923	9.773
1906	12,714,726	1,195,424	9.4	17.96	8.56
1907	9,640,390	833,236	9.64	18.1	9.46
Five years	53,858,751	3,617,295	6.7	15.3	8.6

In this case the plant investment is \$3,046,384, and the producing capacity is now easily 24,000,000 lb. a year. Calculating depreciation at 6 per cent. we get an annual charge of \$182,800 a year, equal to 0.76 cents per pound. Add this to 8.6 and we have 9.36 cents as the dividend cost. It is very probable that with the increased tonnage now possible, the cost will average not over 9 cents.

On a life of twenty years, the plant may be amortized at 8 per cent., equal to about 1 cent per pound. The selling cost may then be put at between 10 and 10½ cents, a figure that fully bears out the conclusions arrived at from other sources.[1]

[1] See Chapter XIII. for discussion of the cost of producing copper from ores of approximately this grade and type.

Detroit Copper Company

Neglecting the explanation of details, it appears that this company earned $3,467,810 from 86,247,889 lb. copper, equal to 4 cents a pound. The cost must have been about 11.3 cents. The capital invested is only $2,158,106, on which depreciation at 6 per cent. gives an additional cost of 0.7 cents per pound. The dividend cost may be calculated at 12 cents.

In all of the above calculations I have failed to exhibit the copper equivalent for gold and silver contained, because the amounts are not given. In most of these mines, however, the value of precious metals is only 2 to 3 per cent. of the total, so that the figures given cannot be far astray from this cause.

Greene Consolidated, Cananea, Mexico

This company has a very large property near the Arizona border in the state of Sonora, Mexico. In 1906 the Greene Cananea Company was formed to consolidate the old Greene Consolidated Copper Company, and the Cananea Central Copper Company. The management has been completely reorganized.

The record of the old Greene Consolidated Company was as follows:

Output and Dividends	Greene Consolidated	
	Lb. Copper	Dividends
1901	28,826,854	$400,000
1902	38,268,407	—
1903	42,310,544	600,000
1904	55,014,339	1,200,000
1905	63,005,848	2,800,000
1906	55,943,739	1,200,000
	283,369,731	$6,200,000

The dividends are up till March, 1907.

It appears that up to that date the dividends, which must represent approximately the earnings, were equal to 2.19 cents per pound copper produced. If we count as copper the value of silver and gold produced, the earnings per pound would be about 2 cents. Since in those particular years the average price of copper was about 14.9 cents, we may conclude the average cost to have been about 12.7 cents; and since at the end of the period it was found necessary to undertake large improvements, it is altogether probable that something should be added for depreciation.

No estimate of the amount of ore in sight is given in the report for 1908.

The report goes into the question of mining costs so thoroughly and with so much good sense and poise that I quote largely from the statements of the general manager, Mr. L. D. Ricketts. It will be seen that the reduction of costs in all departments has been enormous. But it occurs to me to point out one or two reasons for accepting with a little caution the conclusion that the process of reduction is so firmly intrenched that further reductions are inevitable.

First let me note that during 1908 the monthly tonnage treated was about 60,000 against nearly 100,000 in former periods. It is just possible that the reduced tonnage may have great advantages over the full tonnage in that it is secured with *selected labor* and from *selected places*.

Either of these advantages may be of great consequence in the matter of costs, as has been pointed out in the chapter on the Value of Mining Property. It comes as an example of how costs go down in periods of depression.

Second, it is worth considering whether the period under review does not get great advantages from the reconstruction that preceded it. All plants were overhauled and renovated. It is natural to suppose that in consequence everything was in excellent repair — better than average. As to charging up current construction to operating, that is something that always must be done sometime — whether the cost sheets show it or not. There is no great virtue in doing it in this particular case because in this very year, outside of what was charged to operating, there was spent on plant no less than $820,000 or $5\frac{1}{2}$ cents per pound of copper produced from the company's own mines.

Furthermore, let us consider the following: At average prices for the last ten years (15.4 cents copper, 57 cents silver, and $20 gold) the ore for 1908 shows the following values:

Copper	53.4 lbs.	= $8.22		
Silver	0.923 oz.	= .54		
Gold	0.00575 oz.	= 0.115		
Total		8.87	= 57.6 lb. copper.	

The costs for 1908, the lowest on record, are $5.976 per ton. This gives 10.37 cents per pound for the copper, or its equivalent, extracted. With these costs, the profit per pound is 5 cents and we might expect a profit, under average conditions, of some $2.80 per ton mined and treated. With these comments the following is quoted directly from the report.

"The Cananea Consolidated Copper Company, S.A.

AUDITOR'S REPORT

December 31, 1908

Earnings

Total earnings on copper, gold and silver, and net earnings from miscellaneous revenues	$2,427,335.79

Expenditures

Total expenditures account copper, gold, and silver	1,821,029.85
Net profit for year	$606,305.94
Sundry expenditures, including shut-down costs, etc.	820,446.56
Deficit for the year 1908	$214,140.62

Report of General Manager

The figures of production are for the period beginning July 11, 1908, when operations were resumed, to the close of the calendar year. In reading this report I would respectfully refer you to my report of February 15, 1908.

Tonnages

Wet tons domestic ore treated	295,554
Wet tons custom ore treated	72,088
Total	367,642
Ratio of concentration, domestic ore milled	3.12 tons into 1
Ratio of concentration, custom ore milled	4.02 tons into 1

Production

Returnable fine copper in domestic bullion	15,679,685 lb.
Returnable fine copper in bullion from custom ore	2,939,924 lb.
Total	18,619,609 lb.
Silver in domestic bullion	272,651.24 oz.
Silver in bullion from custom ore	175,011.99 oz.
Total silver	447,663.23 oz.
Gold in domestic bullion	1,700.683 oz.
Gold in bullion from custom ore	1,178.150 oz.
Total gold	2,878.833 oz.

Recovery from Ores

Recovery from domestic ore and other material treated was as follows:

Copper 2.652 per cent. Silver 0.923 oz. Gold 0.00575 oz.

The value of the precious metals per ton of domestic copper produced amounted to $21.09.

Development during period: January 1 to December 31, 1908:

Shafts	412.5 ft.
Winzes and raises	3,550.5 ft.
Tunnels, drifts, and crosscuts	9,388.0 ft.
Total	13,351.0 ft.

The Mines

The following statement covers the tonnages and costs of mining at the various mines:

	Wet Tons	Total Cost	Cost per Wet Ton
Puertocitos	18,465.4	$41,549.68	$2.250
Elisa	40,481.4	71,580.00	1.764
Capote	15,923.1	82,088.64	5.155
Oversight	142,824.8	272,766.63	1.910
Veta Grande	91,901.3	191,992.54	2.089
Total	309,696.0	659,997.49	2.131

The Cost of Mining

"The cost of mining for the total tonnage mined was $2.13 per wet ton. For the fifteen months ending October 31, 1907, it was $3.28, and for the year 1905–1906 it was $3.85. Great credit belongs to the Mining Department for this showing under most difficult conditions. The reasons for the decreased costs are twofold. First, the slicing and caving system has been thoroughly learned and applied to the various mines in the modified forms which the conditions demand. This has resulted in a decreased amount of timber and supplies and an increased efficiency of the men. The second reason is that the Mining Department has been entirely reorganized and the average pay per employee has been decreased by this readjustment very nearly 20 per cent. We have, therefore, a decreased cost per man and an increased output per man. For the period in question the output per man has been increased from 1.2 to 1.6 tons, and this covers not only the miners but the muckers, trammers, blacksmiths, and in fact every employee of the mines up to and including the foremen. It is hard to realize the difficulties that have been encountered in accomplishing this, but it had to be done and was done.

"Departing from facts and predicting for the future, I have little doubt that we will be able to maintain and improve upon these costs in spite of the tremendously increased amount of development work we propose to do, and we can look to continued decreases in mining costs rather than increases for some time to come; but in saying this I am keeping in mind certain capital expenditures which are exceedingly urgent. This construction provides cheaper compressed air and more electrical power at the mines. You have authorized and we are now installing an air compressor of 6000 cu. ft. of free air per minute capacity at the power house and will lay a pipe line to four of the mines and replace with this one machine eight uneconomical small machines. Since the reverberatory furnace is generating an average of over 600 boiler horse-power we have a surplus of boilers at the power house and no new boilers are needed, and our power house condenser is abundantly large to take care of this compressor. In addition to this we are now up to the limit of our electrical generating capacity and it is essential that we should put in more power for the use of the mines. Mr. John Langton, consulting engineer, is now making a study and report on our power equipment, and is preparing specifications to be submitted to you. It would appear that with an expenditure of $57,000 we can increase our capacity 1000 kilowatts and reduce the cost of generating power per kilowatt year about 15 per cent. If this unit is put in there is no question but that other capital expenditures will be required, because if we can change over our steam hoists of four of our shafts to electrically driven hoists by the addition of the proper motors we can abandon entirely four very expensive steam plants. If the program is approved and carried out it will require a total expenditure of about $120,000. In making this recommendation I have carefully considered the tremendous expenditures that we have had to make and am still keeping in mind the rule of recommending only expenditures that will pay for themselves in one year's operations."

The Concentrators

"The Cananea ore is probably the most difficult to concentrate of any copper ore in the country on account of the tremendous amount of clay, which is not only not susceptible to dressing, but which prevents proper settling of the fine sands. Our losses on this account are high and there are certain losses that we have proved by experiment we can recover by collecting the fine sands from the large settling tanks below the mill and reconcentrating them. We are now installing a vanner house about 300 ft. in length on the opposite side of the canyon, and will rehandle the fine sands from the tailings over the 40 vanners and 10 card tables that are being installed therein. In conjunction with this vanner house Mr. Cole has installed settling tanks of approved plan, and it includes, of course, appliances for conveying the concentrates to the railroad storage bins. Later on we propose to double the capacity of this plant. The preliminary installation will cost $50,000 and the additional 50 vanners will cost about $30,000 more.

"In all of these improvements we have followed the plan of undertaking no construction that will not pay for itself within a year.

"The cost of concentration of the domestic ores was $0.94 per ton on account of the immense amount of construction charged to operations, but the result will be not only an increased saving, which is badly needed, our present saving being only about 70 per cent., but we can safely see a reduction in cost to 75 cents per ton or under. The same care was taken in reorganization in starting up the concentrator with what undoubtedly is very beneficial results.

THE REDUCTION DIVISION

"The average daily pay-roll at the smelter, including the power house, was formerly $1,823.57, and during the past six months it has been $763.57. The efficiency of blast in converting has been raised from 43 per cent. to 61 per cent., and the efficiency of blast on the furnaces has been raised a corresponding amount.

"The reverberatory ran 150 furnace days. It treated 30,275 tons of net dry charge at a cost of $1.83 per ton, allowing a credit of 60 cents per ton for steam generated in the reverberatory boilers. This average is high because the first few months' run was very much more costly than later on, and we have recently been smelting for about $1.37 per ton, allowing credit for steam generated. The cost of power has been reduced about 40 per cent.

"I give below a table compiled from Mr. Shelby's report, showing comparative results for the six months prior to and the six months subsequent to the shut-down, covering the total Reduction Division costs per ton of ore and old secondaries treated, per ton of new material treated, and per ton of fine copper produced.

"REDUCTION DIVISION COST COMPARISONS

Last six months' operations for 1907 and 1908:

BASIS PER DRY TON

TONS TREATED OR PRODUCED

	Ores and Concentrates		New Material		Fine Copper	
	1907	1908	1907	1908	1907	1908
	220,446	164,361	299,620	217,177	11,103.288	9,295.769
Total costs ...	$6.82	$3.86	$5.02	$2.93	$135.47	$68.47

Mining and Beneficiating

"Copper costs for six months of operation were as follows:

Gross costs, F. O. B. Cananea		$0.0992751
Freight to New York, export tax, refining, marketing, interest, etc.		0.0168642
Total cost		$0.1161393
Credit for value of precious metals	$0.0105446	
Miscellaneous revenues at Cananea	0.0075206	
		0.0180652
Total cost of fine copper sold		$0.0980741
Construction not charged to operation		$0.0070583
Cost including every expenditure		$0.1051324

"The yield of copper per ton of ore beneficiated given at the beginning of this report is misleading in that during July we smelted a considerable tonnage of cleanings found in tearing out old ore bins and other structures. The actual net yield of the ore beneficiated was 51.25 lb. per ton as against 46.58 lb. for the fifteen months ending October 31, 1907. Owing to the decreased cost of smelting we have been able to send leaner ores of the Puertocitos and Elisa class to the smelter with a handsome margin of profit, and we have been able to smelt leaner ores that formerly went to the concentrator. This has resulted in increasing by nearly 50 per cent. the percentage of direct smelting ore to the total ore mined and has caused an increased yield per ton. As a matter of fact, therefore, the average gross copper contents of the ore have not increased even as much as the figures above would indicate. On the other hand, the greater percentage of ore smelted direct has tended to increase the total cost of mining and beneficiating a ton of ore, but with this increase the cost is more than paid for by the increased saving of values.

"The following is the total cost of mining and beneficiating a ton of ore, including every cost until the refined products are sold:

Period	Cost per Ton	Tons Beneficiated
Fiscal Year 1905–1906	$10.21	947,977
August 1, 1906, to October 31, 1907	7.625	1,305,291
July 11 to December 31, 1908	5.976	295,554

"The results show a decreased cost during the six months of 1908 of $1.649 per ton over the previous period, and a decrease of $4.234 over the fiscal year 1905–06. In other words, had we been able to mine and beneficiate the ore for the fifteen months ending October 31, 1907, under present conditions the cost would have been decreased by about $2,150,000 plus the value of the increased saving.

"In making a careful and balanced study of the cost of mining and beneficiating ore two years ago the vital features were obvious. It was necessary to get cheaper mining costs, cheaper smelting costs, cheaper fuel, cheaper power and cheaper transportation. While we have made notable advance on the first four items we have been unable to obtain any adequate concessions in the matter of the heavy freight rates on fuel and supplies. We are virtually in the same location as our neighbors across the line when the great distance from the source of fuel, coke, and supplies is considered, yet we are charged rates that in the aggregate amount to one cent per pound of copper in excess of the rates paid by our neighbors, and the burden is hard to carry. The question is serious, yet we think fair freight rates would mean increased tonnages that give the highest profit to all concerned.

"While predictions are dangerous, and I have in this report only given figures from results actually accomplished, I have no hesitation in saying that we shall be able to continue decreasing the cost of mining and beneficiation and increasing the percentage of saving to a notable degree, although we cannot expect to make reductions corresponding to those made during the past year."

CHAPTER XII

COPPER MINES IN VARIOUS OTHER DISTRICTS

Tennessee Copper Company — Utah Consolidated — Mount Lyell in Tasmania — Granby Consolidated in British Columbia — Utah Copper Company — Northern California — First National Copper Company.

Tennessee Copper Company

Only one mine of importance is found in the United States east of Lake Superior. It is owned by the Tennessee Copper Company, which works several large lenses of cupriferous pyrite. All the ore must be smelted in the blast furnace. For ores of this character I believe this company does the cheapest work in the world. Its reports are excellent and reveal not only the operating costs in detail, but also the plant expenditure and the ore in sight.

The external factors are favorable. Fuel is cheap and transportation to markets much less than for western mines. Wages are about 20 cents an hour, but I do not believe this means cheap labor.

The internal factors are favorable, with the exception of the necessity of smelting all the ore. This is a most powerful element of high cost. The ore yields only 32½ lb. copper to the ton.

The current operating costs for 1907 were as follows:

Mining	$1.22
Smelting	2.14
Administration etc.	0.49
Total	$3.85

To this I think should be added 21 cents a ton for the use of the mining plant and 47 cents a ton for the use of the railroad and the smelting plant, making a total of $4.53.

In detail these costs are as follows:

FIG. 8. — Mill and power plant of Utah Copper Company, Garfield, Utah.

Development	$0.1318	
Mining, hoisting, etc.	0.9389	
Crushing and sorting	0.0804	
General	0.0851	
Total current cost		$1.2162
Add cost of preliminary development amortized in 15 years at 5 per cent. interest and 5 per cent. annual amortization		0.06
Mining plant similarly amortized		0.15
Transportation to smelter	$0.1329	
Blast furnace	1.6279	
Engineering and laboratory	0.0628	
General	0.0852	
Converting	0.2402	
Total current smelting cost		$2.1430
Add amortization of smelting plant and railway as above		0.47
Add administration, shipping, refining and selling expenses		0.49
Grand total		$4.5292

On the basis thus figured, anything received above 12 cents a pound for copper in New York is applicable to dividends, and anything above 14 cents is net profit after allowing for the return with interest of money invested in the plant. These costs are higher than the average by from 5 to 10 per cent. The costs for 1907 were high on account of unfavorable economic conditions throughout the country. It should be explained further that in addition to the copper the sulphur is being utilized so that in future the property will not be wholly a copper mine. Its operations will be nearly equivalent to those of the Rio Tinto Company in Spain.

Utah Consolidated

This company has mined since 1899 large deposits of cupriferous pyrite at Bingham, Utah, averaging by actual recovery for five years 60 lb. copper, 1.33 oz. silver, and 0.104 oz. gold per ton. The silver and gold are worth about $2.88 per ton, so that with copper at 14 cents per pound there is a total metallic extraction equivalent to 80 lb. copper. The ore occurs in large lenses or shoots in limestone. It is approximately self-fluxing, there being a moderate excess of iron over silica. Most of the mining has been done through adit levels. The mining plant is not extensive. The ore is delivered to the railroad over an aerial tramway about 12,000 ft. long. It is transported by rail about 25 miles to the smelter.

The external conditions are, for the Rocky Mountain region, good, and the internal factors, with the single exception of the requirement of smelting all the ore, very favorable for cheap work. The ore is soft, uniform, and occurs in good-sized bodies. The stoping is done in square-set rooms. The item of timbering must be one of the chief mining expenses.

There is nothing in the reports to show the mining or smelting losses; but with this exception the reports are excellent. They give the stockholders in brief but sufficient outline the costs and financial results of the business.

In the five years ending December 31, 1907, the costs were as follows:

Costs per Ton for Five Years, Utah Consolidated

	Per Ton
Mining, 1,260,453 tons	$1.73
Development. 1.400,000 tons	0.30
Transportation, smelting, and refining, 1,276,393 tons	2.80
General expense, 1,276,393 tons	0.23
Current construction, 1,276,393 tons	0.34
Amortization at 5 per cent. interest and 5 per cent. annual amortization of $1,232,274 invested in plant at beginning of period; this being sufficient to retire the investment in 15 years — proportion for five years	0.48
Total cost	$5.88

Recollecting that the ore contains in copper, gold, and silver the equivalent of 80 lb. copper to the ton, we get an average complete cost of producing copper of 7.35 cents per pound. This may be divided as follows: actual operating cost, 6.75 cents; allowance for return of working plant, 0.60 cents. Of course, everything received above 6.75 cents for copper or its equivalent in New York goes to the stockholders as dividends.

The report of the Utah Consoldiated for the year 1908 exhibits conditions that are not comparable with certainty to those of former years. The smelter, which was the principal plant asset of the company, had to be permanently shut down on account of a decision of the court to the effect that its operation was inimical to the agricultural interests of the Salt Lake valley. In 1908 the ore was treated at the Garfield smelter of the American Smelters Securities Company, under terms that the Utah Consolidated believes to be unfavorable. Certain deductions were made from the metal contents of the ores under this contract. The exact amounts deducted are not stated.

On the face of the returns the record for the year were disappointing. The costs were as follows:

		Per Ton
Mining 248,215 tons	$ 461,711	$1.86
Ex. and development	73,441	.30
Mine plant	3,869	.01
Smelting and transportation	921,239	3.71
Depreciation and general	127,569	.52
Current construction	129,621	.52
Add refining and marketing, bullion actually produced	120,400	.48
Total operating	$1,837,850	$7.40

Copper metal, lb.	10,648,243
Silver, oz.	265,284
Gold, oz.	23,441

At the prices current during the year this equals 15,225,000 lb. refined copper. This is 61.4 lb. per ton. Dividing the operating cost of $7.40 per ton by this amount we get 12 cents as the cost of copper per pound.

The ore reserves have been increased so that there is no reason to change the amortization charge of 48 cents a ton given above. This, on account of the diminished yield of the ore is now equal to about 0.8 cents per pound. Adding this we get 12.8 cents as the selling cost of copper for the year.

Needless to remark that this showing is disastrous and undoubtedly the stockholders will await with impatience the inauguration of new smelter arrangements, which, it is announced, will be provided by the new International Smelting Company.

Mount Lyell

The Mount Lyell Company operates a cupriferous pyrite mine and a smelter in western Tasmania. The original Mount Lyell deposit was a great mass of nearly pure iron pyrite containing only 0.6 per cent. copper, but a portion of it had been enriched near the surface. This deposit has been mined almost wholly from an open pit. Another mine, however, called the North Mount Lyell, produces a much more siliceous ore averaging

6 per cent. copper. This ore has to be mined underground. During the last four years, which will presently be reviewed, about 60 per cent. of the ore has come from the Mount Lyell proper and 40 per cent. from the North Mount Lyell.

The external factors are probably nearly average for English-speaking countries. The climate is rainy, but not more so than Cornwall or Scotland. The mine is situated near the coast, so that supplies must be reasonable in cost, and transportation of copper, even to England, must cost less than transportation of western American copper to New York.

The internal factors are, for a smelting enterprise, very favorable. The ores are mined, thanks to the large proportion obtained from the open pit, for less than $2 a ton. The smelting is largely pyritic and the proportion of coke used in the charge is said to be only one per cent.

In four years 1,690,531 tons were mined. In the same period the ore reserves diminished from 4,666,000 to 4,107,000 tons, a loss of 559,000 tons. At this rate of loss the property would last thirty years, but since (1) a large part of the low-grade pyrite which hitherto has been mined from open pits must be taken at greater cost from underground and, (2) there does not seem to be a first-class reason to believe that the rich ores of North Mount Lyell can be found in the same abundance for a long period, it seems safer to estimate a life of twenty years as the amortizing period of the investment. On this basis we may compute the costs as follows:

Costs per Ton at Mount Lyell

Mining 1,690,531 tons	$1.05	
Stripping 1,690,531 tons	0.26	
Developing 1,131,258 tons	0.50	
Total mining		$1.81
Smelting 1,698,793 tons	$1 78	
Converting 1,698,793 tons	0.34	
Railway expenses	0.27	
Freight and marketing	0.72	
Total for smelting, refining, and marketing		$3.11
General expense 1,698,795 tons	$0.25	
Use of plant; being 5 per cent. interest and 3 per cent. amortization for four years on average amount invested (£376,000)	0.35	0.60
Total cost		$5.52

The actual returns of metal from the Mount Lyell ores have been 34,210 long tons copper, 3,056,231 oz. silver, and 91,815 oz. gold. The extraction has been 86 per cent. copper, 99 per cent. silver, and 105 per cent. of the gold estimated by assay to be contained in the ore. There is no statement as to whether the ore treated is given in long tons or short tons, but it is probably safe to assume that the copper output is given in long tons. We have on this basis a recovery of 45.5 lb. copper, 1.8 oz. silver, and 0.054 oz. gold per ton of ore treated. The gold and silver are worth $2.18 per ton, at average prices. This is the equivalent of 15½ lb. copper, and we may figure the metallic contents altogether as equal to 61 lb. copper. On this basis the cost per pound of copper is 9 cents.

Granby Consolidated

The Granby Consolidated Mining, Smelting and Power Company, Limited, British Columbia, has mined in three years 1,995,948 tons and treated 2,088,381 tons. The ore yielded by actual extraction 24.2 lb. copper, 0.38 oz. silver, and 0.06 oz. gold per ton. The silver and gold are worth $1.42 per ton, equal to about 10 lb. copper. The total value, therefore, is equivalent to a little more than 34 lb. copper, and this may be taken as a safe basis for figuring the economic performance of the mine. The ore is chalcopyrite disseminated through porphyry altered by magnetic waters so as to form an approximately self-fluxing gangue. The ore will not concentrate, but is smelted in bulk. A large part of the mining has been done in open pits with steam shovels.

This company does not issue a good report to its stockholders. The statement is too brief; it contains no estimate of ore developed, nor does it give any intimation of the probable life of the mine. The reports give no figures about the capital invested in lands as distinguished from capital in equipment. On these accounts it is possible that the costs indicated may not do the property justice.

Costs per Ton at Granby

	Per Ton
Current operating cost; mining, smelting, refining, and marketing for 2,088,381 tons treated	$3.39
Current construction 2,088,381 tons treated	0.36
Carried forward	$3.75

	Per Ton
Brought forward	$3.75
Return of $14,000,000 invested in lands and equipment at 5 per cent. interest and 5 per cent. annual amortization; this being sufficient to extinguish the investment in 15 years with an output of 11,200,000 tons	2.00
Total	$5.75

On this basis the selling cost of copper or its equivalent in New York is about 17 cents a pound.

It is stated in the reports that a maximum capacity of 3500 tons a days, say 1,200,000 tons a year, has been provided. If this volume of operations can be maintained for fifteen years the amortization charges on the invested capital may be computed at about $1.16 per ton on 18,000,000 tons. This will equal 3½ cents per pound copper and the total cost required to neutralize the investment is 14½ cents per pound. The idea can be expressed somewhat differently, as follows:

Cost of copper for current operation and construction per lb	11 cents
Profit per ton required to return capital in 15 years with 5 per cent. interest	3.5 cents
Total cost required at maximum output for 15 years to make the investment justifiable	14.5 cents

It is pertinent to remark that this is what I mean in all cases by amortization; but in other illustrations I have attempted to amortize only the capital invested in actual plant, while in the case of the Granby the amortization covers the entire investment in lands and property besides plant.

Utah Copper

The actual production for eighteen months ending December 31, 1908, was as follows, the figures being the net return free from all smelter deductions:

	Pounds Copper
Copper metal	54,051,212
Gold, 20,072 oz. equal to	3,000,000
Silver, 163,953 oz. equal to	665,000
Total metallic output expressed in copper	57,716,212

Using the round number of 57,700,000 lb. as a divisor, we may calculate the cost as follows:

	Dollars	Approximate Per Ton Milled	Per lb. copper
Operation (mine and mill)	$2,666,284	$1.20	4.448 cents
Mine development	20,028	.01	.035
Prepaid stripping	121,103	.06	.210
Freight on ore	658,754	.32	1.142
Treatment and refining	1,806,659	.85	3.131
Taxes, etc.	7,588	—	0.012
Total operating	$5,280,416	2.47	9.134
Add depreciation, 6 per cent. of plant cost	387,000	0.12	0.670
Total cost	$5,667,416	2.59	9.804

The cost does not correspond to that reported by the company because, instead of deducting the gold and silver from the cost of copper, as the company does, I adopt the more logical method of calculating an equivalent for the gold and silver in copper metal and charging against the sum thus obtained the total costs. The addition of depreciation is absolutely essential. It is a matter of experience in such plants that about 6 per cent. must be allowed for renewals and changes that usually have the appearance of new construction.

Furthermore, in a theoretical calculation of complete costs we must add the amortization of the plant. In this case there is a guaranteed life of twenty-five years. This means that the capital will be retired with 5 per cent. interest by an annual instalment of 7 per cent. Now the total capital required for this business, outside of the cost of the land (which was probably nominal), averaged almost exactly $5,741,000 on which the instalments for eighteen months would equal $592,805, equal to a trifle over 1 cent a pound. Add this to the 9.8 cents obtained above and we get 10.8 cents as the actual cost of copper to date.

Looking to the future it is not necessary to include the amortization in the calculation of dividends. It is, however, a vital necessity in calculating the cost at which the mine can sell copper, for if the owners were to sell copper, to take this example, at say 10½ cents, because they calculate an operating cost of 9.8 cents, they would be in a fool's paradise. They would be losing part of their capital; burdening themselves with the conduct of a vast business for less real return than they could get for their money by buying gilt-edged bonds and doing nothing.

But we must remember that the period we have reviewed is the first eighteen months of the mine's history. It is entirely likely that the mine will be worked out with an annual production averaging 75,000,000 lb. The managers believe that operating costs will be under 8 cents, which will change to 8.5 on the basis I have used. Let us agree to that and add an annual depreciation charge of $300,000. Let us say further that the capital employed will rise to a net total of $8,000,000. We shall have then the following costs:

Operating	8.5 cents
Depreciation	.4 cents
Amortization	.8 cents
Total cost	9.7 cents

This means that 8.9 cents is the dividend cost and 9.7 cents is the metal selling cost.

Owing to the great prospective importance of the type of mine that it represents, and also because it is an example of a good report to stockholders, I have thought best to reproduce here almost the whole report of the Utah Copper Company for the period of eighteen months ending with the year 1908. This report shows better than any other statement I have seen, matters that occupy the attention of the management, the equipment, and plants required, and the conduct, in general, of such an enterprise.

The problem involved is to take a disseminated ore containing 2 per cent. copper in the form of chalcocite from a very large deposit, concentrate it with a saving of 70[1] per cent. into one ton for every twenty-two tons mined, the concentrate running over 30 per cent. in copper. The company does not smelt its own ores, but has it done by contract by the Garfield plant of the American Smelter Securities Company.

The following report is by the general manager, Mr. D. C. Jackling:

[1] These figures are not being realized. The actual yield of refined copper does not seem to be over 20 lbs. per ton. This fact may invalidate my conclusions as to the cost of copper from this type of deposit. See Chapter XIII.

"UTAH COPPER COMPANY

December 31, 1908

Income Account

54,051,212 lb. copper at .1336 cents	$7,222,406.85	
Debit difference in copper settlement for the period, .0016	87,639.06	
Net price applying for the year's sales, .1320 ..	$7,134,767.79	
20,072.18 oz. gold at $20.00 per oz.	401,443.60	
163,952.87 oz. silver at 54.76 cents	89,780.33	
Shipments of ore other than concentrating ...	37,877.38	
Rents received..........................	9,300.90	
Interest, freight, refunds, sale of power, etc. .	9,399.36	
		$7,682,569.36
Operation	$2,666,284.44	
Mine development	20,027.80	
Prepaid expense — ore stripping	121,103.20	
Freight on ore	658,754.14	
Treatment and refining	1,806,658.52	
State of New Jersey, Annual License Tax	4,005.90	
Extraordinary tailings expense, Bingham Canyon	3,581.98	
		$5,280,415.98
Net profits for period		$2,402,153.38
Interest on bonds	$40,755.00	
Dividends paid	696,387.50	
		737,142.50
Net surplus for 18 months ended December 31, 1908		$1,665,010.88

"UTAH COPPER COMPANY

RECEIPTS AND DISBURSEMENTS

July 1, 1907, to December 31, 1908

Receipts

Balance on hand July 1, 1907	$35,802.68
[1] Issuance of 214,150 shares at $10.00 per share	2,141,500.00
[1] Premium on sale of 214,150 shares at $10.00 per share ...	2,141,500.00
Received from sale of bonds	1,500,000.00
Accounts payable	308,452.40
United Metals Selling Co.	991,899.06
Net surplus for period	1,665,010.88
	$8,784,165.02

[1] These items cover conversion of $4,283,000.00 par value bonds converted into stock at $20.00 per share.

Disbursements

Additions to property acquired	$99,972.41
Cost of developing and equipment of mine	253,417.41
Prepaid expense — ore	624,453.02
Garfield mill and power plant	840,231.99
Garfield ore reserve	5,244.05
Accounts receivable	3,961.50
General treasurer	422,216.33
Stores on hand, supplies, copper in transit, etc.	2,057,890.93
Five bonds redeemed in cash	5,000.00
Retirement of $4,283,000.00 par value bonds by issuance of stock	4,283,000.00
Cash in banks	188,777.38
	$8,784,165.02

"COMPARISON OF ASSETS AND LIABILITIES
June 30, 1907, and December 31, 1908

Assets

	June 30, 1907	Dec. 31, 1908	Decrease	Increase
Cost of property acquired	$5,762,572.00	$5,971,138.82	—	$208,566.82
Improvements as follows:				
Garfield mill and power plant	3,164,786.87	4,005,018.86	—	840,231.99
Copperton plant	108,594.41	—	$108,594.41	—
Mine surface equipment	57,298.24	310,715.65	—	253,417.41
Prepaid expense — ore	212,467.68	836,920.70	—	624,453.02
Garfield ore reserve		5,244.05		5,244.05
Outside investments at cost:				
Garfield Improvement Co.	40,000.00	40,000.00	—	—
Garfield Water Co	100,000.00	100,000.00	—	—
Accounts receivable	90,580.44	117,623.14	—	27,042.70
Sinking fund	23,081.20	—	23,081.20	—
Storehouse supplies and fuel	73,255.71	289,271.59	—	216,015.88
Equity in copper in transit	425,597.97	1,275,573.96	—	849,975.99
Cash in banks	35,802.68	188,777.38	—	152,974.70
	$10,094,037.20	$13,140,284.15	$131,675.61	$3,177,922.56

Liabilities

Capital stock outstanding	$5,118,000.00	$7,259,500.00	—	$2,141,500.00
First mortgage bonds outstanding	2,964,000.00	176,000.00	$2,788,000.00	—
A. S. & R. Co. (treatment and refining charges not yet due	47,991.26	342,698.47	—	294,707.21
Accounts payable .	18,887.36	37,402.35	—	18,514.99
Sinking fund (not yet due)......	16,681.60	—	16,681.60	—
Hospital fund	—	11,911.80	—	11,911.80
Due to General Treasurer ...	422,216.33	—	422,216.33	—
Surplus (amount received above par from sale of stock)	918,000.00	3,059,500.00	—	2,141,500.00
[1] Balance — Net Surplus	588,260.65	2,253,271.53	—	1,665,010.88
Total	$10,094,037.20	$13,140,284.15	$3,226,897.93	$6,273,144.88

[1] Income — Net surplus from Copperton Experimental Plant to June 30, 1907 .... $588,260.65
Net surplus for 18 months ending December 31, 1908.................................... 1,665,010.88
$2,253,271.53

Operations at the Mines

"*Development.* — In the last annual report it was stated that the underground developments, on December 31, 1907, amounted to approximately 90,000 linear feet of workings. Since that time we have driven more than ten miles of tunnels, drifts, and raises; but, at the same time, we have destroyed a very large percentage of our underground workings, partially by stoping operations in connection with our underground mining, but more largely as the result of the operations of steam shovels over areas that had been previously blocked out by tunneling and drifting. The areas containing these workings have, to a certain extent, been dug out by steam shovels, but have to a greater extent been caved by heavy blasting incident to steam shovel work, so that they are not now accessible. As a result of the destruction of both old and new workings in the manner above described, we have not now to exceed approximately twenty miles of openings available for use in underground methods of mining, or accessible for inspection.

"References to the map of the company's mining property appended to this report will show the additional area of fully and partially developed ore resulting from the underground work during the period. In the report for the year ending June 30, 1907, the statement was made that the developed and partially developed area amounted to seventy-two acres. Developments since then have resulted in extending this area about eight acres, so that now the known ore area, fully and partially developed, is approximately eighty acres. The ore thicknesses and values of this additional territory are, generally speaking, similar to those described in the former report, so that the new developments have resulted in additional ore reserves to the extent of about 8,000,000 tons, or at a rate during the period of over three times the rate at which ores were extracted for reduction. The net result of the developments we have made during the period has been that fully developed ore remains approximately as stated in our last annual report, viz., 20,000,000 tons, as the area of this class of ore has been increased to an extent that will more than offset the quantity of ore mined.

"The two classes of partially developed ore, described in the former report, have been increased in the aggregate to the extent of approximately 8,000,000 tons, as above stated, so that we now estimate 60,000,000 tons in these two classes of reserves. In other words, of fully developed, partially developed and reasonably assured ore, the total amounts to about 80,000,000 tons. Of this total tonnage, 65,000,000 tons can be classed as of the better or normal grade, averaging about 2 per cent. copper, and 15,000,0000 tons as of the lower grade, approximating $1\frac{1}{2}$ per cent. copper. In addition to this, we have the lower zone, as described in the previous annual report, the average value of which has been indicated to only a limited extent by diamond drilling, but which is estimated to contain a minimum of 40,000,000 tons that will probably average $1\frac{1}{2}$ per cent. In discussing the above quantities throughout, consideration should be given to the fact that the stated figures include the quantities of ore mined during the fiscal period. This would amount, in percentage, to approximately 3 per cent. of the above described three classes of ore aggregating 80,000,000 tons reserves.

"All the development done during the period has been on the easterly end of the property and on both sides of the canyon,

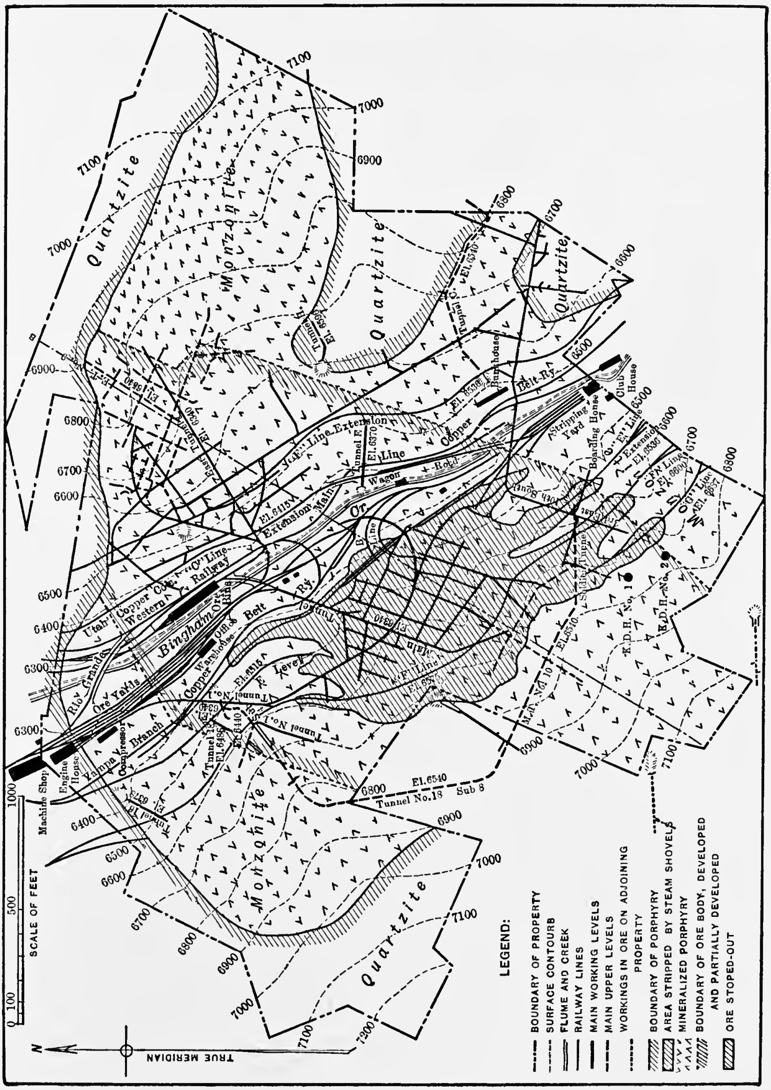


Fig. 9. — Property of Utah Copper Company, Bingham, Utah.

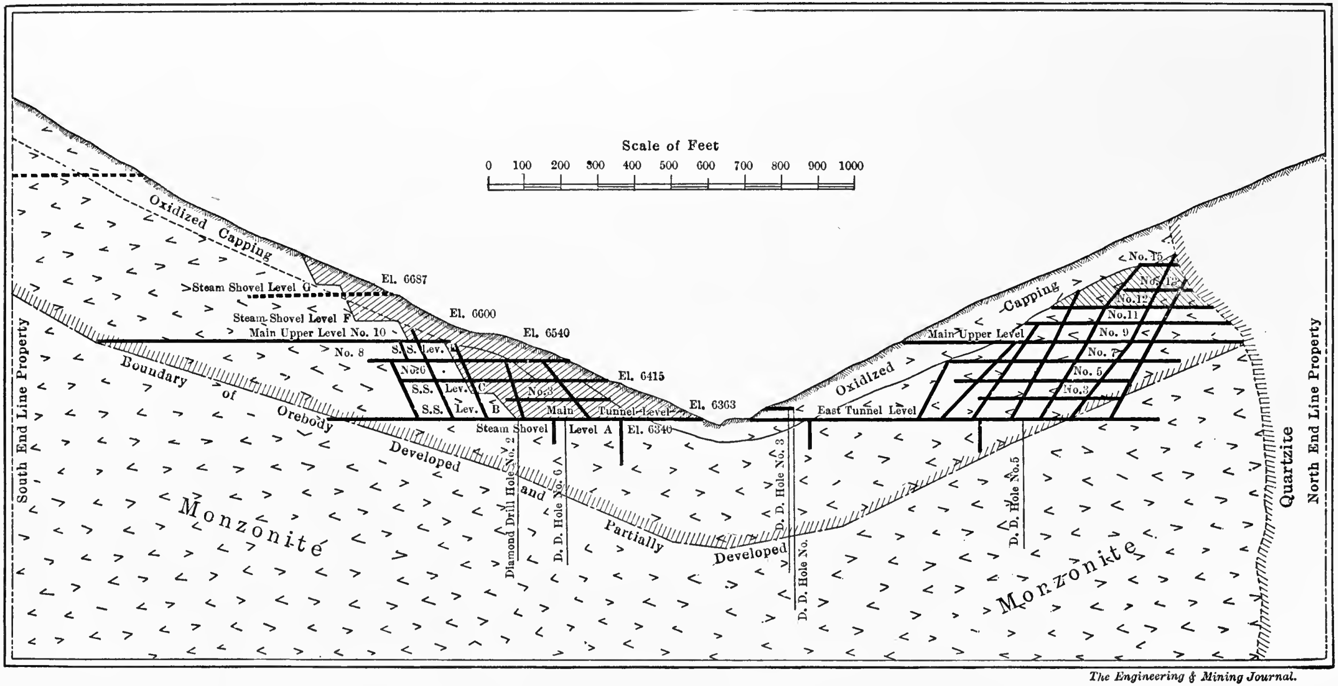


Fig. 10. — Cross-section of Utah Copper Company's Mine, Bingham, Utah.

but the larger part of it has been on the south side of the canyon, in the southeasterly portion of the company's territory. The ore-bearing area is still being extended in that direction.

"*Stripping.* — Stripping operations since their commencement, in August, 1906, have resulted in the removal of 1,705,322 cu. yd. of capping. Of this amount, 1,335,233 yd. have been removed during the fiscal period under discussion. During the first six months of the fiscal period, 367,950 cu. yd. were removed;

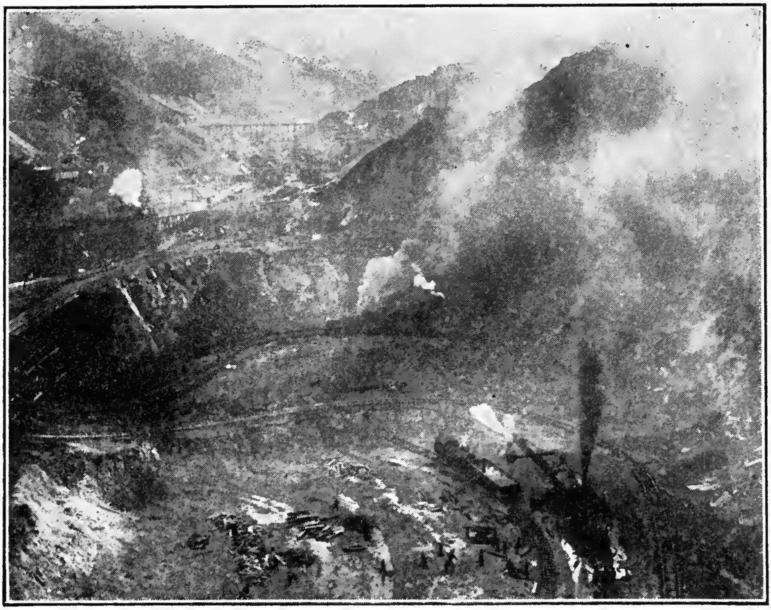


FIG. 11. — Steam shovels at work in pit of Utah Copper Company, Bingham, Utah.

during the second six months, 446,460 cu. yd. were removed, and during the last six months of 1908, 520,823 cu. yd. were removed.

"The total area over which stripping operations have been conducted to date is 19.7 acres. The average thickness of capping, as disclosed by these operations, remains the same as that stated in our last annual report — approximately 70 ft., corresponding to 113,000 cu. yd. per acre. The total amount removed is, therefore, equivalent to stripping of approximately 15 acres, and, at the present time, the actual area completely stripped is slightly in excess of 7 acres.

"The average cost of stripping, throughout the entire operations from their beginning in 1906, has been approximately 32 cents per cubic yard; this cost covering only the removal of capping and its conveyance to available dumping ground. Applying this cost to the average thickness of stripping removed and ore uncovered, the cost per ton of ore uncovered is somewhat less than 4 cents. Stripping operations have been more expensive and difficult in the past than they will be in the future, on account of the very limited area upon which the shovels could work and the expensive tracks it was necessary to build in starting these operations in the narrow canyon. As we develop more room, the rate at which shovels can operate will be increased, and the cost of shoveling correspondingly reduced; but the expected decrease in the actual cost of loading the material will probably be offset by the increased cost of hauling the waste material for greater distances, so that it may be expected that our stripping costs will remain about the same as in the past.

"Since the last annual report, we have secured by purchase and lease the surface rights of about 120 acres of ground, outside of our own property, for dumping purposes. Of this total area, 75 per cent. was acquired by purchase and the remainder by lease. The total dumping capacity of this surface amounts to 6,330,000 cu. yd., or the equivalent of the capping overlying 56 acres of ore, using the average thickness of 70 ft. so far determined. As a matter of total capacity, the ground already secured will be more than is necessary to accommodate any amount of capping that we will wish to deposit in this vicinity, for the reason that plans are now under way to dispose of the capping in another and profitable manner, as will be hereafter referred to in this report.

"*Mining.* — Of the total ore mined during the fiscal period, 33.2 per cent. came from underground, and 66.8 per cent. from steam shovels. During the first six months of the period, the percentages were 39.6 per cent. from underground, and 60.4 per cent. from shovels. During the following six months, the percentages were 34.6 and 65.4, respectively. During the six months ending December 31, 1908, the percentages were 28.7 and 71.3. During the last three months of 1908, the percentages of underground and steam shovel ore were 25 per cent. and 75 per cent. respectively. These figures are given to indicate the gradual decrease of underground mining; or, more properly, the steady increase in the quantity of ore mined by steam shovels.

"The increase in the volume of ore mined by steam shovels is reflected directly in a corresponding decrease in our mining costs. The average cost of both steam shovels and underground ore for the first six months' period above described was 43 cents; for the second period, it was 35 cents; for the third period, 30 cents. The average costs stated cover, respectively, the total costs of every nature at the mine, including development, as well as their proper proportions of all general and fixed charges, such as office expenses, taxes, and insurance. The average costs for the entire period, as applying to the two different methods of mining, were 66½ cents per ton for all ore mined underground and 19½ cents per ton for all ore mined by steam shovel — a saving in favor of the steam shovel method of 47 cents per ton.

"As has been previously stated, the cost of removing the capping from a ton of ore, as shown by our entire experience in the past, amounts to approximately 4 cents. The net difference in favor of the steam shovel method, therefore, becomes 43 cents per ton; this applying to practically all the steam shovel mining we have done, as we only mined a few thousand tons by steam shovels before July 1, 1907.

"From the beginning of stripping operations to date, the equivalent of 15 acres of ore has been stripped, and the total cost of all this work has been about $550,000. It is proper to add to this, however, a proportion of the cost of grading and laying railway tracks about the property and to our dumping grounds for the disposition of capping. The total net cost of such tracks, and of all other construction incident to stripping operations up to date, including general expenses, has been, after crediting retirement fund, approximately $285,000. If we charge all the proper proportion of general expenses and 20 per cent. of all the construction costs to the stripping operations, the total cost, to date, becomes about $690,000. It would not be proper to charge more than 20 per cent. of these construction costs to the stripping already done, because less than that percentage of the area for which these facilities were provided has been stripped. The 43 cents per ton saved on ore mined during the fiscal period by steam shovels, as against what it would have cost to mine the same quantity of ore from underground, amounts to approximately $695,000. It therefore appears that had we charged the entire cost of all our stripping operations, from the date of their inception in 1906 up to the present time, against the steam shovel ore recovered in eighteen months only, it would still have been more economical to mine by the steam shovel method than by the underground method; or, considered in another way, we have stripped 15,000,000 tons of ore, and have mined only slightly more than 10 per cent. of that quantity with steam shovels, but the entire cost of stripping the total quantity of ore could be charged against the mining of one-tenth of it and still the result would show the steam shovel method of mining our ores to be the more economical.

"Our costs of steam shovel mining will decrease, rather than increase, in the future, and it is consequently quite evident that our best interests lie in decreasing as rapidly as possible the scope of underground mining and correspondingly increasing our steam shovel output. It will be necessary, for some years to come, to do some underground work, but we will probably be mining fully 90 per cent. of our ore with steam shovels by the end of 1909, and the underground method, as applying to anything but the development and mining of isolated, and comparatively small, bodies of ore, will be gradually, and as rapidly as possible, discontinued.

"Up to the present time, surface mining operations have been seriously hampered by our inability to secure from the company transporting our ores to the mills an adequate and regular supply of cars, such as to enable us to continuously and most economically operate our ore shovels. Our surface workings have been developed to such an extent that by the end of 1909 we should have no difficulty in producing regularly 10,000 tons per day, if an additional unit to the Garfield plant should be decided upon, thus bringing our milling capacity up to the tonnage stated. In the meantime, we could increase our output gradually to the extent of supplying tonnage for the sections of the new unit as rapidly as they could, in all probability, be completed.

"The ores that have been mined up to date by steam shoveling have not been as high grade as the normal average of the property, because of the necessity of including with them considerable quantities of the partially oxidized and lower grade capping. Before steam shovel operations were begun, some parts of the area where we are now working were mined out for a thickness of 20 to 40 ft., along or below the dividing plane between capping and ore. As this mining was done by caving, the capping settling into the stopes increased the irregularity of the line between ore and capping, and made it impossible to keep the underlying ore as clean as we would have otherwise been able to do. Moreover, aside from this occurrence, which has aggravated the condition, the dividing line between ore and capping is naturally very irregular, and it is impossible to entirely remove all the oxidized material without wasting some good ore. It is therefore necessary to continue taking some of this low-grade material into the ore, until such time as the first cut from off the top of the ore has been removed over a considerable area; in fact, this condition will always apply to newly stripped areas. This feature is the only one of disadvantage that we have encountered in steam shovel mining, but, in the long run, there will be advantages which will very much more than offset it — the principal one being that by this method of mining our operations will slowly, but gradually, become more economical, and, in the end, we will have recovered 100 per cent. of our ores; whereas, by any other method of mining, it would be impossible to avoid losing a considerable percentage of them.

"*Equipment.* — Since our last annual report we have added to the mine equipment two steam shovels, making eight in all; two locomotives, making seventeen in all; and have extended our railroad tracks for mining and stripping purposes to a total of 9.2 miles. During the year 1909 we shall add to our present equipment at least one more shovel and two more locomotives, and shall construct about 6.8 miles of additional standard gage railway for handling capping.

Operations at the Mills

"*Garfield Plant.* — In our last annual report, it was stated that four sections of the Garfield plant were in commission. Four additional sections were started — one each in the months of August, September, November, and December, 1907; and the remaining four, one each in the months of March, April, July, and November, 1908. During the fiscal period there was in operation the equivalent of 8½ sections for the entire period, or about 71 per cent. of the plant. However, the difficulties experienced in obtaining tonnage for the plant, principally through the lack of proper transportation facilities and service, resulted in our only being able to provide 77 per cent. of the rated capacity of that part of the plant prepared for continuous operation, as above stated, or about 55 per cent. of the capacity that the plant is now, and has been since November, 1908, prepared to handle. Had we been able to secure tonnage, the sections of the plant could have been started up more rapidly and the entire plant put in commission at an earlier date.

"*Copperton Plant.* — The Copperton plant also suffered from a deficiency of tonnage, but not to the extent that applied to the Garfield plant, partially for the reason that it is closer to the mines. Of the total tonnage treated at both mills during the period, 83 per cent. went to the Garfield mill and 17 per cent. to the Copperton mill.

"*Production.* — The total gross output of copper at both plants for the period was 56,895,998 lb. of copper contained in concentrates, resulting in a net production of 54,051,212 lb. after smelter deductions were made. The concentrates produced also contained 182,160 oz. of silver and 20,072 oz. of gold. The average grade of concentrates for the period was approximately 27 per cent.

"Of the total gross production of copper above mentioned, 43,873,918 lb. were produced in the twelve months of 1908, this being 77 per cent. of the total for the period. Dividing the eighteen months into periods of six months, the respective productions were as follows:

	Pounds	Per Cent.
July 1 to December 31, 1907	13,022,080	23.
January 1 to June 30, 1908	20,096,329	35.
July 1 to December 31, 1908	23,777,589	52.
Total	56,895,998	100

"Had we been able to secure throughout the period the full capacity of the 71 per cent. average of the Garfield plant that was in operation, we would have produced at that plant alone approximately 62,000,000 lb. — a total, for both plants, of about 71,000,000 lb. for the period; or an average of nearly 4,000,000 lb. per month. If our entire Garfield plant, which is now in operation, could be supplied with its capacity of 6000 tons per day, and its operation should result in the same percentage of recovery we have experienced in the period under discussion, and upon the same grade of ore, the output for both plants would be at the rate of 96,000,000 lb. for eighteen months, or an average of $5\frac{1}{3}$ million pounds per month, corresponding to a production of 64,000,000 lb. per annum. This is what we may expect to do in the immediate future, provided transportation for the required tonnage can be supplied; in fact, we can do somewhat better than this on the same grades of ore, if we can have transported all the tonnage needed, as the Copperton plant can also take more tonnage than it has been receiving in the past.

"It is to be remembered that the results of the period under discussion have been achieved on an ore containing 4 lb. less of copper per ton than the average normal contents of our ore. In addition to this, because of the low grade and oxidized material that has been taken into the ore through contamination of the steam shovel output by capping, the ores have contained an average of fully 5 lb. of their copper contents in oxidized minerals, of which only indifferent percentages could be recovered. Both the grade of ore and the percentage of copper recovered will improve gradually as cleaner ore is procurable, as a result of the extension of completely stripped areas.

"*Cost of Production.* — The average price applying to our sales of copper for the entire period was 13.2 cents. The average cost per pound was 8.85 cents, this being based upon the net pounds of copper resulting after smelter deductions and allowances were provided for, and including all expenses of transportation, refining, and disposition of the metal.

"The deficiency of tonnage, as applying particularly to the Garfield plant, has resulted in the cost per pound of copper being fully a cent higher than it would have been had we been able to secure full tonnage for even the 71 per cent. of the plant averaging in operation. As formerly stated, we were only able to mill 77 per cent. of the capacity of the portion of the plant in operation. The additional 23 per cent., which we were unable to mill, owing to the transportation difficulties before mentioned, could have been treated at little or no additional cost for labor, and, in fact, not so great a cost per ton, because a shortage of ore involves us in more expensive methods of handling it through our ore bins. We therefore would have saved the milling labor cost on this additional tonnage, which amounts to more than one cent per pound of copper produced. If both plants could have been operated at their fullest capacity, a still greater reduction would have been made in the per pound cost. Our other costs would not have increased in direct proportion, as, for instance, the mine, if it had been able to load ore continuously, could have done so at a considerably decreased cost per ton.

"*Capacity of the Garfield Plant.* — We have been able to operate the Garfield plant at full capacity only for short periods since it was completed, on account of our inability to transport the tonnage. For a few days at a time, however, we have demonstrated that it can handle continuously a greater tonnage than its rated capacity. This determination has also been checked by the capacity of the individual sections, which have proven themselves capable of treating more than their rated tonnage. No difficulties have been experienced in the operation of the plant, and no changes, other than in the way of unimportant details, have been found necessary. Considering the quality of ore we have been reducing, its operation has been, and is, entirely satisfactory.

"*Power Plant.* — The construction and operation of our own power plant, to provide power for the entire enterprise, has proven of great advantage and economy in many ways. We are assured of a constant and uniform supply of power for continuous operation at all points, and the cost of power at the Copperton plant and at the mines at Bingham has been very much reduced over that applying formerly, when power was generated at Copperton for the operation of that plant and purchased from others for the operation of the mine. As stated in our former annual report, the power plant at Garfield has a greater capacity than is necessary for the operation of our milling plants at their present capacity, and it will therefore be unnecessary to provide additional power in connection with another 3000-ton unit at the Garfield plant when such addition is made.

"*Water Supply.* — Up to the present time, the springs owned by the company, adjacent to the Garfield plant, have produced ample water for any tonnage we have handled, and it is believed that they will furnish sufficient for the full capacity of the plant, without making it necessary for us to resort to the use of our proportion of the water we are entitled to take from the Garfield Water Company. We therefore have demonstrated conclusively that our total water supply will be ample for very much greater tonnage than we are now prepared to mill.

"*Transportation.* — A number of references have been made in this report to the difficulty we have experienced in securing adequate transportation facilities, as provided for under our contract with the Rio Grande Western Railway Company. Our losses, and the disadvantages under which we have operated, as a result of the failure on its part to give us the desired and necessary service, have been greater than would be indicated by the direct deficiency in tonnage that we desired to mine and mill, but which the railway company was not prepared to transport, for the reason that the tonnages that have been delivered to the mills have been handled at a disadvantage and at an extra cost. We have used every effort to induce the railway people to give us better service, but, so far, without very much encouraging result, and we have, therefore, located and surveyed a line for a railroad of our own between the mines and mills. This location is shown on the appended map of the Bingham and Garfield territory. Negotiations are now pending, which, if consummated, will relieve the situation, and give us the transportation facilities we require. If these negotiations fail, I recommend that construction be commenced on our own railway at an early date.

"*General Remarks.* — In a former portion of this report, reference was made to a proposed method of disposing of capping. We have found that the 1,705,322 cu. yd. of capping so far removed from our orebodies average not quite 1 per cent. copper. Experiments conducted some years ago, and since verified, demonstrate that the larger part of this copper is contained in such forms as can be extracted by a simple leaching process.

"As soon as weather conditions will permit, an open-air plant, of moderate capacity, will be constructed at the Garfield mill, and the proposed metallurgy of this material demonstrated on a fairly liberal working scale. If this experiment proves that our former results along this line of investigation are reliable, it is proposed to build a very large leaching plant in which to treat, along the general lines suggested, the capping removed from the property. The chemicals necessary in the proposed method of treatment should be produced cheaply, as a by-product, at any of the smelters adjacent to Salt Lake City."

Northern California Copper Mines

During the last twelve years a considerable output of copper has been obtained in Shasta County from a number of pyrite deposits that are described as occurring in zones of intensely crushed granitic porphyries. The pyrite masses have been considerably enriched by the leaching of copper from the upper portions and the deposition of it in a lower part of the same deposit. It is to be inferred that the original pyrites, below the zone of enrichment, are pretty low grade, probably too low in many cases to be payable. The following description of the industry is copied from the report on the "Production of Copper in 1907," by L. C. Graton of the U. S. Geological Survey. The output of copper for that year is stated at 28,000,000 lb.

"The ores smelted in 1907 yielded approximately 3 per cent. of copper. The yield per ton in gold was about $1.30 and in silver 2.1 oz., or $1.40, which combined are equivalent to 4.5 cents per pound of copper. In the aggregate several million tons of ore are blocked out in the mines of the Balaklala, the Bully Hill, the Mammoth, the Mountain, and the Trinity companies. The limits of these orebodies are now pretty well defined, and it is doubtful if new bodies can be discovered as rapidly as the present ones are exhausted. The first large body to be worked in the district, that at Iron Mountain, is now nearly worked out, and in spite of the fire which has been burning for several years practically all the ore will be extracted.

"Most of the orebodies thus far discovered are developed by workings not more than 500 ft. deep, but the Great Western workings, in the Afterthought district, exceed this depth, and in the Bully Hill district the lowest level is about 900 ft. below the outcrop. Owing to the rugged topography, tunnels afford easy access to the orebodies, but in a few places winzes from these tunnels are required. Open cutting is employed in part at the Balaklala and the Afterthought mines. Water is not troublesome. Up to the present time square setting has been chiefly employed. At the Mammoth mine the horizontal slicing system, with subsequent caving, is employed, and the quantity of timber required, which was large at the start, is gradually being lessened. Methods requiring less timber may be employed in the mines that are now in the development stage. Native timber is used. Electric power is employed almost exclusively and is derived from the lines of the Northern California Power Company. Much of the coke comes from Australia. The Southern Pacific Railroad crosses the district. The Iron Mountain and Hornet mines are connected with it by a private railway, and the Mammoth by an aerial tramway, which has been replaced by a combination steam and electric road. An aerial tram connects the Balaklala and Trinity mines with the Balaklala smelter at Coram. The Sacramento Valley and Northeastern Railway was completed to the Bully Hill district early in 1908. Work has been begun on a line to the Afterthought district. European labor is employed chiefly.

" Pyrite smelting is now applied almost exclusively to the ores and is very successful. Even the zincky ores of the Afterthought region are handled by the aid of a hot blast. Some experiments are under way to save the zinc now lost at this plant, and some steps in this direction may be undertaken at Bully Hill also. The Mammoth Company was the largest producer of the year, but turned out only matte, which was converted at the United States smelter in the Salt Lake Valley. The construction of converters, as well as of two additional blast furnaces, however, was practically completed in 1907. During that year the fine ore was shipped mostly to sulphuric-acid works near San Francisco, where the resulting cinders were smelted for their copper. The Mountain Copper Company, owing to the raising of the injunction against its Keswick plant, treated part of its output at that smelter and part at its works at Martinez, on San Francisco Bay, where it has, in addition to a small electrolytic refinery, a sulphuric acid and fertilizer plant that utilizes phosphate from Utah and Idaho. The Afterthought smelter shipped its matte to Utah for conversion. Some Shasta County copper ore was treated at the Garfield smelter. The Bully Hill smelter, which has been idle since early in 1906, was enlarged and equipped for pyritic smelting. A reverberatory was also added for the treatment of fines. Work was actively carried on by the Balaklala Company in the construction of its new 1500-ton smelter until October, when construction was stopped, not to be resumed until 1908. This plant, which will treat the Balaklala and Trinity ores, will make matte, which may be converted at the Mammoth works pending a decision regarding the resumption of construction of the San Bruno smelter."

The United States Smelting, Refining & Mining Company gives no information worth speaking of about its operating results. This is unfortunate, for their Mammoth mine is now the largest producer in Northern California.

The only report I have seen upon the mining operations of this district is that of the First National Copper Company. This concern took over in 1908 the stock of the Balaklala Consolidated Copper Company, which had evidently been organized on an inflated basis. The new company with a paid-up capital of $1,500,000, bought all the stock of the old one, which was capitalized at $10,000,000. The comparison of the balance sheets of the two companies is rather amusing. The First National Company has no liabilities to speak of except its own capital stock, and no assets except the capital stock of the Balaklala, each amounting to $1,500,000. Turning to the Balaklala balance sheet we discover "Mines and Mining Property" put down at $8,688,777.05. This item was evidently a fancy price put upon the undeveloped and unequipped mining claims — a good example of mining finance in boom times. It is also a good example of the wisdom of keeping the item of real estate, the opportunity to mine, out of one's computations of mining cost.

Other assets on the Balaklala balance sheet undoubtedly represent real investments, as follows:

Cost of outside properties		$37,015.77
MINE CONSTRUCTION:		
Air drill equipment	$24,759.23	
Locomotives and cars	18,956.23	
Aerial tramway and connections	202,499.21	
Buildings	49,985.49	
Teams and equipment	1,699.43	292,899.59
SMELTER CONSTRUCTION:		
Smelter	$873,682.30	
Converter	102,512.60	
Steam railroad	83,279.41	
Teams and equipment	3,931.28	
		1,063,405.59
Property in dwellings, etc.		88,346.55
Total plant		$1,481,667.50
There is in addition working capital in inventories, supplies and cash, approximately		$600,000.00

We might fairly add to this about $400,000 for the cost of developing the mine and then the total cost of starting the enterprise will amount to approximately $2,500,000.

The president of the company has the following to say in the first annual report:

"During the year we operated the mine for sixty days and the smelter for fifty-two days. In the commencement of operations we expected to find a number of things that would require alterations and would more or less delay us in getting down to a working basis. I am glad to say that we are gradually overcoming all difficulties and are now producing blister copper.

"Attention is called to the fact that we only operated part of two months and one full month, and our expenses are for three full months.

"Commencing operations we had considerable waste in opening our drifts, which has reduced the value of our ores, but all indications are that the ore developed will average about 2.7 per cent. copper, .025 oz. gold, .75 oz. silver.

"Our costs, based on present operations, will be materially reduced when we are mining and smelting to our capacity of 1250 tons of ore per day."

At average prices the ore above mentioned would contain the equivalent of 60 lb. copper per ton. It is not stated whether this is the actual yield, or only the assay value from which losses will have to be deducted.

While it is manifestly unfair to calculate costs on the interrupted operation of only three months, I give the following costs for what they are worth:

BALAKLALA CONSOLIDATED COPPER COMPANY — SUMMARY OF MINE OPERATIONS

OCTOBER, NOVEMBER, AND DECEMBER, 1908

		Cost Per Ton
Development	$1,452.47	$ .077
Mining	29,866.14	1.593
Compressor	787.93	.042
Air drills	1,199.62	.064
Mine tramway	1,807.31	.096
Timbering	1,620.97	.089
Power	1,560.36	.083
Shop's expense	245.64	.013
General expenses, including taxes and insurance	4,250.02	.227
Carried forward	$42,790.46	$2.284

Brought forward	$42,790.46	$2.284
Surface and road repairs	118.03	.006
Repairs to buildings	197.31	.010
Stable expense	438.10	.023
Steel sharpening	666.36	.035
Special construction	1,244.00	.066
Total cost	$45,454.26	$2.424

Ore mined, 18,751 tons.

SUMMARY OF SMELTER OPERATIONS

OCTOBER, 11 DAYS NOVEMBER, 11 DAYS DECEMBER, 31 DAYS

	Amount	Cost Per Ton of Ore
Converters	$1,750.77	.070
Blast furnaces	51,095.00	2.035
Matte and slag casting	4,454.52	1.77
Repairs to plant buildings	1,444.51	.057
Repairs to ore bins	2,110.78	.084
Railroad — operation and maintenance	2,697.14	.108
Unloading custom ore	1,190.72	.047
Sampling mill for custom ore	887.75	.035
Sampling mill for sulphides	2,253.35	.089
Lighting, electric	1,148.75	.045
Water supply and pumping plant	424.78	.017
Assay office	800.44	.032
General expenses, including insurance and taxes	3,199.48	.128
Total expense	$73,457.99	$2.924
Ore smelted, 25,121 tons	66,961.50	2.665
Furnace products on hand — Total cost (see Balance Sheet)	$140,419.49	$5.589
Operating tramway		0.304
Total cost per ton		5.893

Assuming that the 60 lb. mentioned above represents recovered metals, these costs indicate operating costs of about 10 cents per pound. To this will have to be added an annual charge of 6 per cent. on $1,500,000 for depreciation of plant expressed in construction, equal to $90,000 a year. General expense, including taxes, insurance, and administration, will be $35,000 more. On an output of 250,000 tons these items will be 50 cents per ton and the total operating cost of copper will approach 11 cents.

The amortization of $2,500,000 invested in the property with

4 per cent. interest at 15 cents copper and 11 cents cost, equaling 4 cents a pound profit, with an output of 15,000,000 lb. a year, will require five years operation, 1,250,000 tons of ore, and 75,000,000 lb. of copper. Whether the company has this amount in sight or not is not stated.

CHAPTER XIII

THE COPPER MINING BUSINESS IN GENERAL

Division into types — Disseminated Ores — Cost of producing copper from disseminated ores — Outlook in Lake Superior — Outlook of new mines in the West — Quartz pyrite ores in fissure veins — Cost of copper at Butte — Anaconda — Outlook for the future — When all ores must be smelted — Variable character of these deposits due to reconcentration of values — Outlook for the production of copper from cupriferous pyrite masses — The price of copper.

General Considerations

We may divide copper mines into three classes, each presenting a different economical problem: (I) Disseminated ores in which concentration is the all-important thing, smelting being applied only to a fraction of the material mined. (II) Quartz pyrite ores in fissure veins in which the ratio of concentration is low, the proportion smelted considerable, making the costs usually high. (III) Ores that cannot be concentrated and must be smelted in bulk.

I. Disseminated Ores

The first class contains the Lake Superior copper ores in which native copper is disseminated, either in porphyry or in conglomerates derived from porphyries, in the proportion of from 1 to 4 per cent. These ores are concentrated in the mills (with 20 per cent. loss in milling) to from 1 to 4 per cent. of their original volume. This is the proportion smelted.

We have in this group also the disseminated porphyry ore of Bingham, Utah, containing 2 per cent. copper in the form of chalcocite. This ore concentrates with 70 per cent. recovery into 4½ per cent. of its original volume. The disseminated ore of Ely, Nevada, which concentrates into 12½ per cent.; that of the Clifton-Morenci district in Arizona, which concentrates into 15 per cent.; that of Nacozari, Mexico, which concentrates into 17 per cent.; the ore of the new Miami Copper Company at Globe, Arizona; and the Braden copper mines of Chili, may all be included in this class.

These ores now produce a third and will soon yield one-half of the copper of North America, and they may be described as the most important, most profitable, and most promising source of copper.

On the basis of the ton mined these ores are far more cheaply worked than any other copper ores. The internal conditions for cheap mining are excellent. The orebodies are large, uniform and firm. There are some, such as Utah Copper, Nevada Consolidated, and others, which present the great advantage of being accessible to open-pit methods of mining.

The cost of concentrating (including transportation to mills) is determined largely by the external factors of the cost of water, fuel, transportation, and labor. The variation is between the figures of 40 cents in Lake Superior to $1 in less favorable situations. The internal factor of the mineralogical complexion of these ores does not, to my knowledge, introduce in this class any great difficulties.

The cost of smelting, refining, and marketing this class of ores presents the same external variables as that of concentrating. An internal factor of significance is the effect of concentration on the fluxing qualities of the ore. In terms of the concentrates smelted we have in general the following factors: (1) The cost and quantity of fuel and flux required for reduction; (2) the richness of the concentrate which determines, *a*, the cost of converting or bessemerizing; *b*, the cost of transportation to market; and *c*, the cost of electrolytic refining.

Manifestly the cost per ton smelted is more a question of the richness of the ore smelted than of anything else; thus in Lake Superior, where the external factors are extremely favorable, the cost of smelting, refining, and marketing per ton of 70 per cent. concentrates is about $15, while the concentrates of Ely, Nevada, carrying 13½ per cent. copper smelted and sold under the most costly conditions, are estimated to cost only $10.50 per ton.

Manifestly also the supreme factor of cost is the divisor which represents the proportion smelted. In the case of Lake Superior an ore producing only 2 per cent. concentrates divides its cost of $15 per ton by 50, so that, as spread on the ore milled, the cost is only 30 cents a ton. In the case of Ely ores the $10.50 cost can only be divided by 8 and the resultant cost on ore mined is $1.31.

The salient facts regarding the cost of mining disseminated ores may be expressed in the accompanying table:

COST OF MINING DISSEMINATED ORES

		Low	High
Mining	Open pit	$0.50	
	Underground	1.25	$2.50
Concentrating		0.40	1.00
Smelting, refining, and marketing		0.15	1.30
	Open Pit	$1.05	$4.80
	Underground	1.80	

At the average price of 15 cents for copper, these figures mean that under the most favorable conditions a Lake Superior ore, if it could be mined from an open pit, might meet expenses with a yield of only 7 lb. per ton. If mined underground about 12 lb. is the minimum; while under the most unfavorable conditions a yield of 32 lb. may be required.

COST OF PRODUCING COPPER FROM DISSEMINATED ORES

The average cost of producing the entire output of copper is hard to determine, because a respectable fraction is sold by obscure mines which may not always be profitable, and whose records are not to be had. I have taken the ground that the price must be controlled by the leading and profitable producers which sell the bulk of the output of each district. In order to form some idea of the cost to such leaders, I have compiled the following information, the justness of which will be evident to any reader.

The Calumet & Hecla Mining Company had produced up to June, 1908, approximately 2,040,000,000 lb. of copper, on which its earnings were approximately $115,000,000 net. This mine had built up its enormous plant almost entirely out of earnings, so that for its forty years of activity its real and complete cost of production must equal the selling value of its output, less the profits. The actual price received for Lake Copper in the last forty years has been almost exactly 15.3 cents per pound. Now the profit of $115,000,000 from 2,040,000,000 lb. is equal to

5.63 cents per pound. Subtract this from 15.30 cents, and we get 9.67 cents as the cost of the entire product.

Similarly, the Quincy mine has produced 413,000,000 lb. at a total cost of $45,500,000, equal to 11 cents a pound. The Copper Range mines, Baltic, Trimountain, and Champion, had produced, up to 1907, 209,000,000 lb. for $27,316,000, equal to 13.07 cents a pound. The Wolverine had produced, up to 1907, 87,000,000 lb. for $7,783,000, equal to 8.9 cents a pound.

This entire group has produced 2,740,000,000 lb. for $275,-364,000, equal to a trifle over 10 cents a pound.

Looking to the future it is plain that the cost of copper from the Lake Superior district and from these same mines will exceed this figure. In some former article published in the *Engineering and Mining Journal* on this subject, I stated that the copper from disseminated, concentrating deposits could be produced for 9 cents. I was misled in making this statement by taking too narrow a view of the situation. The Calumet & Hecla in its ten most prosperous years, from 1897 to 1906, produced 855,-000,000 lb. at about 8¼ cents a pound. This figure, in the light of fuller consideration, appears to be quite 1.4 cents below the average for the life of the mine to date; and still more below the prospective costs.

The situation is as follows: During the ten fat years mentioned above, the mine was in bonanza. The ore yielded quite 50 lb. per ton. Nearly all the production was from the great conglomerate ore shoot, which has been quite exceptional among Lake Superior deposits in richness. But, according to testimony given by Mr. Alexander Agassiz, the president, and by Mr. James McNaughton, the manager of the Calumet & Hecla, in the Osceola lawsuit, it appears that by 1908 the average yield of the conglomerate had fallen to 40 lb. per ton, and the yield is steadily diminishing. The experience of the Tamarack was that the conglomerate just below the Calumet & Hecla line yielded only 20 lb. and was unprofitable. It appears probable, therefore, that the remaining ground on the conglomerate is likely to yield not more than a mean between 40 lb. and 20 lb., or 30 lb. per ton. The testimony is that between 20 and 24 million tons of conglomerate will still be produced. This means only 600 to 700 million pounds. It does not seem probable that this will cost less than 11 cents on the average. This is about what it costs on the Osceola lode where worked by the same company.

When we remember that it has cost the Quincy 11 cents, that it is costing the Osceola Consolidated 12 cents, the Mohawk over 11 cents, it does not seem likely that there is any prospect of any great output below that figure. The Wolverine is indeed producing for less than 8 cents, but its output is so small as to have little effect. The Copper Range mines can hardly expect to fall under 11 cents for complete costs. Their product thus

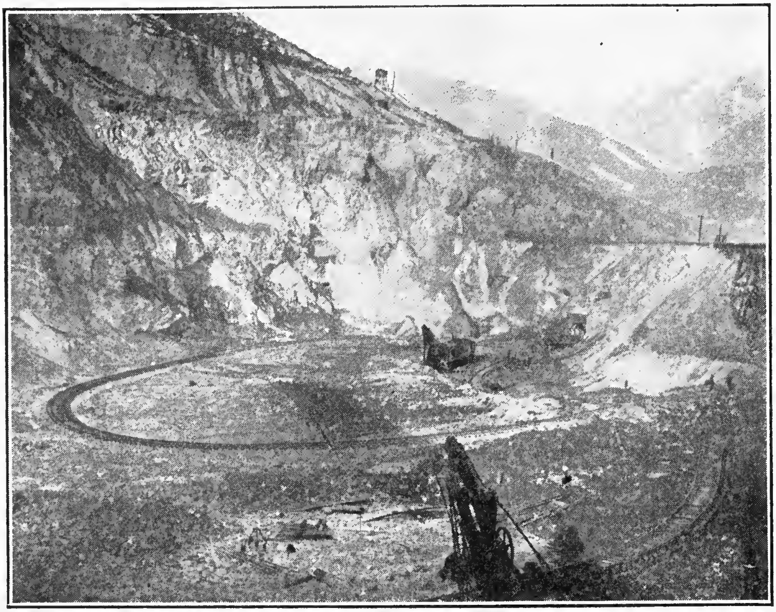


Fig. 12. — Pit at Bingham, Utah.

far has cost over 13 cents, but this includes the whole cost of equipment. A deduction of 2 cents a pound for the 209,000,000 lb. produced by the Copper Range mines makes over $4,000,000, which seems to be all that should be charged to the future for plant. It seems, therefore, that if the Copper Range can cover all expenses for 11 cents, it will do very well.

When we consider that these figures are for the best mines in the district, and that the factor of increasing depth increases both the cost and the danger of impoverishment, we may conclude, I think with safety, that there will be no real profits from the Lake mines under 11 cents, and very little under 12 cents.

Cost of Mines of Disseminated Copper Ores in the West

This industry really belongs to the future. While some disseminated ores have been mined for years at the Clifton-Morenci district in Arizona, and at Nacozari in Mexico, it is only with the launching of Utah Copper, Boston Copper, Nevada Consolidated, Miami Copper, and Ray Consolidated, that mines of this class have become important. The full effect of these producers will not be developed for some years, but they all report great quantities of ore in sight and enough operating has been done to throw some light on the probable results. The ore reasonably to be counted on is reported somewhat as follows:

Bingham, Utah	100,000,000 tons at 22	= 2,200,000,000 lb.
Ely, Nevada	33,000,000 tons at 30	= 1,000,000,000 lb.
Globe, Arizona	100,000,000 tons at 30	= 3,000,000,000 lb.
Ray, Arizona	80,000,000 tons at 25	= 2,000,000,000 lb.
Others	40,000,000 tons at 30	= 1,200,000,000 lb.
Total	353,000,000 tons at 26	= 9,400,000,000 lb.

It appears further that there is still a probability of sufficient development of new ore to make good the estimate of copper production in spite of any losses in mining. In the case of Utah Copper, Boston Consolidated, and Nevada Consolidated, a large amount will be mined with steam shovels in open pits, where there will be no mining losses. The remaining ore will be subject to underground losses that probably will not average more than 15 per cent.

Referring to the analysis in the preceding chapter of the cost of producing copper by the Utah Copper Company, it will be seen that an estimate is given of cost on the basis of an average annual production of 75,000,000 lb., or its equivalent, as follows:

Operating costs	8.5 cents
Depreciation = $300,000 a year for new construction	.4 cents
Total dividend cost	8.9 cents
Add amortization $560,000 a year	.8 cents
Total selling cost	9.7 cents

There are not yet available for Nevada Consolidated any such figures on costs as are now afforded by Utah Copper, but it is currently reported that it is producing copper at a cost of 7.35 cents. Probably the value of gold and silver is deducted from the cost. If we figure in this gold and silver as the equivalent of copper we increase the cost by about 10 per cent., which would bring the actual cost up to about 8.1 cents for operating. Assuming that the depreciation and amortization charges will be the same as in the case of Utah, we have the following:

Copper, silver, and gold in ore realizable equals the equivalent of 33 lb. copper per ton.

Operating cost	8.1 cents
Depreciation	.4 cents
Total dividend cost	8.5 cents
Amortization	.8 cents
Total selling cost	9.3 cents

The remaining properties in the group have no experience that warrants making anything but an engineering estimate, but we have the estimates of Mr. J. Parke Channing for Miami, and Mr. D. C. Jackling for the Ray Consolidated, that the copper at those properties can be produced at 9 cents a pound. If these estimates are upon the same basis of calculation as those given in the annual statements I shall have to translate them into my own language as follows:

Operating cost	9.0 cents
Depreciation cost	.4 cents
Total dividend cost	9.4 cents
Add amortization	.8 cents
Total selling cost	10.2 cents

The whole matter resolves itself into the following calculation. Dividends will be paid from these properties on the basis of cost for

Utah copper	1,750,000,000 lb. at 8.9 cents
Nevada consolidated	780,000,000 lb. at 8.5 cents
Miami and Ray [1]	1,300,000,000 lb. at 9.4 cents
Average for	3,830,000,000 lb. at 9.0 cents

[1] I doubt if the Ray district can produce copper so cheaply. I prefer an estimate of dividend cost of at least 11 cents for that district. The fact of the matter is that the new Porphyry mines cannot produce copper at notably low costs except where they may be worked with steam shovels. How far this method can be extended among this class of deposits is a doubtful but highly interesting question.

The minimum selling price justified is obtained by adding an estimated amortization of capital of $\frac{8}{10}$ of a cent per pound, making the total real cost 9.8 cents per pound, say for round numbers, 10 cents for practically 2,000,000 tons of refined copper.

II. Quartz-Pyrites with Low Concentration

Of quartz-pyrite ores I have given the conspicuous examples of Butte and of the Wallaroo and Moonta. There is substantial agreement on the following points:

(1) A high mining cost owing to, *a*, high development cost due to searching for ore shoots through much barren vein material; *b*, considerable selection of ore in the process of mining; *c*, soft ground requiring elaborate timbering and filling.

(2) A high concentrating cost due in part to the use of hand sorting, but particularly to the careful milling methods required to prevent undue losses.

(3) Smelting costs are high because, first, a low degree of concentration gives a large proportion to smelt (from 25 to 50 per cent.); second, because the siliceous and aluminous character of the gangue renders smelting rather difficult; third, because the ore as mined is necessarily of fairly high grade.

The external conditions in Butte are somewhat less favorable than at the Wallaroo and Moonta, but in neither case are the high costs due to them. I believe that high costs are inherent to quartz-pyrite ores in fissure veins.

	Australia	Montana
Mining	$4.68	$3.78
Milling	1.00	
Smelting, refining, and marketing	2 37	4.62
General expenses	0.58	
	$8.63	$8.40

Applying to these costs the average price of 15 cents per pound copper, it is evident that such ores must yield about 60 lb. copper or its equivalent in order to pay expenses. With the impoverishment of the ores with increasing depth, costs have increased, until to-day the average Butte copper must cost more than 11 cents and perhaps 12 cents. At the Wallaroo and Moonta copper has averaged in cost almost exactly

10 cents, and lately as high as 15 cents. The last figure, however, was an incident of the boom of 1906, and must be considered abnormal.

Other mines of this class are the Old Dominion and others on the great fault fissure of Globe, Arizona, and in part, at least, those of Cananea, Mexico. Whatever geological grouping may be appropriate, the economic results are similar to the illustrations given, and bear out emphatically the generalization that cupriferous pyrites with a highly siliceous and aluminous gangue, occurring in shoots in fissure veins, are essentially high-cost ores at every stage of the process.

Cost of Producing Copper at Butte

Let us examine critically the record of the Anaconda Copper Mining Company to get some light on the past and future cost of metal at Butte. At the beginning it is well to explain that the record is only a broken one, there being no reports showing the exact condition of the company for a period of seven years, from 1898 to 1905. During this dark age there were indeed some scraps of information given out, but the output, even, has not been stated with authority. We have, however, enough information to enable one to make some fairly accurate deductions as to the past and future cost of production.

The present company was reorganized and began business July 1, 1895. It had at that time little or no surplus in its treasury. Up to April, 1908, it had paid $39,500,000 in dividends, and had accumulated a surplus of $6,261,000. It seems fair to conclude that in 12½ years the earnings were $45,500,000.

This had been obtained from an output which, as just mentioned, is not stated with authority but is approximately 1,228,000,000 lb. copper, 45,365,000 oz. silver, and 196,000 oz. gold.

The average price of metals for the period was 15 cents for copper, 57 cents for silver, and $20 for gold. It is not strictly accurate to apply these prices to the entire output, but as the output has been fairly uniform for the period there is no likelihood of inaccuracy sufficient to throw our calculation far astray.

Let us now convert the silver and gold into their equivalent in copper at 15 cents a pound. We find that

45,365,000 ounces silver at 57 cents equals	172,387,000 lb.
196,000 ounces gold at $20 equals	25,968,000 lb.
Add the copper metal	1,228,000,000 lb.
We get the total copper equivalent	1,425,455,000 lb.

By dividing the profit of $45,500,000 by $1,425,000,000 we get the average profit per pound, which is 3.19 cents. Subtract this from the average price of 15 cents, and we have the cost, which equals 11.81 cents per pound. Of course if the value of gold and silver were deducted from the cost and the remaining sum only charged against the copper, the latter would be substantially cheaper, but that does not seem logical.

Let us now leave the sphere of approximations and examine those parts of the record where exact figures are given. In the two years ending June 30, 1897, we find that the total output was as follows:

		Value
Tons dry ore	2,681,623	—
Pounds refined copper	239,400,895	$25,041,240
Ounces silver	11,249,792	7,387,965
Ounces gold	38,680	798,000
		$33,227,205

The copper equivalent is 317,660,000 lb., this being equal to 118.5 lb. per dry ton.

The total expenses for the period were $24,855,214.29 and the cost per pound for operating was therefore 7.825 cents. To this may be added a total increase of capital accounts of $967,-641.70. If we write this all off to operating the cost is increased by 0.304 cents and the total becomes 8.129 cents per pound.

The total cost per ton was $9.23.

After making the reports of which the above is a summary, the company issued no reports till 1905. We have satisfactory reports for the years 1905, 1906, and 1907. This period represents the progress of the company for an average of nine years. For the three final years the record was:

Tons produced	4,075,725
Copper metal, lb.	253,363,226
Silver, oz.	8,098,139
Gold, oz.	43,420
Equivalent in copper	286,136,000
Copper equivalent per ton, lb.	70.02

Total receipts	$50,089,139
Dividends paid	$16,650,000
Net diminution of surplus	769,000
Actual profits	15,881,000
Net value per lb. copper	17.514 cents
Net profit per lb. copper	5.553 cents
Net cost per lb. copper	11.961 cents
Total cost per ton	$8.394

The meaning of these figures is so obvious as scarcely to require comment. We find the mines producing practically the same tonnage as nine years before. The cost per ton has diminished $1.24. The yield of ore has diminished from 118.5 lb. to 70.2 lb. per ton, in spite of the fact that the later production has been helped out a little by the re-working of slags from the earlier period. The diminution in the grade of the ore has far outweighed the diminution of cost per ton, so that the cost of copper has risen from 8.129 cents to 11.961 cents, a net increase of 3.832 cents per pound. It is fair to remark that the costs in the latter period were adversely affected by the shortening of hours of labor, increased wages, and the general inflation of prices of a boom period; but it must be noted that these adverse conditions did not become acute until the middle of 1906, and in any event cannot go far in accounting for the great cost increase.

I am not fully qualified to express an opinion as to how far the experience of the Anaconda represents that of other Butte mines, but all indications are that it represents them pretty accurately. We find that at the earlier period the Anaconda was producing better ores than any other mines have recently produced. Some rich ore has been found in the lower levels, below 2000 ft. in depth, but not enough to arrest the decline in metal contents for the total output. There is, of course, no reason to doubt that by careful selection of ores the decline may be temporarily overcome, but this can only be by a proportionately rapid depletion of reserves.

It seems perfectly certain that the selling cost of Butte copper is fully 12 cents a pound and is constantly rising. The rise is not likely to be stopped by anything short of a diminution of output, which would be caused by the extensive selection of ores in order to bring them up to a higher grade. A good deal can undoubtedly be done to hold costs down. Whenever it is imperative wages can be cut. A diminished output at profitable cost is better than a large output without profit. The Anaconda mines are undoubtedly developed and worked somewhat in advance of the average of the district, because they are the oldest. How far in advance they are cannot be stated, but the logic of events to date is that in ten years more, if tonnage is maintained, this property will be no longer profitable.

III. When All Ore must be Smelted

I have given as examples of the third class of copper mines; *i.e.*, that in which all the ore must be smelted, Bisbee, Arizona, Tennessee Copper, Utah Consolidated, Granby Consolidated, and Mount Lyell. To this list might be aded the Rio Tinto pyrite mines of Spain and Portugal, the mines of Shasta County, California, United Verde in Arizona, Cerro de Pasco in Peru, and others of less importance.

Economically we may make the following distinctions in this class:

(1) Cupriferous pyrites in an advanced state of alteration and reconcentration, so that only a small part of the original mass can be mined. In this case mining costs as well as smelting costs are inevitably high. Bisbee, Arizona, is a good example.

(2) Cupriferous pyrites in their original state or moderately enriched. In this case there is usually presented a large mass of homogeneous ore easily mined and easily treated. Tennessee Copper, Utah Consolidated, and Mount Lyell are examples. At these properties the cost per ton is from $4.20 to $6.

(3) Disseminated, self-fluxing ores not very pyritic. Granby Consolidated is an example.

Speaking generally, it must be admitted that mines of class III produce a goodly proportion of the world's copper. The list of big producers includes the Rio Tinto, the Copper Queen, Calumet & Arizona, United Verde, and many other mines not so big, but very profitable. Rio Tinto seems to produce the cheapest copper in the world, but I believe this is due to the fact that the sulphur is also utilized to an important extent. Leaving out this case, in which copper only costs 5 cents per pound, it does not seem probable that much copper from these ores is produced at less than 10 cents per pound.

Taking a number of mines of this class of which we have records for a considerable period, we find the following:

Pounds of Copper Equivalent		Approximate Costs	
		Dividend Cost	Selling Cost
308,000,000	Copper Queen, 5 years	9.0	10.0 cents
166,000,000	Calumet & Arizona, 5 years	8.9	9.4 cents
42,000,000	Superior & Pittsburgh, 3 years	17.3	20.0 cents
115,000,000	Utah Consolidated, 6 years	7.35	8.06 cents
70,000,000	Granby Consolidated, 3 years	11.	17.
100,000,000	Mount Lyell, 4 years	8.35	9.
	First National, 3 months	11.	15.
40,000,000	Tennessee Copper, 6 years	12.	14.

Calculating out a rough average from these figures it appears that this group of mines has averaged a dividend cost of 9.4 cents and a selling cost of 10.8 cents for the period mentioned.

It is very well worth remarking that where the original pyrite masses are highly altered and the payable ores concentrated into small portions of the original orebody, rich ores have often been developed out of material which was originally too low grade to pay. This is the case of Bisbee, Arizona, and in Shasta County, California, and probably at Cerro de Pasco. Such bonanza orebodies are sure to be variable in their output and may come to a sudden end. They are exasperating to the mining engineer who tries to calculate their possibilities, and dangerous to the investor. It is seldom possible to put much ore in sight, or to count with assurance on a long life for the property. Nevertheless they are often exceedingly profitable.

Where certain portions of the orebodies are enriched, but the original masses are still payable, the mines may exhibit painful variations in cost and profits, but still remain prospectively valuable for a long time ahead. Such cases are the Utah Consolidated, which has had a bad year, the Mount Lyell, and probably the United Verde.

Where the pyrite masses are in their original condition they are apt to be uniform and reliable producers. Undoubtedly the Rio Tinto mine in Spain has a longer assured life and more stable operating conditions than any other copper mine in the world. The Tennessee Copper property is apparently the only mine of this class in America, but probably others will be developed.

The Price of Copper

I feel very confident that the analysis of costs demonstrates as valid the following conclusions:

1. No copper can be produced in North America under present economic conditions at a profit for less than 10 cents a pound.
2. At 11 cents a pound only half the present output can be produced.
3. At 12 cents many of the largest producers would only be getting a new dollar for an old one.
4. At 15 cents the business as a whole is prosperous and profitable only to an entirely legitimate degree.
5. As long as the demand increases as it has increased steadily for the past quarter century, it is safe to count for the next ten years on an average price of 15½ cents, which has been the approximate average for the last ten years.

CHAPTER XIV

LEAD

Lead mining in general — Division into three economic types — Disseminated ores — Fissure veins — Ores resulting from concentration of mixed sulphides — Production of lead by states — Southeast Missouri — Occurrence of ores — Exploration — Mining — Milling — Smelting — Calculations of aggregate capital required and results — Cost of lead from this district.

Lead Mining

While a geological description of lead deposits would be rather tedious and difficult to make, a classification of lead ores from an economic standpoint is easy. As in the case of copper they fall naturally into three groups.

1. Disseminated sulphide ores that can be concentrated in a high ratio, *i.e.*, where far the greater part of the material mined can be discarded mechanically as waste, leaving only 3 to 10 per cent. to be smelted.

2. Fissure vein deposits, almost always carrying an important amount of silver, and often gold and copper. Such ores concentrate in a moderate ratio. From 10 to 35 per cent. must be smelted.

3. High-grade bunches of carbonates or sulphides already concentrated by nature so that the ore must be smelted as mined, the only rejection of waste being by hand sorting.

Without going much into detail it will be interesting to pursue the characteristics of these ores a little further.

1. In the United States practically the only disseminated ores are those of the Mississippi Valley region, principally in Missouri. They have been deposited by waters circulated from the surface downward, and depositing lead ores in the beds of limestone most favorable, through their chemical or mechanical structure, for the reception of such ingredients. These deposits are invariably sharply limited in their extension downward.

They are confined to certain beds that the geologist can soon recognize. The horizontal extent may be very great, sufficient to give these deposits great importance and a long prospective life. The southeast Missouri district is by a good margin the most productive in the world. Here the mining conditions are closely parallel to the copper districts of Lake Superior and to the newly developed disseminated copper ores of the West. This holds good as to costs. As in the case of copper ores of this class, the total cost of production per ton of ore is between $2 and $3. The lead ores of this class are about three times as rich as the copper ores, hence the cost of lead is only one-third the cost of the copper; a fact that, as a corollary, holds good with regard to the selling price of the metal.

2. The fissure vein deposits are of much greater geological complexity and interest. The Cœur d'Alene mines belong to this class. They are for the most part original deposits caused by hot waters ascending along fissures from great depths and from an unknown source. There is nothing simple about the process either geologically or chemically. The fissures were not simply open cracks in the rock, they were more apt to be crushed zones where the circulation of water was often brought to a stop by the infiltration of minerals and again started by renewed fissuring. There were thus several distinct periods of mineralization. Sometimes the successive mineralizations were of the same character, sometimes of quite diverse characters.

In the case of the principal deposits of the Cœur d'Alenes the lead ores were deposited at the expense of, and replacing, certain iron carbonates that had been deposited earlier. The iron carbonates had often replaced large quantities of the original quartzite rock in the fissure zone. There had been a still earlier mineralization of quartz and iron pyrites along still earlier fissures. After the lead had been deposited there was a recurrence of deposition of the iron carbonates which attacked some of the lead sulphides.

All these complicated processes were of deep-seated origin. After the real mineralization had all ceased the orebodies were exposed to the effects of the circulation of surface waters. As the surface was slowly eroded away the air-carrying waters from the surface reached gradually deeper and deeper into the original deposits, attacking and rearranging the minerals, enriching some parts of the orebodies and impoverishing other parts.

In the Cœur d'Alene mines, the effect of the last process upon the value of the ores was not very great. The oxidation did not affect the veins more than a few hundred feet down from the outcrops. The far greater portion of these deposits is original, and the mineralization promises to extend far downward. In other words, the surface action has nothing to do with the depth limit of profitable mining. That limit is quite unknown. Wherever the end of an orebody has been found the geological reason for it has either been that the fissure entered a different and less favorable rock formation, or else the reason for termination is obscure. Certain formations of quartzite are now recognized as being far more favorable for the deposition of lead ores than others. With this sole limitation the Cœur d'Alene veins promise to be productive to very great depths.

Other great lead-bearing fissures have a somewhat different character. The great Broken Hill lode in Australia, which has produced more than $325,000,000 in gross value of lead and silver, from which over $60,000,000 has been paid in dividends, is mineralogically as much of a zinc deposit as a lead deposit, though the proportion of silver is nearly the same as in the Cœur d'Alenes. At Broken Hill the effect of surface waters in rearranging the minerals was of capital importance. Although the original ores have been proved to be payable, the metallurgical difficulties encountered upon passing from the oxidized zone into the unaltered sulphides were so serious as to bring the development of the mines for a time almost to a standstill. A brief further description may be interesting.

The Broken Hill lode is one of the greatest mineral deposits of any kind in the world. It is certainly the greatest of its class. It is some 2½ miles in length and contains ore shoots as much as 300 ft. thick of massive ore averaging some 35 per cent. in lead and zinc sulphides. The geological relations of the mass are somewhat obscure. At one time it was thought to be conclusively proved that it was a "saddle reef," *i.e.*, a bed folded back upon itself so as to form a deep trough, approximately lenticular in cross-section and plunging to the south. I believe doubt has been thrown on this explanation, which seems a little improbable. At any rate it is a huge, highly mineralized mass, acting in all essential respects like a fissure vein, in a region where the rocks are highly metamorphosed and compressed.

The original minerals seem to be in the proportion of lead sulphides, about 15 per cent., zinc sulphides about 20 per cent., with a gangue of quartz, calcite, garnet, and rhodonite. The metallic assays are lead and zinc, each about 13 per cent., and silver 5 to 10 oz. per ton. In the lower parts of the mine the ore forms a hard compact mass, containing no waste, in which the valuable minerals are closely knit together with the gangue, making the concentration and separation of the metals difficult, expensive, and unsatisfactory. But the surface waters, to a depth of from 250 to 400 ft., had removed the zinc and left a bonanza orebody containing 33 per cent. lead and 20 to 30 oz. silver; an ore of easy metallurgical treatment accessible to mining in an open pit. At the surface, therefore, the realization of the values presented no difficulties even in the Australian desert; but when it suddenly became necessary to separate a lessened percentage of lead from an obstinate accompaniment of zinc (for the two metals cannot be smelted together), facing at the same time a loss of half the silver, in a region where water was scarce and everything expensive it required a good part of the money earned from the surface bonanza to solve the problem. It required nothing short of discarding the old smelting plants altogether and beginning anew; worse than that, experimenting with new processes. The outcome has been that the original ores have proved to be payable, but to a diminished degree. Lead can no longer be produced so cheaply, while the great masses of zinc ore, formerly discarded, have become valuable and a formidable factor in the zinc market. Under no circumstances, however, can the original ores become anything like so valuable as the altered surface ores (except, indeed, through their much greater volume).

Lead ores from such fissure veins as the above bear a close economic as well as natural resemblance to the copper mines on fissure veins. It will be noted that the costs in the Cœur d'Alenes and at Broken Hill, per ton, are not far from those of the copper mines of Butte, of Wallaroo, and Moonta, and of the Old Dominion at Globe, Arizona. The total cost for the whole process is from $6 to $10 per ton. As noted in the case of disseminated ores, the lead is about three times as abundant as copper, justifying prices inversely proportional.

3. The third class of lead ores, simply smelting ores, are nearly always of an origin similar to the surface ores, just described, of Broken Hill. They are usually the result of the reconcentration of mixed sulphides of iron, zinc, lead, and copper. It very often happens that the original ores are quite unpayable, owing either to their low grade, or to the fact that their volume is insufficient to warrant the expensive installations of plant necessary to work them. Lead ores of this kind usually form an insignificant fraction of the ore deposits from which they are derived, but often they are of high grade both in lead and silver, are near the surface, and can be mined profitably even in small quantities. For this reason a considerable amount of lead and silver is derived from a multitude of small shipments of this kind of ore, from hundreds of different places. In some few cases, such as Leadville, Colorado; Tintic, Utah, and Park City, Utah, such ores have been important sources of lead. In those camps the rich lead ores have been the principal resource of some of the mines. A certain amount of concentrating ore is obtained with the high-grade ore, but in each case, if the high-grade ore were absent, the lower grade ore would not be payable. Other districts producing this type of ore are Eureka and Pioche, Nevada; Aspen and Creede, Colorado, and Santa Eulalia in Mexico.

I shall give no very clean-cut examples of the cost of mining these ores. Those of Park City will give a general idea. The cost per ton in general for this class is high, certainly not less than $20 per ton for mining and smelting. In Park City the cost is between $10 and $15 for mining alone, to which must be added for freight, smelting, refining, and losses from $20 to $25 a ton more, making a total of $30 to $40 a ton.

Ores of this class bear a close parallel in manner of occurrence, methods of exploration, and high costs to the similarly derived copper ores of Bisbee, Arizona.

Production of Lead by States

State	1907	1908
Arizona	2,200	1,867
California	850	490
Colorado	47,332	26,707
Idaho	111,697	98,394
Kansas	1,800	2,400
Missouri	123,613	125,216
Montana	2,005	2,309
Nevada	3,400	3,676
New Mexico	1,900	611
Oklahoma	400	1,000
Utah	54,738	43,995
Wisconsin	3,500	3,486
Other states	1,204	600
Undistributed	—	2,026
Zinc smelters	1,320	1,290
Total	355,959	314,067

The above table will show at a glance the sources of lead supply in the United States and their comparative importance. I propose in the following pages to give an idea of the state of the business in Missouri, Idaho, and Utah. These three states produce more than 80 per cent. of the total for this country. A chapter is added by Mr. W. R. Ingalls (*The Mineral Industry*, 1908) on Silver Lead Smelting in the United States, to show not only the relations of the Western mines to the custom smelters of the country, but also the business results of the American Smelting and Refining Company, by far the largest factor in the smelting, refining, and marketing of lead and precious metals in North America.

Missouri is first in the list of states in the production of lead ores, and first in that of zinc ore. The mining is confined to two districts, the southeast and the southwest. The southeast district produces ores from which, in round numbers, 100,000 tons of pig lead are smelted yearly; from the ores of the southwest — or Joplin — field the product is 25,000 tons of lead and 140,000 tons of spelter.

In both fields the external conditions are favorable. Mining is conducted in the midst of the great agricultural regions of the

Mississippi Valley, where the cost of living is low, labor abundant, fuel and transportation cheap, and markets close at hand. The internal factors also are favorable to low costs. The depths reached are not great, the orebodies are fairly large. In southeast Missouri the orebodies are persistent, though somewhat irregular, while those of the Joplin field are not only irregular, but non-persistent. In both districts, however, exploration by drilling provides against underground perplexities. In both fields also, the ores are favorable for water concentration.

In the southeast district there is, unfortunately, little to be found in the way of reports of mining companies. The following notes are from my own observation, and while I cannot vouch for the accuracy of the figures as representing any particular property, I believe that they may be taken as fairly representing the district as a whole.

Southeast Missouri Lead

Mining in southeast Missouri is based on orebodies that carry an average of about 5 per cent. in metallic lead, or a little more. The ore is called disseminated from the fact that the galena is often sprinkled through the limestone, although usually most of the lead is confined to rich streaks. The ore concentrates well and can be turned into a 65 or 70 per cent. product, with a saving of 80 per cent. Commercially speaking, therefore, the ore yields about 4 per cent. net lead. Developments have proved that the orebodies are exceedingly persistent and extensive, though they show such irregularities that it requires time to demonstrate this.

The formation lies approximately flat, though grades of from 3 to 10 per cent. are not uncommon. It has, throughout the district, a gentle dip toward the southwest. The ore now being mined occurs in the lower 100 ft. of the St. Joe limestone, and often at the very bottom of this formation in contact with an underlying sandstone. Occasionally it happens that in the 100 ft. just mentioned there are successive enrichments, making workable orebodies one above the other. In this case more than one level may be necessary. But it is more common to find only one large irregular sheet of ore immediately above the sandstone, so that it can all be worked from one level; although sometimes the ore may shoot up some distance above the general level. The upper orebodies are relatively unimportant.

In the Flat River district proper, these orebodies are arranged in several parallel zones trending N. 50 degrees W. These zones lie in a space about $3\frac{1}{2}$ miles wide from N.E. to S.W., and

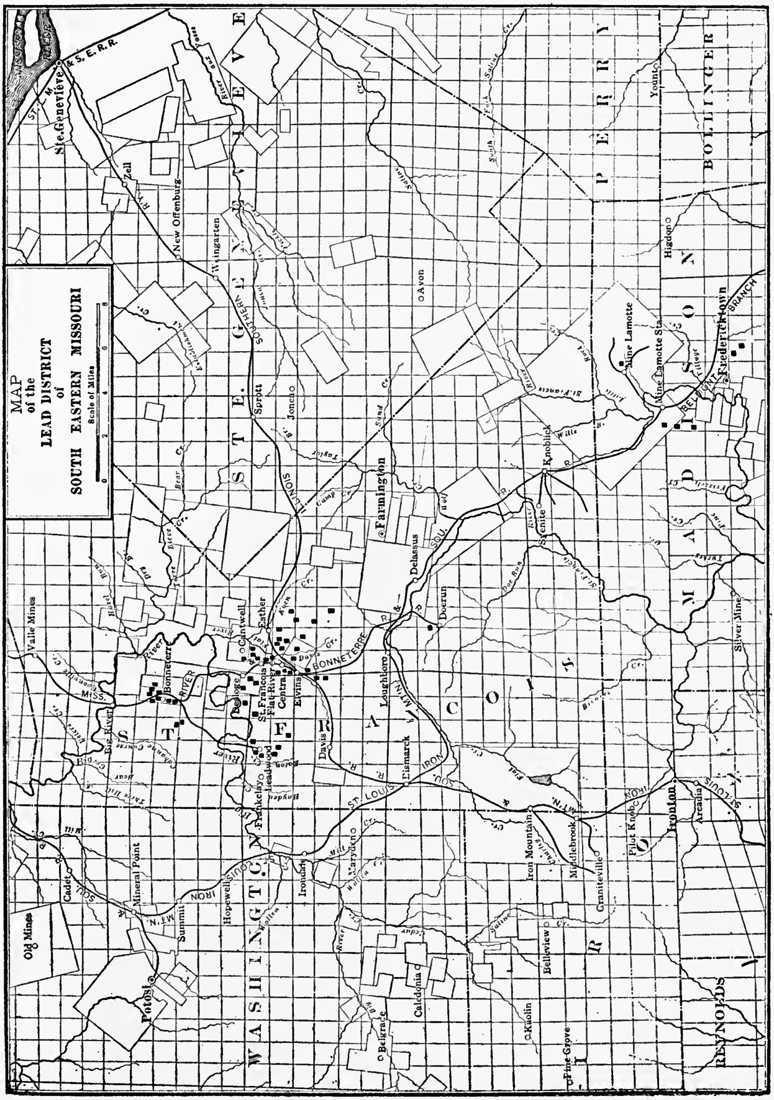


Fig. 13.

about 9 miles from N.W. to S.E. It is expected that these zones will be extended materially both to the northwest and to the southeast. I think there is also very good reason to expect that other zones will be developed southwest of those now worked. There are some indications already of three such new zones at the west end of the district.

I do not know why the ore follows this N.W.-S.E. course. I have never been able to see any system of persistent fissuring in that course. Most of the fissures have a course of E.-W. to N.E.-S.W. These fissures have a most obvious relation to the orebodies, which often follow them out long distances on either side of the real ore channel.

The sketch, Fig. 14, shows this relation in plan. The ore

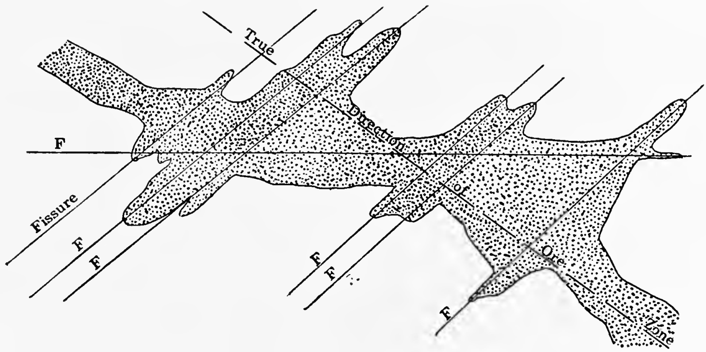


Fig. 14.—Sketch showing relation of orebodies to fissure, S. E. Missouri.

zone may carry some lead scattered through the rock on both sides of the workable channels, which may be only 5 ft. wide. The fissures are apparently the source of the ore from which it has fed out into the surrounding rocks. The richest ore, therefore, is right at the fissure, and it fades out on either side, so that midway between fissures the ore may be too poor to work.

Fig. 15 is a longitudinal section of the ore zone across the fis-

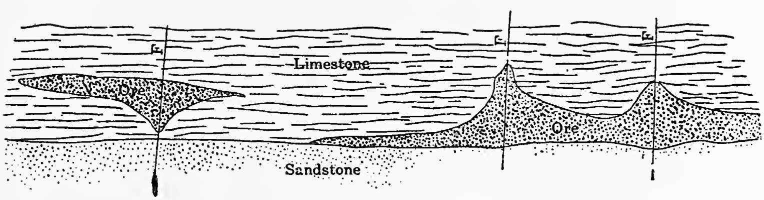


Fig. 15.—Sketch showing cross-section of orebodies in S. E. Missouri.

sures, showing this relation. The ore is workable to a thickness varying from 6 ft. to as much as 100 ft.

Explorations in the Southeast District

It will be evident from the above that the exploration of these orebodies by the sinking and drifting methods used in Western mines would be difficult and unsatisfactory. To follow the ore underground, it is almost necessary to stope the ore as you go. There is enough vertical irregularity to prevent following the ore successfully by horizontal drifts; and there is enough horizontal irregularity to make it impossible to keep in the channel, unless you are prepared to follow up each turn. If the ore rises you must be prepared to go up after it; if it sinks you must go down after it.

The problem of blocking ore out ahead has resolved itself entirely into diamond drilling from the surface. This varies in difficulty according to the depth. The formation dips slightly toward the southwest, while the surface rises a little in that direction. The southwestern part of the field is, therefore, the deepest part. In the older mines at Flat River, the depth to the sandstone is only 300 to 400 ft. In the newer mines like the Derby (Federal) and the Hoffman (St. Joe) the depth is 500 to 600 ft. In the deepest part, between Leadwood and Irondale, the depth is from 500 to 800 ft. When the depth is not over 550 ft., the drilling is all through very favorable rock; but where it is deeper, the cherty Potosi limestone comes in. This cherty formation is very hard to drill through, and it is best, whenever it is found, to use a churn drill through that formation, and then put in a diamond drill.

The drill is used first to find out in a general way the position of the ore channel by running a line of holes N.E.-S.W. at intervals of about 200 ft. When lead ore is found that looks worth following up, holes are put in closer in the attempt to follow it in its usual N.E.-S.W. course. If ore is found in considerable amount in 15 or 20 holes, enough is blocked out to justify sinking a shaft. As a general rule it is not found desirable to try to map out the orebody accurately by drilling until some progress has been made in stoping it, and more knowledge gained about its peculiarities.

Owing to the soft nature of the richer ore streaks, the drill cores invariably give an underestimate of the value of the ore. Even where ground is most carefully drilled, the actual mining shows from 20 to 100 per cent. more lead ore than the drilling would indicate. It is very common to have blank holes in the middle of a good orebody through grinding up of the ore streaks. Owing to the irregular shape of the deposit, some poor ground is apt to run into the middle of the space occupied by the ore. For these reasons it often happens that one-half the holes, even in good stoping ground, do not indicate pay ore.

The cost of drilling for many years went constantly upward, owing to the increased price of diamonds and of labor. Where drilling could be done ten years ago for 40 to 50 cents a ft., in 1907 it cost from $1 to $1.25 per ft. In the deeper holes, where the Potosi limestone must be penetrated, the cost probably averages $1.50 per ft. Perhaps recent events have reduced these costs again.

The above description refers especially to the mines in the vicinity of Flat River only. At Bonne Terre the orebodies are a little different, in that the longer axis there seems to extend N.E.-S.W., instead of N.W.-S.E. These orebodies are northeast from the ore zones of Flat River. It now seems very probable that a connection will be established between Bonne Terre and the Flat River orebodies.

Extent of the District

The Flat River district proper, containing developed mines, is a quadrilateral area of about 30 sq. m., or 19,000 acres. If we extend the lines so as to take in Bonne Terre and Irondale, we get a triangular area of about 60 sq. m., or 38,000 acres. This area is now producing metallic lead at the rate of about 100,000 tons a year. The output doubled between 1901 and 1907.

Outside of this area are a number of other places where ores of the same kind have been mined. At Doe Run, Fredericktown, and Mine La Motte are important occurrences which differ from the above-described field only in that they are in shallower basins of limestone, which are interrupted by knobs of pre-existing granite. At Fredericktown the ores carry, besides lead, copper, nickel, and cobalt. At the North American mine at that place considerable ore has been found that carries 5 per cent. copper and 2.5 per cent. nickel and cobalt. Everything indicates that there are possibilities of extension in copper mining in that neighborhood. The copper ores have exactly the same structural characteristics as the orebodies above described, except that, instead of pure galena, the ore is mainly sulphides of copper, nickel, and cobalt.

Problem of Mining in the Southeast District

The most difficult part of actual mining operations is the preliminary exploration by drilling. This determines the depth to which the shafts must be sunk, and their location. Usually only one level is necessary, but the fact that the ore does not lie exactly flat makes some provision for hauling cars up and down hill necessary. This can best be done, I believe, by electric haulage. This has been installed at one of the Federal plants and is very effective. Provision must also be made sometimes for secondary pumping to raise water from depressions that may reach lower than the shaft-pumping station.

The stoping is very simple. No timbers are used. Round pillars of ore are left, containing 10 to 15 per cent. of the ore. It is often possible to leave pillars in the poorer parts of the deposit by laying out the main entries so as to follow the rich ore along the fissures. Underground diamond drilling is necessary in some mines to prospect ahead for water channels. These are open fissures that carry so much water that, if broken into carelessly, they make disastrous gushes. Some shafts are pretty wet, making 1300 to 1500 gal. of water a minute. The usual output from each shaft is about 300 tons a day. This output may be greatly exceeded, however, by the use of electric haulage so as to cover a large area from one opening. Ventilation may be secured by drilling large churn-drill holes from the surface.

The most economical power equipment used in the district is at the plant of the St. Louis Smelting and Refining Company. Here a central steam plant operates a compressor and an electric generating plant. The mill, hoists, and pumps are operated by electricity. Electric trams are also used to haul the ore from various shafts to the mill.

The cost of mining, hoisting, and pumping is from $1 to $1.50 per ton. To this may be added 10 cents a ton for drill prospecting, and about 10 cents a ton for hauling the ore to the mill.

The total cost of ore is, therefore, from $1.20 to $1.70 at the mill.

The Problem of Milling the Ores

The milling[1] practice is now pretty well established. The ore is ground to 9 mm. Everything smaller than 9 mm. is screened out as soon as the ore passes the crusher. When crushed, the ore is screened to various sizes, from 9 to 2 mm., and this product jigged. The tailings from the coarser jigs are all re-ground. The material below 2 mm. is classified and treated on Wilfley tables, as are also the re-ground tailings. Middlings from the tables are also re-ground in Huntington mills and treated on Frue vanners.

The cost of milling in a 1000-ton plant is from 30 to 75 cents per ton. The cost of a concentrating mill, together with a power plant for the mines, may be estimated at $500,000 for 1000 tons capacity. The new plant built by the Federal Lead Company handles about 2400 tons a day. It is built of steel and concrete, has a large air-compressing and electric plant, and elaborate crushing and sampling arrangements. It cost $900,000.

The Problem of Smelting the Ores

Smelting may be considered either on a custom or an operating basis. The ore leaves the mill in the shape of a concentrate carrying 70 per cent. lead and 5 per cent. moisture. Freight to East St. Louis is about $1.50 per dry ton. This ore may be sold to custom smelters, who will pay for 90 per cent. of the lead at current quotations, and charge from $6 to $8 per ton smelting charges. On this basis, the cost of freight and treatment figures as follows:

	Lead, 4 Cents	Lead, 5 Cents	Lead, 6 Cents
Freight	$1.50	$1.50	$1.50
Treatment say	7.00	7.00	7.00
Deduction 10 per cent., 140 lb	5.60	7.00	8.40
Total	$14.10	$15.50	$16.90

On an operating basis the cost is about $6 per ton, and the loss, with the best practice, 3 per cent.:

[1] Since this was written a considerable change has occurred through the extensive use of Hancock jigs.

	Lead, 4 Cents	Lead, 5 Cents	Lead, 6 Cents
Freight and treatment	$7.50	$7.50	$7.50
Deductions, 42 lb. lead	1.68	2.10	2.52
Total	$9.18	$9.60	$10.02

On average prices there would be a saving of about $5.50 per ton of concentrates in operating a smelter. But it must be remembered that the above costs could only be secured by a plant handling a considerable tonnage, say 3000 to 4000 tons a month.

Let us now consider the cost of the entire operation with due regard to both capital and operating charges. In the utter lack of any official statements of the companies operating in the Flat River district I shall have to make an estimate of my own, with due apologies to the secretive persons who control the mines for rashly guessing at their secrets, and to the public for any inaccuracies.

The companies operating in the district are the following:

	Mill Capacity	Shafts Operated 1908	Dividends Not Stated
Desloge Lead Co.	800 tons per day	3	$6,308,357
St. Joe Lead Co.	2,700 tons per day	8	1,859,893
Doe Run Lead Co.	800 tons per day	4	Not stated
St. Louis Smelting & Refining Co.	1,500 tons per day	4	Not stated
Federal Lead Co	3,000 tons per day	6	Not stated
Five companies	8,800 tons per day	25	

Total output 1908 estimated at 100,000 tons pig lead. If we call this an average output and figure that the mills ran 300 days a year, we get a total of 2,640,000 tons and an average yield of less than 4 per cent. I believe that this is an overestimate for tonnage and an underestimate for yield for this particular year, but not for the long run. I shall base my calculations on the performance of this district on a yield of 4 per cent. refined lead, at a price of 4½ cents per pound. I shall exclude from my calculations, as usual, the money paid for mining land on the theory that that is a part of the profit won from the industry.

I shall proceed to compute the capital invested in the industry and figure the use of it as an integral part of the operating cost.

Capital in Exploration of Lands

This must amount to about $2,500,000. The greater part of this has been spent by the St. Joe and Doe Run lead companies, with the Federal Lead Company (including the Central) a close third. It is probable that the ore in sight is sufficient for about seven years.

Capital in Shafts and Mining Plants

This I estimate at $2,100,000, being $60,000 each for the twenty-five shafts in operation and for ten other shafts discarded or not operating.

Capital in Milling Plants and Power

I estimate this at $4,400,000, being $3,400,000 for plants in use, and $1,000,000 for discarded plants, experiments, and failure.

Capital in transportation equipment from mines to mills, but not including railroads leading out of the district, may be estimated very roughly at $1,500,000.

Capital in Smelting Plants

Including some capacity for smelting outside ores, this amounts to some $2,500,000, including workmen's houses, lands at plants, etc.

Working capital, $2,800,000, being equal to the value of the lead output for three months.

We have then:

Capital in explorations	$2,500,000
Capital in mining plants	2,100,000
Capital in milling plants	4,400,000
Capital in transportation plants	1,500,000
Capital in smelting plants	2,500,000
Working capital	2,800,000
Total	$15,800,000

This is equal to $6 per ton of annual output.

The use of this capital can hardly be calculated at less than 10 per cent. which is sufficient to return the investment in fifteen years with 5 per cent. interest. This calculation does not apply to working capital, however, for that is a quick asset that can always be liquidated. As long as it is in the business, however, it must be considered worth 5 per cent. We have then for amortization:

10 per cent. on $13,000,000 risked in business	$1,300,000
5 per cent. on 2,800,000 working capital	140,000
Total annual charge	$1,440,000

This is equal to $14.40 per ton lead and 57.6 cents per ton of ore mined.

The depreciation, or current construction of plants, to take care of changes in method, improvements, removals, etc., should be calculated at 6 per cent. on capital invested. This will equal $780,000, accounting for $7.80 per ton of lead and 31.2 cents per ton crude ore.

We have now covered all the charges incident to the business except the current operating charges. These may be estimated as follows, giving due consideration to varying conditions:

	Per Ton, Crude	Per Ton Concentrate Yield 65 Per Cent.	Per Ton, Pig Lead
Mining and hoisting	$1.00 to $1.50	—	$25.00 to $37.50
Transfer to mills	0.05 to 0.10	—	1.25 to 2.50
Milling	0.30 to 0.50	—	7.50 to 12.50
General expense	0.10 to 0.20	—	2.50 to 5.00
Freight to St. Louis	.097 to 0.097	$1.60	2.44 to 2.44
Smelting	.378 to .378	6.00	9.23 to 9.23
Total operating	$1.925 to $2.775	—	$47.88 to $69.17
Add depreciation	.312 to .312	—	7.80 to 7.80
Dividend cost	$2.237 to $3.087	—	$55.68 to $76.97
Add amortization	.576 to .576	—	14.40 to 14.40
	$2.813 to $3.663	—	$70.08 to $91.37

We find that the mines can pay dividends on what remains above from 2.8 to 3.85 cts per pound, say for an average 3.3 cents. They can justify their investment at a price of from 3.5 to 4.5 cents, or in round numbers, 4 cents per pound.

This I believe is a fair exhibit of the entire business. I do not pretend that the mines will not show great differences from these figures. The differences I have placed in the operating cost columns are intended to cover, for mining: the difference between a thick and a thin orebody, between dry and wet mines; in milling, the difference in the milling quality of the ores, between simple and elaborate processes, and between small mills and big ones; in general expense, the difference between simple and elaborate managements. There have been failures in the district. I am striking an average of the successes.

That these figures are not far from the truth may be gathered from the records of the St. Joe Lead Company, which paid more than $5,700,000 in dividends and built up its property greatly from an output of about 300,000 tons of lead. This indicates a profit of 0.95 cents per pound. Deducting this from an average price of 4.5 cents we get an average cost of 3.55 cents, less whatever surplus may be credited from surplus in the treasury. The cost, of course, fluctuates with the times. It is always possible during periods of depression to produce more cheaply by cutting wages and curtailing construction and development; on the other hand, in boom times wages are raised and people embark in unusual expenditures for expansion and development. As a matter of fact, lead was sold in St. Louis from the Flat River district, in the years following the panic of 1893, as low as 2.6 cents per pound without loss; but in the boom period of 1906–7 it is doubtful if any of the mines were producing it for less than 4 cents.

CHAPTER XV

SILVER-LEAD MINING

Characteristics of Cœur d'Alene region — The Wardner vein — Detailed cost statements and records of Bunker Hill & Sullivan Mining and Concentrating Company — Summary of present operating costs — Canyon Creek mines — Average costs and results — Smelting, refining, and marketing — Relations of mines to American Smelting and Refining Company — Calculation of complete mining and smelting costs, losses and profits on Bunker Hill average ore — Broken Hill district in Australia — Smelting costs at Broken Hill and in America — Silver-Lead mines of Park City, Utah — Average costs at Daly-West — Daly-Judge and Silver King — Smelting costs and profits.

THE external factors which affect mining in the Cœur d'Alene are the most favorable of the whole Rocky Mountain region. The altitude is moderate; the climate mild; timber and water power are abundant and cheap. Transportation to consuming centers is, however, expensive, and wages are high. Labor is efficient and abundant. The mines are generally deep, measured from the surface, but the configuration of the country has permitted their attack by adit levels; so that most of the ore has not needed hoisting from great depths, and pumping operations have generally been inexpensive.

The internal factors are favorable. The veins are typical fissures. The ore is galena, which seems to be a metasomatic replacement of pre-existing veins of iron carbonate. Ransome believes that the Burke and Revett quartzites, flaggy, evenly bedded, light-colored rock about 3000 ft. thick, contain nearly all the payable ore, although veins are found traversing an immense mass of slates and quartzites of presumable Algonkian age, some over and some under the productive formations. The whole sedimentary series is estimated to have a thickness of 13,000 ft.

The ore shoots are persistent and profound, with a thickness varying from 8 to 100 ft., and a length varying from 100 to 1000 ft. normal to the plunging axis. Single bodies have produced several million tons of ore. The ore in the main has to be concentrated. The proportion shipped to the smelters varies from a quarter to a tenth of the amount mined. Of the proportion shipped a considerable amount is picked out by hand either underground or at the mill, the lower grades being concentrated. In addition to the sorting of first-class ore, there is a still larger sorting of waste in the stopes. In many cases it is necessary for safety to fill the stopes, and in all cases it is economical to reject waste. The various mines differ greatly in the amount of sorting and filling done. Several have run for years without shipping any first-class ore and without sorting any waste in the stopes, everything mined being sent to the concentrator. On the other hand, one prominent mine, the Hercules, ran several years without a mill, shipping only first-class ore.

Producing Mines

The mines may conveniently be divided into two groups: the Wardner and the Canon Creek. In Wardner there is only one vein and two important mines: the Bunker Hill & Sullivan, an independent concern, and the Last Chance, owned by the Federal Mining and Smelting Company.

The Wardner vein has been the subject of a good deal of litigation, and has been well and often described, but I will hazard a new idea concerning it: The principal object of attention has always been a great mineralized fault called the "foot-wall," having a strike of north 40° west, and a dip of 45° southwest. This fault, in my judgment, originated the lead mineralization of the district, but in an indirect way. It intersects some veins whose course is more nearly east and west, or even north 70° east. These veins may originally have had only a siderite filling. The Bunker Hill fault probably reopened these veins and started the lead mineralization which replaced a large part of the original siderite. The fault movements continued in part after the lead mineralization had made considerable progress, for the lead ores have been crushed into paste along the footwall. At any rate, at and near the footwall fissure there are a number of powerful ore channels, some of which have been followed for a distance of 3000 ft. down the slope, with very little or no change in their value or character.

The mining is done almost wholly by the filling method.

Whether square sets are put in first and then filled, or whether the stopes are filled without timbering, depends on the firmness of the ground. This varies in different parts of the mines. In nearly all cases enough waste for the filling can be sorted out of the vein-stuff itself.

The Bunker Hill mine in twenty-two years up to June 1, 1908, had produced as shown in the following tables, which are much more complete than any cost statements given elsewhere in this volume. It would be scarcely desirable to repeat often mining costs at such length in a work such as the present, but these details will undoubtedly be of interest to many students of mining problems. Accordingly I shall give not only the figures as presented in the reports of the company for 1908, but also some comments on the conditions and methods employed.

The first table shows the progressive history of the mine from the beginning, in various periods. In this the reader will find everything of importance relating to the ores of the mine; but for convenience I shall calculate out the avearge contents of the shipping product for the whole period and for the year 1908.

	1908	22 Years
Average yield per ton crude ore, lead per cent.........	9.8	9.68
Ounces silver, ounces..................................	3.84	3.82
Average contents of shipping product lead per cent.......	43.17	51.45
Silver, ounces..	16.58	20.31

It will be observed that while the yield of the crude ore per ton is almost exactly the same as for the entire period the grade of the shipping product has dropped about 15 per cent. No significance attaches to this except that in recent years a considerable tonnage of low-grade concentrates containing less than 10 per cent. lead and a high percentage of iron has been shipped on account of its favorable fluxing qualities. In earlier periods no such ore was shipped. Of course with the present grade of shipping ore the cost per ton will be considerably different for smelting charges than with the higher grade of past shipments.

Bunker Hill & Sullivan, Wardner, Idaho

DATA PER TON OF ALL ORE MINED, BOTH SHIPPING AND CONCENTRATING

	May, 1886, to May, 1892, inclusive 6 yr. 1 mo.	June, 1892, to May, 1900, inclusive 8 yr.	June, 1900, to May, 1907, inclusive 7 yr.	June, 1907, to Mch., 1908, inclusive 10 mo.	April, 1908 1 mo.	May, 1886 to April, 1908, inclusive 22 yr.	Future expectations
Assay values, lead, lb	295.56	220.90	217.34	229.50	214.06	225.60	220.00
Assay values, silver, oz	5.99	5.23	4.61	4.76	4.26	4.92	4.82
Recovered values, lead, lb	274.60	178.30	195.10	196.20	176.70	193.60	187.00
Recovered values, silver, oz	5.96	3.76	3.67	3.84	3.45	3.82	3.86
Average New York daily market prices, lead, dollars, per 100 lb.	4.33	3.65	4.615	4.515	3.993	4.18	4.18
Average New York daily market prices, silver, cents, per oz.	97.37	66.54	59.64	61.45	54.50	72.63	50.00
Average New York market prices when products sold, lead, dollars, per 100 lb	4.36	3.72	4.788	4.451	3.993	4.427	4.20
Average New York market prices when products sold, silver, cents, per oz.	95.94	65.96	61.18	61.46	54.50	65.18	50.00
Gross assay value of ore, dollars	18.63	11.67	13.23	13.35	10.868	13.19	11.65
Tailing loss in concentrating, dollars	0.94	2.56	1.64	2.08	1.932	2.13	1.87
Net value of ore, dollars	17.69	9.11	11.59	11.27	8.936	11.06	9.78
Cost of mining, dollars	2.319	2.277	1.752	1.568	1.523	1.930	1.50
Cost of tramming, dollars	0.114	0.103	0.079	0.084	0.077	0.088	0.07
Cost of concentrating, dollars	0.623	0.351	0.252	0.423	0.372	0.315	0.35
Cost of general expenses, dollars	0.947	0.360	0.261	0.352	0.302	0.332	0.28
Total operating costs, dollars	4.003	3.091	2.344	2.427	2.274	2.665	2.20
Cost of betterments, etc., dollars	3.401	1.019	0.501	0.533	0.437	0.800	0.30
Cost of shipping, smelting, and marketing, dollars (including loss in smelting)	8.95	3.99	5.47	5.45	3.940	5.16	3.50
Total costs of every kind, dollars	16.354	8.100	8.315	8.410	6.651	8.625	6.00

Mining profit, dollars	1.336	1.01	3.275	2.86	2.285	2.435	3.78
Other earnings, dollars	none	0.124	0.831	0.090	0.043	0.509	0.04
Total profits, dollars	1.336	1.134	4.106	2.95	2.328	2.944	3.82
Dividends, dollars	0.884	0.672	3.929	4.518	2.377	2.804	3.00
Cash and cash assets, dollars	0.452	0.462	0.177	[1] *1.568*	[1] *0.049*	0.140	—

Miscellaneous Data

Shipping, smelting, and marketing, including loss in smelting, per ton of product shipped, dollars	42.69	25.02	27.95	23.05	20.88	27.40	19.25
Total tons of ore mined	169,752	1,116,212	2,002,146	272,220	31,550	3,591,880	—
Average number of tons per month	2,326	11,627	23,835	27,222	31,550	13,606	40,000
Total tons of shipping ore and concentrate	35,616	177,930	391,953	64,409	5,950	675,858	—
Average number of tons per month	488	1,853	4,666	6,441	5,950	2,560	7,273
Total contents of all products shipped: tons lead	23,310	99,538	195,378	26,712	2,788	347,726	—
Total contents of all products shipped: ounces silver	1,011,527	4,199,359	7,358,755	1,045,892	108,941	13,724,474	—
Average output per month: tons lead	320	1,037	2,326	2,671	2,788	1,317	3,740
Average output per month: ounces silver	13,952	43,743	87,604	104,589	108,941	51,987	154,400
Number of tons of ore mined per one ton of product shipped	4.77	6.27	5.11	4.23	5.30	5.31	5.50
Value of silver recovered per pound of lead marketed, cents	2.083	1.391	1.150	1.203	1.064	1.286	1.032
Number of pounds of lead contained in ore per ounce of silver contained in ore	49.35	42.22	47.11	48.19	50.28	45.95	45.64
Number of pounds of lead recovered per ounce of silver recovered	46.07	47.42	53.16	51.09	51.22	50.68	48.45
Percentage of contents of both shipping and Concentrating ore recovered for shipment: lead	92.89	81.16	89.87	81.16	82.44	85.81	85.00
Percentage of contents of both shipping and Concentrating ore recovered for shipment: silver	99.49	71.89	79.61	80.67	80.98	77.64	80.00

[1] Other resources than profit drawn upon in payment of dividend.

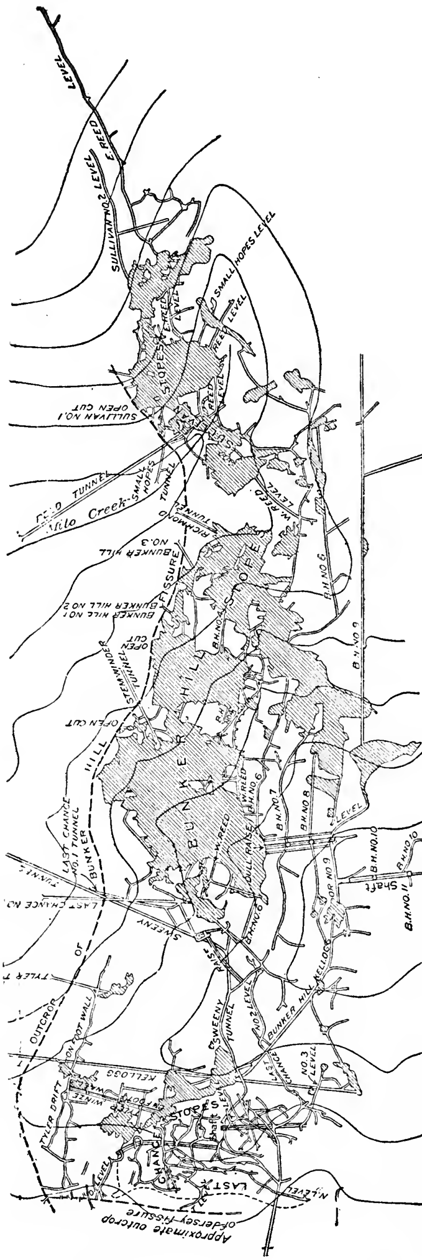


FIG. 16. - Orebodies along Wardner Vein.

The following table shows the stoping cost in detail. Nearly all the ore comes from large tabular masses having a dip of only 30° from the horizontal. In some places the hanging wall is loose. Most of the ore is mined in square-set rooms that are filled with waste, either sorted from the orebody or obtained from development work, almost as fast as the ore is mined. Under these conditions it will be plain to any mining man that the costs are low. The statements are for the year ending May 31, 1908.

"*Stoping.* — The mine was in operation for the full period of one year, and produced 330,730 tons of concentrating ore, at a cost of $511,288.16, as follows:

Details for Labor and Supplies	Total for the Year	Average per Ton for the Year	Highest Cost per Ton for One Month during the Year	Lowest Cost per Ton for One Month during the Year
Foremen, bosses, blacksmiths, machinists, tool-packers, etc.	$60,982.27	.185	.191	.165
Timberman and carpenters	25,109.38	.076	.082	.063
Miners	125,148.48	.379	.400	.339
Carmen	15,918.00	.048	.042	.058
Shovelers	133,176.50	.403	.450	.379
Power labor	7,708.40	.023	.027	.021
Repair labor	7,492.70	.023	.025	.021
Explosives	30,019.37	.091	.111	.087
Illuminants	7,482.08	.023	.026	.017
Lubricants	1,329.87	.004	.004	.006
Iron and steel	4,158.20	.013	.014	.012
Miscellaneous supplies	11,667.61	.035	.032	.025
Timber and lagging	61,629.00	.186	.199	.165
Power supplies	7,876.30	.024	.024	.027
Wood	9,292.80	.028	.030	.030
Stable and stock	2,297.20	.007	.007	.006
Total	511,288.16	1.548	1.664 Nov.	1.421 May"

The stoping of shipping ore simply represents the sorting out of a variable amount of high-grade galena to be shipped direct to the smelters, thus avoiding the losses in the concentrating mill. It will be observed that this sorting adds something to the cost. On this ore the cost of concentrating and mill losses are avoided altogether so that this is the most profitable product of the mine.

"*Shipping Ore.* — The mine also produced 4340 tons of crude shipping ore, at a cost of $8,445.27, as follows:

Details of Labor and Supplies	Total for the Year	Average per Ton for the Year	Highest Cost per Ton for One Month during the Year	Lowest Cost per Ton for One Month during the Year
Foremen, bosses, blacksmiths, machinists, tool-packers, etc.	$1,468.04	.338	.242	.200
Timbermen and carpenters	255.20	.059	.071	.027
Miners	1,808.25	.416	.503	.338
Carmen	260.00	.060	.073	.056
Shovelers	2,808.04	.647	.973	.575
Power labor	80.10	.018	.036	.011
Repair labor	102.70	.024	.030	.021
Explosives	330.50	.076	.153	.055
Illuminants	96.98	.022	.024	.026
Lubricants	11.05	.003	.008	.001
Iron and steel	51.30	.012	.018	.015
Miscellaneous supplies	171.81	.040	.039	.032
Timber and lagging	847.10	.195	.290	.136
Power supplies	75.30	.017	.045	.017
Wood	78.90	.018	.041	.026
Total	$8,445.27	1.945	2.546 May	1.536 April

"Making the total ore mined 335,070 tons, at a total cost of $519,733.43."

Tramming in this case represents the cost of taking the ore out through a two-mile tunnel and dumping it into the mill bins.

"*Tramming.* — The electric railroad was in operation for the full period of one year, during which time it delivered to the concentrator 335,070 tons of ore, at a cost of $27,640.76, as follows:

Details of Labor and Supplies	Total for the Year	Average per Ton for the Year	Highest Cost per Ton for One Month during the Year	Lowest Cost per Ton for One Month during the Year
General labor	$1,200.00	.003	.003	.004
Trammers	11,062.05	.033	.030	.036
Power labor	2,773.37	.008	.008	.010
Repair labor	4,248.75	.013	.020	.007
Illuminants	300.00	.001	.001	.001
Lubricants	470.00	.001	.001	.001
Iron and steel	320.00	.001	.003	—
Miscellaneous supplies	1,340.00	.004	.005	.003
Power supplies	4,060.59	.012	.013	.010
Wood	1,866.00	.006	.011	—
Total	$27,640.76	.082	.095 Feb.	.072 June

"During the above period of one year the railroad was in operation, 732 shifts of eight hours, of which 42 shifts were lost, as follows:

24 shifts on account of Sunday lay-off.
4 shifts on account of July 4th.
4 shifts on account of miner's picnic.
2 shifts on account of Thanksgiving Day.
2 shifts on account of Christmas.
2 shifts on account of mill shut-down.
4 shifts on account of cold weather, stopping operations.

"Besides the above ore there were trammed 20,800 tons of waste, making the average work of the railroad 486 tons per shift, or 515 tons per shift of actual operation, at a cost per ton of ore and waste handled of $.078. This cost includes hauling of timbers and other supplies and the taking of the larger percentage of the men to and from their work."

Concentrating at this mine represents the rejection of gangue to the extent of 80 per cent. of the crude ore. The process consists of rather coarse crushing, jigging, and the treatment of a considerable proportion of fines on vanners and Wilfley tables. The cost has been increasing of late years, owing to refinements in the process, *i.e.*, it has been found desirable to spend more money in the mill to make a higher saving. The cost has gone up as follows:

1905	18 cents
1906	18.5 cents
1907	24.4 cents
1908	37.2 cents

These costs are for operating alone. It is evident that this increase of cost will be justified by the saving of an additional 6 or 7 lb. of lead per ton milled. I imagine the results are far better than that.

"*Concentration.* — The concentrator was in operation for the full period of one year. Of the 366 days there were lost $30\frac{10}{24}$ days, as follows:

150 hours on account of screens, elevators, and rolls.
55 hours on account of belts and Huntington mills.
34 hours on account of general repairs.
72 hours on account of holiday lay-offs.
218 hours on account of Sunday lay-offs.
48 hours on account of miner's picnic.
30 hours on account of electric power off.
50 hours on account of slush ice.
11 hours on account of pulleys, pumps and jigs.
16 hours on account of short of ore.
9 hours on account of repairs to tail race.
27 hours on account of short of water.
10 hours on account of broken line shaft.

"In the above period 330,930 tons of ore were concentrated, making the average work of the concentrator 904 tons per day, or say, 986 tons per 24 hours of actual operation.

Detail of Labor and Supplies	Total for the Year	Average per Ton for the Year	Highest Cost per Ton for One Month during the Year	Lowest Cost per Ton for One Month during the Year
General labor	$15,226.58	.046	.067	.034
Millmen	46,129.07	.139	.150	.127
Laborers	2,603.48	.008	.008	.004
Power labor	2,866.46	.008	.007	.005
Crusher labor	1,520.04	.005	.007	.004
Repair labor	3,688.58	.011	.013	.011
Illuminants	1,475.50	.005	.004	.004
Lubricants	1,730.00	.005	.005	.005
Iron and steel	930.00	.003	.002	.003
Miscellaneous supplies	23,184.79	.070	.082	.064
Lumber	1,370.00	.004	.008	.005
Roll shells	1,685.00	.005	.005	.007
Trommel screens	1,336.00	.004	.003	.003
Crusher supplies	1,900.00	.008	.008	.005
Wood	13,310.80	.040	.044	.028
Power supplies	4,205.00	.013	.007	.023
Total	$123,161.30	.372	.420 Oct.	.332 April

"*Shipping Expense.*—We shipped 72,468.80 tons of concentrates and middling ore and 4304.30 tons of crude ore, or a total of 76,773.10 tons, at the following expense:

	Total	Cost per Ton
General labor	$1,110.00	$.014
Laborers	3,256.09	.042
Contractors	10,418.86	.137
Illuminants	120.60	.001
Miscellaneous	284.35	.004
Representative at smelter	146.07	.002
Total	$15,335.97	.200

"*Superintendence and Office Expenses.*—Superintendence and Office expense amounted to $28,726.03, as follows:

Superintendence and surveying	$16,440.00
Bookkeeping and assaying	6,562.57
Wood and illuminants	910.00
Office supplies	1,087.47
Assay supplies	1,310.00
Telegrams and telephone expense	523.51
Sundries	1,892.48
Total	$28,726.03

"*Legal Services.* — Legal services amounted to $3000, being the salary of the company's local attorney.

"*Contingent Expense.* — Contingent expense amounted to $13,422.54 as follows:

"This completes the list of direct operating charges at the mine, but it does not end the expenditures of the company. We must add the following:

"All other Wardner Expenditures, aside from warehouse accounts, were,

Improvements	$109,272.08	
Taxes	59,646.98	
Insurance	3,853.84	
Real estate	9,716.00	
Dividend reserve	2,069.58	
Sale of electric light	10,735.13	
Sale of water	823.82	
Purchase of mining property	8,970.70	
Mine office fixtures	486.20	
Litigation	13,676.64	
Exploration	44,362.18	
		$263,613.15
Less certain local receipts at Wardner and San Francisco		37,226.02
		$226,387.13"

To these expenses must be added for freight and treatment on ore shipped to the smelters $1,004,896, equal to $3 per ton mined and $13.09 per ton shipped. From the value of the ore so shipped a deduction was made for assumed losses of $333,092, equal to $1 per ton mined and $4.35 per ton shipped.

"*Exploration.* — Details for 1908 and ore reserves 4846 feet of drifts, crosscuts, raises and winzes were driven, at a cost of $44,362.18, as follows:

Details for Labor and Supplies	Total for the Year	Average per Foot for the Year	Highest Cost per Foot for One Month during the Year	Lowest Cost per Foot for One Month during the Year
Foremen, bosses, blacksmiths, machinists, tool-packers, etc ...	$2,639.66	.545	.776	.324
Timbermen and carpenters	180.75	.037	.128	—
Miners	6,568.00	1.355	1.718	.527
Shovelers	9,685.87	1.999	2.730	1.195
Contractors	5,107.50	1.054	.994	1.424
Power labor	2,511.50	.518	.537	.458
Repair labor...................	504.60	.104	.129	.078
Explosives	7,516.50	1.551	1.847	1.166
Illuminants	515.94	.106	.166	.078
Lubricants	284.08	.059	.067	.057
Iron and steel	290.50	.060	.092	.026
Miscellaneous supplies	2,168.48	.447	.423	.104
Timber and lagging	1,762.10	.364	.369	.144
Power supplies.................	2,348.40	.485	.739	.401
Wood	2,278.30	.470	.696	.200
Total	$44,362.18	9.154	11.411 Feb.	6.182 June

"The above development has given to the property a tonnage of standing ore ready for extraction never before equaled in amount or grade during the many years of operation of the mines. The most valuable and extensive developments were made on No. 10 and No. 11 levels, in the Bunker Hill mine, these levels being 200 and 400 ft., respectively, below the No. 9, or Kellogg tunnel, level and the deepest levels in the district. Orebodies were also opened in the Tyler No. 8 level, in the Stemwinder mine, and the Vann Intermediate, in the Sullivan mine. Sinking of the shaft from the Kellogg Tunnel level has been accomplished, and at the present date (September, 1908) has reached a depth of 600 ft. vertically below the Kellogg Tunnel, where the No. 12 level is to be established and crosscutting for the orebody started. This should be completed early in 1909."

"*Ore Reserves.*—We have ore reserves partially blocked, of date Oct. 12, 1908, as follows:

Stemwinder mine	60,856 tons
Sullivan mine	903,247 tons
Bunker Hill mine	1,845,575 tons
Total	2,809,678 tons"

We may summarize the whole operation as follows:

	Cost	Per Ton Mined 335,070 tons	Per Ton Shipped 76,773
Stoping	$519,773.43	$1.551	$6.77
Tramming	27,640.76	.082	.36
Concentrating	123,161.30	.372	1.60
Shipping	15,335.97	.200	.20
Superintendence	28,726.03	.085	.37
Legal services	3,000.00	.009	.04
Contingent expense	13,422.54	.040	.18
Construction, taxes, insurance, exploration	226,387.13	.676	2.94
Total mining and milling	$957,447.16	$3.015	$12.47
Add smelting	—	3.000	13.09
Total costs	—	$6.015	$25.56

Cost Per Pound Lead

The number of pounds lead realized may be computed at 227, and the cost per pound 2.65 cents. I get this by taking the number of pounds lead realized per crude ton, 196, and adding thereto the value of 3.84 oz. silver in lead at the proportionate prices for the year; equaling 57.6 lb.; making a total of 253.6 lb., less 10.3 per cent. deducted for loss, leaving a total of 227 lb. The prices received for lead were 0.18 cents per pound less than the New York market prices, but as this deduction did not apply on the silver the total loss on this account may be calculated at only 0.13 cents per pound of lead equivalent. Adding this to the 2.65 reached above, we get 2.78 cents as the real cost of lead to the mining company. Of course this includes the profit made by the smelting company on these ores. What that profit is, there is no means of calculating; but it does not seem improbable that whatever profit is made in smelting would represent only a fair amortization of the capital required. We shall not be far wrong if we take a round figure of $2.75 cents as the real cost of lead from this mine for the year.

Average Results

The total cost of operating this mine has been in summary:

Current operating expense — per crude ton	$2.665
Creating plant	.800
Total	$3.465

Thus the amortization and depreciation charges equal just 30 per cent. of the current operating charges.

Canyon Creek

The Canyon Creek mines differ from the Wardner mines only in the shape of the orebodies. The dip is not far from vertical; the ore shoots are much longer, thinner, and more regular. Wages average 46 cents an hour, 4 cents higher than in Wardner. Details of cost are not given.

The Federal Mining and Smelting Company for three years reported as follows:

Operations of the Federal Mining and Smelting Company for the Last Three Years

Total tons mined and milled	2,428,112
Tons lead in shipping product	166,912
Ounces silver in shipping product	10,300,049
Percentage lead	6.87
Ounces silver per ton	4.24
Value of product	$24,310,441
Smelting, refining, and deductions	10,514,773
Net value to mining company	13,795.668
Profits reported	6,160,247
Total cost	7,635,421
Cost per ton, mining and milling crude ores	3.14
Cost per ton, concentrates shipped	22.03
Smelting, refining, and marketing concentrates	30.35

It will be seen that these figures indicate conditions similar to those of Wardner. Further elaboration of detail seems unnecessary. The costs are higher than at the Bunker Hill, but the difference at the mine is to be explained by the factors, (1) higher wages, (2) a greater amount of hoisting and pumping,

(3) a charge for railroad transportation from mines to mills, (4) a greater number of power and mining plants to maintain, and a higher power cost. In each case these factors are inherent to the problem and cannot be removed.

The cost of mining and milling, of construction, of freight and treatment; and the value of the ore to the mines, free from smelter deductions for a period of five years during which the average price of lead in New York was 4.6 cents and of silver 59.2 cents, are given for a number of properties in accompanying tables:

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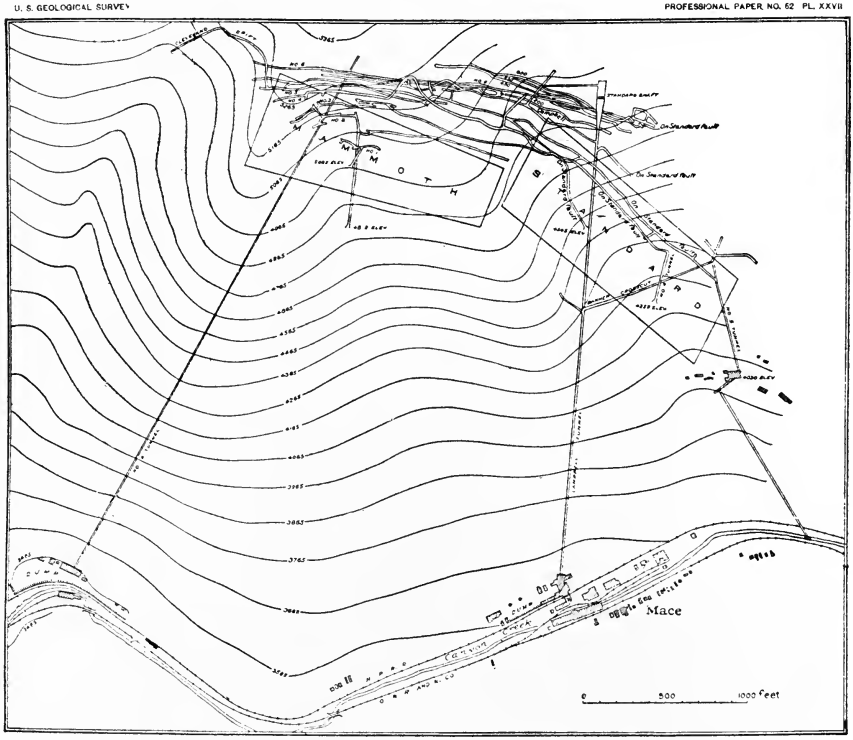

MAP SHOWING PLAN OF DEVELOPMENT OF STANDARD-MAMMOTH MINE.

From the company's surveys. Top is north.

FIG. 17.

Cost and Value of Ore per Ton at Six Mines for Five Years
(New York prices: lead, 4.6c; silver, 59.2c.)

	Tons	Cost Mining and Milling	Construction	Total	Freight and Treatment	Total Cost to Mine	Value to Mine	Profit
Hecla	402,000	$3.43	$0.47	$3.90	$2.56	$6.46	$9.57	$3.11
Standard	1,244,571	2.91	0.15	3.06	2.37	5.43	7.29	1.86
Tiger-Poorman...	488,675	2.94	0.10	3.04	1.71	4.75	4.99	0.24
Morning	924,416	1.96	0.15	2.11	2.51	4.62	5.42	0.80
Last Chance.....	670,164	2.66	0.08	2.74	2.99	5.73	8.19	2.46
Total and averages	3,729,826	—	—	$2.90	$2.43	$5.33	$6.93	$1.60

Estimated Average Value of Chief Items

Smelter deductions	$1.50
Loss in milling, 20 per cent. (In some of these mines where no first-class ore is shipped, the loss is probably greater; where a good deal is picked out the loss is probably less).........	2.11
Gross value of ore before milling, at N. Y. quotations.........	10.54
Per cent. lead, before milling	8.66
Ounces silver per ton, before milling	4.33
Cost to mine per pound lead at New York	3.54 cents
Cost to mine per ounce silver at New York	46 cents
Cost of lead in New York (actual cost)	3.36 cents
Cost of silver in New York (actual cost)	43.5 cents

If these mines were all owned by the American Smelting and Refining Company, and the cost of the whole process from mine to market were to be given, it would probably be something as follows:

Total value recovered per ton	$8.00
Cost of mining, milling, and construction..........................	2.90
Cost of smelting, refining, and marketing..........................	3.20
Profit per ton	1.90

The Hercules mine has the following interesting record, the tonnage being given in selected crude shipping ore and concentrates:

Tons shipped		56,446
Current mining and milling cost	$10.38	$24.02
Construction	13.64	
Freight to smelter	11.15	19.67
Treatment charges	8.52	
Total cost		$43.69
Total value free of deductions		82.69
Profit per ton		39.00

This mine started without capital and created its plant out of ore. It is interesting to note how this affects the cost of mining and also to compare the costs with those of the Bunker Hill & Sullivan which went through the same process. In twenty years the Bunker Hill mined about 3,400,000 tons of ore out of which it built up its plant, paid for costly litigation involving its very life, and fought several disastrous strikes at a cost of about $1 a ton in addition to its current operating cost of $2.60.

If the Hercules mined one ton of concentrates to four of crude, its costs were for five years:

Current operating, per ton	$2.60
Cost of plant	3.41

Doubtless when this mine shall have reached the age of the Bunker Hill its cost for construction will have diminished to about the figure attained by the latter company.

Cost of Smelting, Refining and Marketing

I have considered results as they are to the mining companies. It is interesting, in order to compare the results in the Cœur d'Alene with those obtained elsewhere, to see what the actual cost for smelting, refining, and marketing is, and thus find how the figures would stand if the mining, milling, and smelting were all done by one concern.

It appears from the reports of the largest two companies that the average ore shipped carries about 46 per cent. lead and from 18 to 28 oz. silver. Let us average the silver at 23 oz. We may assume an average price for lead in New York to be 4.60 cents per pound and silver 60 cents per ounce. At these rates our average ore will be worth as follows:

Lead, 920 lb., at 4.6 cents	$42.32
Silver, 23 oz., at 60 cents	13.80
Total	$56.12

On this, however, the smelters only pay $45.95, deducting $10.17 for losses; in addition to which they charge about $16 for freight and treatment, making a total of $26.17 per ton.

APPROXIMATE COST OF SMELTING CŒUR D'ALENE ORE

Freight on ore to Denver at $8 per ton, allowing for 6 per cent. moisture	$8.51
Freight, bullion to New York (46 per cent. of $6.40)	2.90
Refining bullion, lighterage, etc. 46 per cent. of $8.67	3.99
Losses (silver, 4 per cent.; lead, 6 per cent.)	3.10
Costs at blast furnaces (Ingalls)	5.28
Total	$23.78

Profit on this basis $2.40 per ton.

Such a profit spread over the crude ore mined, averaging about 6⅔ tons to each ton of concentrates smelted, is only about 35 cents a ton. It does not seem in the slightest degree unreasonable. It is even possible that the real profits do not equal this amount because Mr. Ingalls may have underestimated the capital employed in the smelting business. (See following chapter on Silver-Lead Smelting.) He states the cost of a smelting plant at $3 per annual ton. This may be sufficient for a successful plant, but a very large concern like the American Smelting and Refining Company finds its business migratory. This involves discarding plants from time to time. This means the investment of large sums in mistakes. Taking this element into consideration the smelting rates for the Cœur d'Alene ores seem all the more reasonable.

Let us then return to the Bunker Hill & Sullivan, the only mine for which our figures are complete, and calculate the whole process through, including both capital and operating costs and milling and smelting losses as they would be if the mine were owned by the American Smelting and Refining Company. We have the actual costs, grade of ore, and prices realized by the mining company for a period of over twenty years. There is no reason to believe that if it started over again it would get any better results, so that it seems best to take them with no alteration, except to assume average prices of 4.6 cents for lead and 60 cents for silver. This is more nearly like the experience of the history of the smelting company. During the life of the mine the position of silver has changed profoundly. It would be interesting to figure on the same terms for the American

Smelting and Refining Company also, but since that is impossible it seems best to apply the average results deduced by Mr. Ingalls for the last seven years.

	Assay, Crude			
	Lead, %	Silver, oz.		Gross Value
Tons mined, 3,591,880	11.28	4.92		$13.33
Milling losses	1.62	1.10		2.15
Recovery by milling	9.66	3.82		11.18
Cost of mining	$2.665			
Cost of plant	.800			
Total cost to mining company excluding purchase of land				3.47
Tons shipped, 675,858	51.45	20.31		
Value per ton shipping product, gross		$59.52		
Freight to smelter		8.51		
Freight to refining 51 per cent. of 6.40		3.26		
Refining 51 per cent. of 8.67		4.42		
Loss in smelting and refining lead, 6 per cent.			2.84	
Loss in smelting and refining silver, 3 per cent.			37	
Reduction to bullion		5.28		
Total smelting costs per ton concentrate		21.47		
Tons crude ore per ton concentrate		5.31		
Cost smelting and refining per ton crude				4.04
Total costs mining		3.47		
Total costs smelting		4.04		7.51
Total losses milling		2.15		2.75
Total losses smelting		.60		
Total costs and losses				10.26
Profit per ton				3.07

Fairness of Custom Smelting Rates

If we proceed to calculate the cost of lead we get a surprising result. The lead equivalent in the ore is 230 lb. actually saved. Dividing this into the total cost of $7.51 we get 3.265 cents per pound as the total *selling cost* of lead from the Bunker Hill lode. The surprising thing is that this cost is higher than the actual cost to the mining company for 1908 by nearly ½ cent. While it is true that in this case we are figuring on a higher mining cost by 46 cents a ton than those for 1908, that only accounts for 0.2 cents per pound, leaving 0.26 cents still to be accounted for. In my calculation of smelting costs I have assumed reduction in Denver and refining on the Atlantic coast. It seems probable that a saving is made on these figures by smelting at more favorable points for freight rates. But whatever saving can be thus secured is not likely, at the best, to counterbalance the apparent loss to the smelting company. We are driven to conclude that the Cœur d'Alene ores are treated at exceedingly favorable rates on account of the use of their lead contents as a collector for precious metals in other ores. Mr. Ingalls calculates that an average percentage of lead in the charge is 10 per cent. This would be about 12½ per cent. in the ore treated. If we take the latter figure and assume that the smelting company only charges the ore with the refining of that amount of bullion we may reduce the cost for freight and refining of bullion to $1.90 per ton instead of $7.68 (freight $3.26, refining, $4.42). On this basis the smelting company comes out whole.

At any rate the conclusion seems warranted that there is no sound basis for adverse criticism of the American Smelting and Refining Company for its treatment of the Cœur d'Alene mines. On the contrary, it undoubtedly gives better terms to the operators than they would be able to secure by smelting for themselves.

Costs in the Broken Hill District

For an interesting comparison let us turn from the Cœur d'Alene to the Broken Hill district in Australia, where the Broken Hill Proprietary mine is by far the greatest lead-silver producer in the world. This property has produced in eight years of which reports are available to me, 4,001,969 long tons of ore, which yielded 398,470 long tons of lead, 35,504,331 oz. silver, and 32,886 oz. gold. Reducing this to terms of short tons in order to make comparison with American mines more obvious, we have 4,482,202 short tons, yielding 9.95 per cent. lead, 7.92 oz. silver, and 0.008 oz. gold. The cost for mining, concentrating, smelting, refining, marketing, general expenses, and depreciation has been exactly $9 per ton.

The cost statements issued by this company look upon the whole operation as a unit, *i.e.*, no sharp line is drawn between mining, concentrating, and smelting. As nearly as I can judge, however, the costs per ton for the year 1906 were as follows:

Short tons mined, 653,362	
Cost for mining and development	$3.01
Concentration	1.06
Smelting, refining, and marketing	3.86
General expense and depreciation	.75
Total	$8.68

These costs seem to be near enough the average to give a fair conception of the general results. The figures covering depreciation are adequate. About $2,000,000 has been written off the accounts in eight years and the whole plant of this great concern stands on the books at the end of the period at only $1,933,575. There were 3,000,000 tons of ore then developed.

The costs of this mine are high, owing to unfavorable external factors. The climate is extremely arid; the country is a desert. Fuel, water, labor, and transportation are all expensive. As a good example let us take the fuel and flux account which amounted to $1.39 per ton, about twice as much as would be required for mining and smelting the same amount of Cœur d'Alene ore at the points where the work is done. Mine timber costs 30 cents per ton mined, twice as much as at the Bunker Hill. These figures indicate such a set of external factors as to explain why it costs $4.07 per ton for mining and concentrating at the Broken Hill against $3 or less in the Cœur d'Alenes. The internal factors for mining are good.

On the smelting side we find that the proportion to be smelted is high, being one ton in 2.9, against one ton in 3.84 at the Bunker Hill. The actual cost for smelting, refining, and marketing Broken Hill concentrates is $11.19 per ton smelted. This includes freight on ores from the mine at Broken Hill, N. S. W., to Port Pirie, which is $2.12 per short ton. It does not seem to include freight on bullion from Port Pirie to market. Costs mean the production of metals ready for delivery at Port Pirie. These facts seem to permit of the following comparison with American results on Cœur d'Alene:

Smelting Costs of Broken Hill and Cœur D'Alene Ores

	Broken Hill	Cœur d'Alene
Freight from mine to smelter, neglecting moisture	$2.12	$8.00
Freight, smelter to refinery		2.90
Smelting	9.07 (Smelting and Refining)	5.28
Refining		3.99

It appears, therefore, that for equivalent work the American practice in smelting costs about the same as the Australian. We find that Broken Hill ores averaging 28.8 per cent. lead cost for actual smelting and refining $9.07 per ton against $9.27 per ton for smelting and refining Cœur d'Alene ores averaging 46 per cent. lead. The freight in American practice performs the triple function of bringing the ores nearer to bases of fuel supply, of bringing them in contact with other ores that can be profitably smelted in conjunction, and of bringing them nearer the markets where they are to be finally sold.

If the freight items are to be neglected entirely the comparison is unfair to the Broken Hill work, because that company, while not paying freight on its ore beyond Port Pirie, does pay freight on its fuel and other smelting supplies to Port Pirie. We are, therefore, brought to conclude that there are no figures for determining just what differences there are in smelting and refining costs between the Broken Hill and the American works. It is quite plain that mining and milling are more costly in Broken Hill than in the Cœur d'Alene and that for this the unfavorable external factors of the Australian desert are a sufficient explanation.

Taking the average cost of working the Broken Hill ores at $9 per ton and assuming that the products sell in the proportion of 3.15 cents[1] per pound for lead, and 60 cents per ounce of silver, we find that Broken Hill ores are worth $11 a ton, and that lead during the period reviewed has cost 2.78 cents per pound, silver 49 cents per ounce, and gold $18 per ounce.

Lead and Silver from Park City, Utah

In this important district there are, (1) ore deposits in fault fissures, and (2) replacement deposits in limestone. Of the fissure veins worked thus far only one, the Ontario, has been remunerative. It seems that geologically the ores are all of fissure origin. A great flat formation of quartzite is overlaid by 200 ft. of limestone; the limestone is covered in turn by a bed of soft black shale. Faults traversing the formation produce fracturing in the quartzites and limestones, and form channels

[1] I have assumed 4.6 cents per pound as an average price for American lead. The tariff makes the difference.

for the ready circulation of water; in the shales the fissures are entirely closed up.

The result is that the mineralization caused by waters flowing upward through fissures is stopped by the shale and compelled to seek out lateral channels in the limestone. Waters of this origin have caused the deposition of important orebodies in the limestones and quartzites. The fissuring has served to facilitate the circulation laterally fully as much as vertically. In some cases the ultimate source of the mineralization is unknown; but in other cases the flat ore shoots in the limestone were fed from the Ontario fissure.

The Ontario mine was practically worked out many years ago. Since 1893 most of the ore has come from the limestone deposits. Of these the principal mines are the Daly-West, the Daly-Judge and the Silver King. These mines are very similar. The orebodies usually have a pitch of between 5 and 15° from the horizontal, and are from 50 to 200 ft. wide, and from 3 to 30 ft. thick. They follow fissures, and hence have fairly well defined courses for considerable distances, but they frequently leave one fissure to follow another. Where the limestone is brecciated at the intersection of fissures the orebodies are largest.

The original ore was a mixture of sulphides of iron, lead, copper, and zinc, carrying considerable silver and some gold. Oxidation has effected an important rearrangement. Nearest the surface the ores are lead carbonates free from zinc; lower are lead sulphides rich in silver, but free from zinc; lower still there has been an important regeneration of zinc-blende, and at this zone the ores are much inferior in lead and silver content. The zinc regeneration is immediately above the unaltered sulphides; these are sometimes payable, but have not been worked much.

Costs at Park City Mines

A great deal of gangue occurs in the ore and must be sorted out. At the same time much of the ore is high-grade and cannot be improved by concentration; one-third to one-half of the ore mined is of this character. Exploration and development are expensive, owing to the dip and irregularity of the orebodies. These internal factors make the costs high.

The external factors are about the average for the Rocky Mountain region.

Daly-West Production in Seven Years

	Tons
Crude ore shipped direct	224,418
Ore milled	489,415
Total	713,833
Concentrates shipped	97,634
Total shipments	322,052
Lead, 73,942 tons, at $92	$6,800,000
Silver, 17,167,000 oz., at 57 cents	9,785,000
Gold, 13,847 oz., at $20.67	280,000
Copper, 12,164,000 lb., at 15 cents	1,800,000
Total value	$18,665,000
	$58 per ton

Freight, treatment, and deductions	$8,327,000 =	$25.83 per ton
Cost of mining and milling		13.72 per ton
Total cost		$39.58 per ton
Profit per ton shipped		18.42

Results per Ton Mined

Average value, $28.40.	
Cost of mining and milling	$6.26
Milling losses, average 8 per cent.[1]	2.24
Freight, smelting, refining, and deductions	11.66
Total cost	$20.16
Profit per ton mined	8.24

[1] See explanation below.

Summary of Daly-West Costs — 1900 to 1906 Inclusive

	Per Ton Mined and Milled	Per Ton Ore and Concentrates Shipped
General expense	$0.42	$ 0.92
Exploration and development	0.60	1.31
Mining	3.38	7.40
(Per ton milled)	(1.36)	
Milling	1.00	2.19
Construction	0.30	0.66
Shipping and selling	0.56	1.24
	$6.26	$13.72

One may indulge a little skepticism as to the accuracy of these reported savings in the lead. It seems that the ore must have been assayed for lead by fire assay which gives inaccurate results, or there must have been errors in sampling and weighing. I

MILL SAVING REPORTED

	Lead, Per Cent.	Silver, Per Cent.
1900	92.	67.69
1901	92.87	70.16
1902	93.	72.
1903	97.9	72.3
1904	99.	70.5
1905	99.5	72.5
1906	98.44	73.04

prefer to believe that the saving of lead was about the same as that reported for silver. We may lump the whole mill saving roughly at 75 per cent. On this basis the mill losses would be about 8 per cent. of the entire product.

The Daly-Judge mine is west of the Daly-West, and the ore-bodies are in the zone of zinc regeneration, or in the original sulphides underlying that zone. The mine has not been very profitable. Attempts have been made to improve the mill from time to time and the result has been a considerable cost for construction, but since the improvements do not seem to guarantee future earnings the construction should probably all be charged to operating.

SIX YEARS' OPERATION, DALY-JUDGE MINE (213,000 TONS)

Lead, 19,375 tons	$1,785,000
Silver, 1,390,000 oz.	792,000
Gold, 4,800 oz	99,000
Copper, 272,000 lb.	41,000
Zinc, 8,614 tons	900,000
Total value	$3,617,000
Cost of smelting, refining, and marketing and smelter deductions (losses) — total	$1,845,000
per ton	$8.66
Mining and milling costs	7.27
Probable mill losses	3.00
Total costs and losses	$18.93
Profit	1.00
Total value of ore as mined	$19.93

Details of Cost for 1907

Mining	$3.03
Exploration and development	0.40
Concentrating	0.95
Shipping and selling	0.33
General expense	0.53
Construction	0.21
Total	$5.45

These costs are lower than the average. During the period under review the mine was shut down for two years in order to prosecute development. Development in the whole period has averaged about $1.50 per ton.

The Silver King is a rich and profitable mine. It does not publish reports, but its costs are approximately $9.40 per ton mined and milled and $15.50 per ton of selected ore and concentrates shipped. The ore is richer than the Daly-West in lead and much richer in gold, but about the same in silver.

The Park City ores present the following factors making high costs: (1) Relatively small orebodies that must be followed over large areas, thus establishing a high cost for exploration and development; (2) a careful selection of the ores and the rejection of large amounts of waste; (3) a large percentage to be smelted and a very high charge for smelting.

Smelting Costs Applied to Park City Ores

Let us take the average ore produced by the Daly-West mine and calculate smelting results on it, assuming a freight rate of $1.50 per ton to Salt Lake from the mines, and prices of 4.6 cents per pound lead, 15 cents per pound copper, and 60 cents per ounce silver. Let us assume also that all refining is done at the Atlantic seaboard. The lead and copper together amount to almost exactly 25 per cent. of the ore.

The assay of shipping product is as follows:

			Gross Value New York
Lead	22.96 per cent.	=	$21.12
Copper	1.89 per cent.	=	5.67
Silver	53.31 ounces	=	31.99
Gold	.043 ounces	=	.87
			$59.65

Freight to Salt Lake on concentrates		$1.50
Freight to New York on bullion 25 per cent. of $10.80		2.70
Refining 25 per cent. of $8.67		2.17
Reduction to bullion		5.28
Losses 3 per cent. silver	0.96	
6 per cent. lead	1.27	
$33\frac{1}{3}$ per cent. copper	1.89	4.12
	4.12	$15.77

The actual deductions for freight, treatment and losses, were $25.86 per ton, so that we must estimate a profit of $10.09. This is a very different result from that obtained in the case of Cœur d'Alene ores.

Assuming that these figures are not far from the truth, and assuming 2.2 tons mined to one ton shipped, we have for the whole problem of silver-lead ores at Park City the following minimum costs per ton mined, as shown by the experience of the last seven years:

Mining, milling, and all costs to mining company	$6.26
Smelting, refining, and marketing	7.17
Total	$13.43

Since mill losses must be estimated at not less than 10 per cent. on low-grade ores and smelting losses at 5 per cent. more, the actual costs can only be 85 per cent. of the original value. In round numbers, therefore, an ore in Park City must be worth $15 a ton before there can be a profit in it for anybody. At average prices this figures about 11 per cent. lead and 9 oz. silver.

CHAPTER XVI

THE COST OF SILVER-LEAD SMELTING[1]

Blast-furnace operation — Roasting — Cost of smelting plant — Calculation of interest and amortization — Functions of copper in lead smelting — Freight and refining — Cost of refineries — American Smelting and Refining Company — History and statistics — Tonnage smelted — Average grade of ore — Growth of profits — Division of ore value — Costs and contracts on average ores — Conclusions regarding derivation of profits.

THE cost of smelting and refining in the United States ranges widely among the various plants, depending upon the size and nature of the plant; the cost of labor, fuel, fluxes, and material; the character of the ores smelted, etc. Thus, nine plants during the same period of six months, a few years ago, showed costs of smelting referring to the blast-furnace operation only, per ton of charge (ore and flux), which ranged from $2.50 to $4.80. This appears in the following list: A, $3.418; B, $2.525; C, $3.260; D, $3.331; E, $3.754; F, $3.429; G, $3.929; H, $4.039; I, $4.781. Average, $3.607.

In the treatment of the argentiferous ores of the West, the present practice is to roast only those that are low in lead, and charge raw into the blast-furnace the rich galena. The cost of roasting is $2 to $2.50 per ton of ore roasted. The cost of smelting a ton of charge in a large modern plant, under favorable conditions, is about $2.50, of which about 84 cents is for coke and $1.66 for labor, power, and supplies. The expense of administration amounts to about 16 cents additional. Consequently, the total cost per ton of charge (ore and flux) is about $2.66. If the ore amounts to 80 per cent. of the charge, which corresponds to the ordinarily good practice, the cost per ton of ore is about $3.33.

[1] This article is a condensation of one published originally in *Eng. and Min. Journ.*, of Aug. 15, 1908. While the present article is greatly condensed from the original, certain points have been amplified and figures have been brought up to date.

An average of the work of many large smelting plants shows that for every ton of charge smelted in the blast furnace, about 0.4 ton of material (ore and matte) must be roasted. The cost of roasting ranges from $2 to $2.50 per ton. Taking the lower figure, in view of economies that have been effected by the blast-roasting process, we may figure that on the average 80 cents is to be added to the cost of smelting, making the total cost per ton of ore about $4.12. Figuring on the same basis of 80 per cent. of ore in the charge, the average for the nine works previously mentioned would be $3.607 ÷ 0.80 = $4.50 approximately.

Interest Charges, Amortization, etc. — Works, capable of smelting 1000 tons of ore per day, or roughly 330,000 tons per annum, cost nearly $1,000,000, or about $3 per ton of annual capacity. Reckoning amortization at 10 per cent. per annum, and interest on the investment at 6 per cent., the smelter must add 48 cents per ton of ore smelted on account of these fixed charges. Moreover, the smelter is bound to carry a large stock of ore on hand. Assuming that the works which is treating 330,000 tons of ore per annum has always 30,000 tons on hand, and that the average value of the ore is $30 per ton, the interest charge on each ton of ore smelted is upward of 15 cents. A month's delay in realizing on the products adds 15 cents more.[1] This makes a total of $5.28 up to the production of base bullion. The smelter recovers about 95 per cent. of the lead and 97 per cent. of the silver in the original ore. He pays the miner for only 90 per cent. of the lead and 95 per cent. of the silver, wherefore he has a certain leeway on these metals, as he may have also on gold for which he pays the miner only 95 per cent., but recovers 100 per cent.[2]

[1] It will appear subsequently that this estimate of the time that ore and crude metal are in process of treatment is under, rather than over, the average. As a matter of fact smelters roughly figure interest on the basis of 90 days.

[2] The actual extraction of lead is less than 95 per cent., but in good practice it is 95 per cent. on the basis of fire assay, on which much of the ore is purchased, so it is proper to figure 95 per cent. However, this is drawing it rather tightly upon the smelter, and considering the further loss of 1 per cent. which the lead suffers in refining the smelter who pays for 90 per cent. of the lead in the ore does not obtain any great margin on this item, nor does he on the purchase of the silver. The smelter does not really recover 100 per cent. of the gold, although he may apparently do so, and even more, because of the cumulative effect of small amounts of gold, too little to figure in the ore settlements, which give the smelter more to start with than his books show.

Copper. — Besides the gold, silver, and lead of the ore there is a certain amount of copper, modern practice demanding the presence of 0.5 to 1 per cent. in the charge in order to insure a clean slag. This copper goes partly into the slag, and partly into the base bullion (from which it is recovered during the refining process), but chiefly it is obtained in the form of matte, which is concentrated up to about 40 per cent. copper and then is despatched to Omaha, where it is converted into blister copper. The converting of this leady matte is more costly than the treatment of ordinary copper matte, and indeed throughout the lead smelting process copper is subject to high losses, especially in the slag of the first smelting, which follows from the common metallurgical principle that losses are quantitatively constant (or nearly so) and proportionately variable. Consequently in the treatment of an ore so low in copper as 0.5 to 1 per cent. the percentage of loss is large. It may be generalized as 30 per cent. It is for this reason that the smelter makes so large a deduction from the copper in the ore (1.3 units from the wet assay) and pays for it at 3 to 7 cents less than the price of refined copper at New York. Of course it will be understood that the deduction of 1.3 units pertains to ores that contain sufficient copper to deserve payment, and that those ores when mixed with many others that contain no copper give an average furnace charge with 0.5 to 1 per cent. copper. It may be explained also that all of the copper does not finally appear as refined metal, a fairly large quantity being obtained and marketed as bluestone. In the generalization which I am attempting it is impossible to go far into these details.

Freight and Refining. — The products of the smelteries are base bullion and lead-copper matte. The latter goes to Omaha for converting and the blister copper thence is passed on to Perth Amboy for refining. The base bullion goes to Denver, Omaha, Chicago, and Perth Amboy. As in the case of smelting there are differences among these works as to the cost of refining and other conditions, but inasmuch as the prices for lead and copper are based on the market at New York it is best to confine attention to the refining and handling of base bullion at that center.

The freight rate on base bullion from Salt Lake City to New York is $10.80 per ton; from Denver and Pueblo to New York it is \$6.40 per ton. The cost of refining is \$6 to \$6.50.[1] Other costs are lighterage, \$0.625; selling, \$0.40; miscellaneous, \$0.325. This gives a total of \$7.60 exclusive of freight. The cost of a lead refinery is about \$6.66 per ton of annual capacity, on which amortization at 10 per cent. and interest at 6 per cent. come to \$1.07, making the total cost of refining, lighterage, selling, etc., about \$8.67. Consequently, the charges on a ton of ore smelted at Salt Lake and yielding 10 per cent. of lead are as follows: Smelting, \$5.28; freight on bullion, \$1.08; refining, etc., \$0.87; total, \$7.23.

In addition to this total, the reports of the American Smelting and Refining Company indicate a general expense amounting to 25 to 40 cents per ton of ore smelted, the smaller figure being achieved in the more recent years. Consequently we may put the total cost of smelting and refining at about \$7.50 per ton of ore.

In custom-refining it is the practice to pay the smelter, *i.e.*, the seller of the base bullion, for the gold at \$20 per ounce; for the silver at the New York price less 1 cent per ounce (this is 98 per cent. when silver is worth 50 cents per ounce); and for the lead at 98 per cent. of the New York price. The actual extraction of lead is 99 per cent. The loss of silver is so small that it may be disregarded for present purposes.

American Smelting and Refining Company. — The reports of this company throw but little light upon the subject of the cost of smelting. Its statement of assets, gross earnings, profits, etc., for a series of seven years, is given in the accompanying tables. Before proceeding to discuss these figures, it is important to make certain explanations. In each year the figures are for the fiscal period ending April 30, wherefore the major part of the period pertains to the preceding calendar year. The item that I have entered as "Repairs" is given in the reports of the company as "Ordinary Repairs and Betterments." What I have called "General Expense" includes all of the general expenses of administration, together with interest and taxes. "Net Earnings," so-called by the company, are evidently not properly designated, being merely the operating profit. The true profit, or actual net earnings, appears later in what the company calls "Net Income." Under "Improvements," I have entered what the company calls "Appropriation for Extraordinary Improve-

[1] At Chicago the cost is only \$4, and under favorable conditions lead refining should be done at that figure.

ments and New Construction." From the uniformity of this account, I judge that it represents chiefly the new construction undertaken to replace worn-out or antiquated plant; in other words, it is in this way that the company makes good the depreciation of its property, which otherwise would have to appear in an amortization account.

Except in its recent statement to the New York Stock Exchange that the average amount of ore smelted is 3,500,000 tons per annum, the smelting company has never made any statement of its production of metals or amount of ore smelted. The nearest that it has come to communicating this important information was in the report for the fiscal year ended April 30, 1903, wherein it stated that the volume of business transacted during the year is reflected in the following figures: Metal content of ore purchased: gold, 1,025,132 oz.; silver, 62,389,438 oz.; lead, 492,960,350 lb.; copper, 47,919,666 lb. Fuel consumption: coal, 544,790 tons; coke, 433,431 tons; fuel oil, 3,523,904 gal. Freight traffic: total tonnage moved, 4,434,484.

I. A. S. and R. Co. Comparative Statement of Assets

Year	1903	1904	1905
Property account	$86,845,671	$86,845,671	$86,845,671
Investment account	1,028,598	1,680,306	(a) 3,982,576
Metal stock (Au., Ag., Pb., Cu.)	18,010,687	17,032,300	16,418,543
Material, fuel, flux	1,107,253	1,224,688	1,118,902
Cash	2,339,154	4,047,423	4,636,649
Total assets	$109,331,362	$110,830,387	$113,002,340

(a) Does not include 177,510 shares of the common stock, American Smelters Securities Company, par value $17,751,000.
(b) Includes $500,526 as "net current assets."

Year	1906	1907	1908
Property account	$86,845,671	$86,845,671	$86,845,671
Investment account	(a) 4,179,915	(a) 3,810,595	3,950,088
Metal stock (Au., Ag., Pb., Cu.)	19,415,200	18,251,587	17,519,664
Material, fuel, flux	1,114,893	1,317,544	1,380,742
Cash	4,757,929	6,706,984	5,629,034
Total assets	$116,313,607	$116,932,381	(b) $115,825,725

(a) Does not include 177,510 shares of the common stock, American Smelters Securities Company, par value $17,751,000.
(b) Includes $500,526 as "net current assets."

II. A. S. and R. Co. Comparative Statement of Income Account

Year	1902	1903	1904	1905
1. Earnings	$7,038,682	$9,403,711	$9,425,443	$10,506,683
2. Repairs	791,306	770,854	818,141	878,648
3. General expense	1,385,757	1,056,786	701,729	729,224
4. Net earnings	4,861,619	7,576,786	7,905,573	8,898,811
Employees' fund	—	—	91,254	216,816
6. Improvements	—	655,683	597,582	425,289
7. Metal account	1,300,000	1,500,000	500,000	637,795
8. Net income	3,561,619	5,421,103	6,716,737	7,618,912
9. Dividends	3,500,000	3,500,000	4,750,000	6,000,000
10. Surplus for year	61,619	1,921,103	1,966,737	1,618,912
11. Total surplus	2,951,968	4,873,071	6,839,808	8,458,720

Year	1906	1907	1908
1. Earnings	$11,665,886	$13,250,058	$9,403,282
2. Repairs	828,582	976,535	933,130
3. General expense	675,945	763,854	836,866
4. Net earnings	10,161,358	11,509,669	7,633,287
Employees' fund	449,204	540,420	*Nil.*
6. Improvements	938,100	1,054,996	622,096
7. Metal account	*Nil.*	*Nil.*	*Nil.*
8. Net income	8,774,055	9,914,253	7,011,191
9. Dividends	6,750,000	7,000,000	—
10. Surplus for year	2,024,055	2,914,253	11,191
11. Total surplus	10,482,775	13,397,028	13,408,219

Tonnage of Ore Smelted. — These data enable us to arrive approximately at the amount of ore purchased, and we may assume that the amount smelted was approximately the same. It is a fair assumption that the ores were purchased in substantially the proportions required to make a suitable smelting mixture, and that the lead content was in the neighborhood of 10 per cent. of the total ore. The purchase of 246,480 tons of lead would therefore imply 2,464,800 tons of ore. Some of the copper purchased was included with the lead charge, but some was smelted separately. As to this particular I can do no more than surmise that 100,000 tons of copper ore may have been smelted separately, and that the total amount of ore smelted by the company in this year was about 2,564,800 tons. It will appear that this estimate is probably not far out of the way. In 1901 the American plants of the company alone were smelting at the rate of about 2,000,000 tons of ore per annum, and from that time onward business increased. In the fiscal year ending April 30, 1903, the total movement of freight is given as 4,434,484 tons. Deducting 991,221 tons for fuel (allowing 13,000 tons for the oil) and 270,439 tons of lead and copper, we have left 3,172,824 tons for ore and limestone, of which the latter would normally be about one-sixth, deducting which there remains 2,644,018 tons for ore. There is some traffic in matte and other products from one works to another, but making allowance for such duplications and overestimates it seems not unreasonable to assume 2,500,000 tons of ore smelted. On this basis, namely 2,500,000 tons, it appears that the total actual profit to the company in the year ending April 30, 1903, was a little less than $2.20 per ton of ore. Inasmuch as this is determined by making the tonnage the divisor of the whole profit of the company and it is not to be doubted that even in 1902–03 the company was making handsome returns from its mercantile and investment accounts. I believe it is reasonable to assume that its profit in smelting properly considered, at that time may have been about $2 per ton. Mr. Edward Brush, of the company, before the Ways and Means Committee, December 16, 1908, stated that in the fiscal year ended April 30, 1908, the company smelted 3,372,750 tons of ore. The net profit in that year was $7,011,191. Consequently the total profit per ten of ore was a little less than $2.08. The actual smelting profit was, of course, something less, because the company realizes more or less from its various ventures that are not to be referred directly to its smelting business.

Average Grade of the Ore. — The figures given for the fiscal year ending April 30, 1903, also convey valuable information respecting the average metal contents of the ore smelted in the United States and Mexico. Proceeding still on the assumption that the total tonnage was 2,500,000, the average was 0.41 oz. gold, 24.95 oz. silver, 197.4 lb. lead, and 19.17 lb. copper. The substantial accuracy of this deduction is confirmed by the report of the census for 1904. (The census confusingly designates the year as 1905, because its investigation was made at that time, but the investigation related to 1904.) According to the census, the amount of argentiferous ore treated in 1904 was 2,271,724 tons, which yielded an average of 0.42 oz. gold, 16.53 oz. silver, 198 lb. lead, and 22.72 lb. copper. It is to be remarked that the figures of the census relate only to ore smelted in the United States, while my previous figures have included the ore smelted both in the United States and in Mexico. Moreover, the latter figures are for contents of the ore purchased, while the census figures are for yield of the ore. However, the agreement is sufficiently close to confirm the belief that my estimate is a close approximation.

Another interesting deduction may be made from the statistics of the smelting company for the year ending April 30, 1903. During that period, the average price for silver was 50¼ cents per ounce; of copper, 12.452 cents per pound; of lead, 4.147 cents per pound. Computing ore of the average grade shown for the year ending April 30, 1903, on the basis of 100 per cent. of the metal contents at the average New York prices for silver, lead, and copper, and $20.56 per ounce for gold (which is what the United States Smelting, Refining, and Mining Company realized for its product in 1907, although the coinage value of gold is $20.67 per ounce), it appears that the maximum gross value of this average ore was $31.54 per ton, itemized as follows: 0.41 oz. gold at $20.56, $8.4296; 24.95 oz. silver at 50¼ cents, $12.5374; 197.3 lb. lead at 4.147 cents, $8.1820; 19.17 lb. copper at 12.45 cents, $2.3867. Total, $31.5357. Having already shown that the average profit per ton of ore smelted in that period was probably about $2, the actual net profit to the smelter was a little more than 6¼ per cent. of the ore value.

Subsequent Increase in Profits. — It is impossible to follow analytically the subsequent history of the company in any way that has a very sound foundation. The reports show a marvelous increase in the profits, which were $5,421,103 in 1902–03 and $9,914,253 in 1906–7. During this period of four years the amount of ore smelted by the company increased greatly, but there is no reason to surmise that it increased in the same ratio as the profits; indeed, there is sufficient evidence to warrant me in saying positively that it did not, and that if the tonnage of ore smelted in each year were made the divisor of the net profits reported the quotients would be steadily increasing up to the last year or two. However, any such figuring would be misleading, because the company has undergone great expansion and derived greatly increased profits from sources that are not properly referable to the direct smelting operations. The company avers that it has not increased treatment charges, and there is much evidence in support of that assertion.

Explanation of Increasing Profits. — In directing attention to the subject of the increasing profit shown by the reports of the smelting company, it is important to consider a variety of conditions. It is well known that it is much more economical to smelt on a copper basis than on a lead basis. The difference in favor of the former is fully $1 per ton of ore. Consequently, the more copper ore to be smelted, the more the profit, and the increasing net earnings of the smelting company are doubtless due to some extent to the increased amount of ore smelted on the copper basis. It is also well known that the margin on ore purchased in Mexico is much greater than on American ores, and a large part of the profit of the smelting company is derived from its Mexican business, which has been rapidly increasing. The lowest margin, probably, is realized by the smelteries in Colorado, which until lately have treated in the neighborhood of 1,000,000 tons per annum and operate rather uniformly at that rate. A few years ago the profit in smelting in Colorado was only about $1 per ton, and probably it is no larger at the present time. It is claimed also that the profit in smelting in Utah has been only about $1 per ton since competition has been active at that point. On the other hand the profit at non-competitive points and in Mexico must be large.

The increase in the earnings of the smelting company has also been promoted without doubt by its profit-sharing system, which was designed to increase efficiency and has had that effect. The company has benefited from economies in administration, as is clearly shown by the decreasing amount to the account of general expense. Furthermore, it has derived great advantage from the introduction of metallurgical improvements, such as the Huntington-Heberlein process, and the concentration of operations at the most economical plants. Finally, we come to the question of metal stock account, wherein the purchaser of ores may lose or make a great deal through fluctuation in the value of the metals. In the long run such fluctuations are expected to balance, and temporary gains or losses are commonly charged to an account representing quotational profit or loss. In a long upward trend of prices, a buyer of ores may realize a great profit; and similarly in a sharp decline, he may suffer an immense loss. From 1901 to the end of 1907 the general trend of the metal markets was upward, and undoubtedly the greatest factor in the increase in net income up to April 30, 1907, was the appreciation in the value of metals on its hands, just as since June, 1907, its net income suffered severely from the decline. The company carries in its statement of assets an item of "metal stock" ranging from \$16,418,543 to \$19,415,200, which represents its valuation of ores and metals on hand. The nature of its business requires that large quantities of ore and crude metal be in stock at all times. It appears from the data deduced in this article that the stock necessarily carried is from 20 to 25 per cent. of the annual turnover; in other words, the ore and its products are in process of treatment and in transportation for 2½ to 3 months.

Division of Ore Value. — Now let us see what division is made of the value of an ore assaying 0.41 oz. gold, 24.95 oz. silver, 179.3 lb. lead, and 19.17 lb. copper, which was the composite of all the ore bought by the American Smelting and Refining Company in 1902–03. The smelter and refiner probably realized, from this ore approximately as follows: gold, 0.41 oz. at \$20.56, \$8.43; silver, 24.95 oz. × 0.97 at 50¼ cents, \$12.16; lead, 197.3 lb. × 0.94 at 4.147 cents, \$7.69; copper, 19.17 lb. × 0.7 at 12.45 cents, \$1.67. Total, \$29.95.

The expenses from the time of receipt of the ore at the smelting works to the sale of the refined metals are approximately as follows:

1.	Smelting, 1 ton @ \$4.50	\$4.50
2.	Converting 40 lb. copper matte @ 0.7 cents	0.28
3.	Freight on 190 lb. lead bullion @ 0.43 cents	0.82
4.	Freight on 13½ lb. copper bullion @ 0.5 cents	0.07
5.	Refining 190 lb. lead bullion @ 0.38 cents	0.72
6.	Refining 13½ lb. copper bullion @ 0.7 cents	0.09
7.	General expense	0.40
8.	Amortization	0.25
9.	Tie-up of metals	0.30
10.	Metal account	0.30
	Total	\$7.73

1. As previously computed. 3. The rate of 0.43 cents is the mean of the rates from Salt Lake and Pueblo; this assumption is necessarily arbitrary. 4. In this case also the assumption of freight rate is necessarily arbitrary. It is intended to cover all freight charges on copper from the time of leaving the first smelter. Copper matte goes to Omaha from East Helena, Salt Lake, Denver, Pueblo, and elsewhere — even from Perth Amboy — and the copper bullion thence goes to Perth Amboy. Probably the assumption of 0.5 cents per pound to cover all of this movement is too low. 7, 8. These figures are deduced from the reports of the American Smelting and Refining Company; the allowance for amortization appears to be too low. 9. As previously computed. 10. This appears to be the average allowance that has been made by the American Smelting and Refining Company, as insurance against depreciation of metals on its hands.

Inasmuch as the smelter is supposed to realize a profit of $2 per ton of ore, the total deduction for its account must be $7.73 + $2 = $9.73, and from the value of the ore, $29.95, there is left $29.95 — $9.73 = $20.22 to pay for the ore and the freight upon it to the smelting works.

Now let us see how that would figure out to the producer. We may assume a settlement on the lines of the following: gold, 0.41 oz. at $19.50, $8; silver, 24.95 oz. × 0.95 × 50¼ cents, $11.91; lead, 197.3 lb. at 2 cents, $3.95; copper, 19.17 lb. at 5.45 cents, $1.04; total, $24.90; deducting a treatment charge of $4.68 leaves $20.22 as the net value to producer. This corresponds to an ore contract reading, "Gold to be paid for at $19.50 per oz.; silver at 95 per cent. of the New York quotation; lead at 40 cents per unit; copper at the New York quotation, less 7 cents per pound; treatment charge, $4.68 per ton; neutral basis; delivery at smelter's works." This has a familiar sound, except that so small a percentage of copper is not always paid for, but it must be remembered that I am here figuring on a composite ore, the copper of which is obtained chiefly in special classes of a higher average of all ores smelted.

Conclusions. — After a consideration of the data, it is impossible to escape the conclusion that the great increase in the net earnings of the American Smelting and Refining Company from year to year is to be attributed to: 1. Enlargement in the volume of business. 2. Institution of economies (*a*) in administration; (*b*) through centralization of operations; (*c*) through metallurgical improvements; (*d*) through increase in operative efficiency. 3. Appreciation in the value of metals, due partly to natural causes, and partly to manipulations by the company. The profits on exempt lead, and on contracts with the producers of lead ore, whereby the value in excess of a certain price per pound is divided between the producer and the smelting company, must contribute largely to the treasury of the company. Since the middle of 1907 the depreciation in the value of metals has offset some of the gain previously realized. 4. Increase in the amount of ore smelted on the copper basis, which is more profitable than the lead basis. 5. Increase in earnings of subsidiary companies, such as the steamship company. 6. Earnings from investments of surplus, *e.g.*, the preferred stock of the American Smelters Securities Company. 7. Profits from investments, *e.g.*, the sale of a portion of its holding of the stock of the United Lead Company, carried into earnings for the year ending April 30, 1907.

The position of the smelting company being so strong in many respects, and the surplus which it carries being so large, the company may be forgiven for not writing off anything for amortization of its plants. As I have previously pointed out, the outlay made on account of extraordinary improvements is of the nature of an amortization account, but the amount expended so far in this way is of doubtful sufficiency. The smelteries and refineries now owned by the company must be worth in the neighborhood of $15,000,000, *i.e.*, it would cost that amount to replace them. The average amount expended for extraordinary improvements during the five years ending with April 30, 1907, was a little less than $750,000 per annum, which is only 5 per cent. of the physical value of the plants. This, it seems to me, is an insufficient allowance for amortization.

According to the statement filed by the company in the New York Stock Exchange, in January, 1909, its smelteries and refineries were the following:

SMELTERIES

Place	Plant	Furnaces	Annual Capacity
Denver, Colo	Globe	7	322,000
Pueblo, Colo	Pueblo	7	328,000
Pueblo, Colo	Eilers	6	295,000
Durango, Colo	Durango	4	146,000
Leadville, Colo	Arkansas Valley	10	509,000
Salt Lake, Utah	Murray	8	523,000
East Helena, Mont.	East Helena	4	235,000
Omaha, Neb.	Omaha	2	82,000
Chicago, Ill.	National	2	60,000
Maurer, N. J.	Perth Amboy	3	140,000
El Paso, Tex.	El Paso	10	492,000
Monterey, Mex.	Monterey	10	460,000
Aguascalientes, Mex.	Aguascalientes	10	720,000
Chihuahua, Mex	Chihuahua	3	153,000
		86	4,465,000

REFINERIES

Place	Plant	Lead Tons	Copper Tons	Gold and Silver Oz.
Omaha	Omaha	156,000	....	36,000
Chicago	National	84,000	....	16,400,000
Maurer	Perth Amboy	66,000	66,000	36,000,000

The annual product of the refineries is about as follows: gold, 1,250,000 oz.; silver, 66,000,000 oz.; lead, 225,000 tons; copper, 66,000 tons.

CHAPTER XVII

ZINC MINING

Statistics of spelter production — Southwest Missouri — Geology of Joplin district — Exploration — Mining methods — Milling methods — Losses in mining and realization — Cost statements — Wisconsin zinc mining — Generalized statements of cost of producing spelter from ores of Wisconsin, Leadville, and Joplin.

ZINC MINING

THE following tables show the production of the United States and of the world. It is to be observed that Table No. 1 showing the production of spelter (which is simply the trade name for metallic zinc) gives the output of the States where smelting is done rather than where the ore is mined. This conveys to a certain extent a false impression. As a matter of fact, the principal production of zinc ores is obtained from Missouri, Wisconsin, Colorado, and New Jersey: (For tables see pages 309 and 310.)

SHIPMENTS OF ORE FROM THE JOPLIN DISTRICT
(IN TONS OF 2000 LB.)

Year	Zinc Ore	Lead Ore	Year	Zinc Ore	Lead Ore
1895	144,487	31,294	1902	262,545	31,625
1896	155,333	27,721	1903	234,873	28,656
1897	177,976	30,105	1904	267,240	34,362
1898	234,455	26,687	1905	252,435	31,679
1899	255,088	23,888	1906	278,930	39,189
1900	248,446	29,132	1907	286,589	41,742
1901	258,306	35,177	1908	259,609	38,532

PRODUCTION OF ZINC IN NEW SOUTH WALES
(IN TONS OF 2240 LB.)

	1903	1904	1905	1906	1907	1908
Spelter	286	299	544	1,008	984	1,065
Zinc in ore exported	14,625	22,318	30,637	33,427	76,645	113,853

PRODUCTION OF SPELTER IN THE UNITED STATES

States	1900	1901	1902	1903	1904	1905	1906	1907	1908
Colorado	—	—	—	877	4,906	6,599	6,260	5,200	3,079
Illinois (a)	37,558	44,896	49,672	49,526	47,607	45,357	48,238	56,103	50,244
Kansas	57,276	74,270	87,321	87,406	103,721	114,948	129,741	133,561	99,136
Missouri	20,138	13,083	10,548	9,894	12,056	11,800	11,088	11,594	10,196
Oklahoma	—	—	—	—	—	—	—	5,094	14,867
South and East (b)	8,259	8,603	10,698	10,799	13,513	23,044	30,167	38,060	32,989
Total tons of 2000 lb.	123,321	140,822	158,239	158,502	181,803	201,748	225,494	249,612	210,511
Total tons of 2240 lb.	110,028	125,734	141,283	141,520	162,324	180,132	201,343	222,868	187,887
Total metric tons	111,794	127,751	143,792	143,792	164,921	183,014	204,548	226,398	190,933

(a) Up to 1903, inclusive, includes also the production of Indiana. (b) New Jersey, Pennsylvania and Virginia, and (since 1903) West Virginia.

PRODUCTION OF ZINC IN EUROPE AND AMERICA

(IN METRIC TONS)

Year	Austria	Belgium	France	Germany	Holland	Italy	Russia	Spain	United Kingdom	United States	Total
1896	6,888	113,361	45,585	153,082	4,770	Nil	6,257	6,133	25,278	70,432	421,786
1897	6,236	116,067	38,067	150,739	6,600	250	5,868	6,244	23,805	91,070	444,946
1898	7,302	119,067	37,155	154,867	6,700	250	5,664	6,031	28,387	103,514	468,937
1899	7,192	122,843	39,274	153,155	6,235	251	6,331	6,184	32,322	117,644	491,331
1900	6,742	119,315	36,305	155,799	6,845	547	5,693	5,611	30,207	111,794	465,438
1901	7,558	127,170	37,600	166,283	7,855	511	6,090	5,354	29,877	127,751	516,049
1902	8,309	124,780	36,300	174,927	9,910	485	8,280	5,569	40,244	142,552	552,356
1903	8,949	131,740	37,416	182,548	11,515	126	9,901	5,134	44,110	143,792	569,971
1904	9,159	137,323	41,600	193,058	12,895	189	10,607	5,887	46,218	164,921	621,857
1905	9,204	142,555	43,200	198,208	13,550	5	7,520	6,184	50,125	183,014	653,565
1906	10,711	148,035	46,536	205,691	14,650	69	9,610	6,209	52,587	204,548	698,646
1907	11,359	154,492	(c)49,733	208,195	14,990	(b)	9,738	(c)6,000	55,595	226,398	736,500
1908	14,224	165,018	(c)49,800	216,874	17,255	(b)	9,753	(c)6,018	54,472	190,933	724,347

Zinc Mining Statements

I have not been able to secure any statements by zinc-mining companies showing the same outline of the business that can be secured in the case of most other mining enterprises. Through a certain familiarity with the business, however, I am able to supply a perspective of results in some of the more important fields in the following sketches of zinc-mining operations of Joplin and of Wisconsin. At the end of the chapter will be found some generalized statements of the cost of mining ores of certain assumed grades in these districts and in Leadville, Colorado. As a matter of fact there is no such thing as a complete zinc-mining business in the United States outside the operations of the New Jersey Zinc Company, which is apparently one of the most secretive of all corporations. The product in general is obtained through the combined, but more or less disjointed, efforts of leasers and custom smelters.

The Southwest Missouri Zinc District

This district produces 60 per cent. of the spelter of the United States, and, therefore, bears nearly the same relation to the zinc business as Lake Superior mines bear to the iron business of the country. Perhaps no other district of equal importance is so little understood by outside mining people.

The Joplin field is a very extensive one, more or less ore having been mined over an area of perhaps 2000 sq. m., but within this extensive field by far the greater part of the production has come from three or four localities. Of these the most important may be called the Webb City zone, which is said to have produced about one-half of the entire output of the field. In the immediate vicinity of the city of Joplin, there are very extensive mineralized zones extending in a northwest and southeast direction. A third place that has produced extensively is in the neighborhood of Galena, Kansas. I shall attempt a general description of these orebodies by using as an example the great Webb City zone.

This productive area extends from Oronogo on the northwest to Porto Rico and Duenweg on the southeast, a distance of ten miles. For this distance the average width of the zone is perhaps three-quarters of a mile, though it widens at one or two places to a mile and a half and narrows at other places to a quarter of a mile. In a rough way, I estimate the productive ground at 4800 acres. It would not be inaccurate to describe this entire tract as a continuous orebody, although it shows great irregularities. The total production of this zone has been approximately 3,000,000 tons of zinc and lead ore, derived from mining and milling 75,000,000 tons of rock. The value actually realized has been about $90,000,000, but at present prices the amount would be much greater. The production of the zone for 1907 was 109,229 tons zinc ore worth $5,000,000, and 24,336 tons lead ore worth $1,700,000, approximately, making a total value on the ground of $6,700,000. The spelter realized from this production may be estimated at 55,000 tons, worth in St. Louis $6,390,000. The pig lead realized may be estimated at 19,000 tons, worth in St. Louis $1,985,000. The average price of spelter was 5.812 cents at St. Louis, and of lead 5.225 cents. On these prices the average yield to the miner was $45.23 for zinc ore and $68.73 for lead ore.

Geology of the Joplin District at Large

The rocks in which the ore occurs constitute a flat-lying formation of chert and limestone about 250 ft. thick. At the bottom of the formation is a persistent bed of flint about 20 ft. thick, called the Grand Falls chert. Above this is limestone containing many layers and nodules of flint. Originally this cherty limestone formation was all covered by a stratum of black shale, which occasionally contains a little coal. The greater part of this shale has been removed by erosion, but certain portions of it still remain in the form of long strips filling trough-like depressions in the underlying limestone.

The orebodies of the region are all contiguous to these areas of depressed shale, occurring either under or along the sides of the shale troughs. These troughs of shale are called, by the way, "soapstone bars." The explanation which I believe to be the true one of the occurrence, both of the shale troughs and of the ore, is as follows:

The limestone, along certain lines (of an origin not at present explicable), was dissolved out while the shale formation still overlaid the entire region. The caverns formed by this dissolution finally became so large that they caved in, allowing the overlying shale to settle down into the pits thus formed to a depth of from a few feet to as much as 150 ft. below the surface of the cherty limestone formation. The dissolution of the limestone did not affect the chert beds. These were broken up during the subsidence caused by the disappearance of the lime. The result was that underneath and along the sides of the shale filling of the troughs there were great quantities of broken flint mixed with mud derived from the soft overlying shale. There were also masses of limestone, of all sizes, remaining on the sides and even in the bottom of the troughs. The limestone remnants increase in quantity as you go from the center of the trough until finally you reach the solid unaffected masses.

Ore has been deposited in the brecciated, or disturbed mass of flint and limestone boulders and clay occupying the space between the depressed shale in the center of the trough and the unaltered formation at its bottom and sides. The ore was brought in by surface waters. Naturally the deposition of ore was not uniform. It is supposed that the organic matter in the shale was the precipitating agent which caused the deposition of zinc and lead sulphates picked up by the surface waters during the process of the erosion of the Ozark plateau to the southeast. At any rate the ore is found in exceedingly irregular bodies in the broken ground along the troughs of shale, or "soapstone bars."

Naturally, channels of dissolution such as those described as causing the troughs would be of varying extent and depth. This is the case. In some of the larger channels the limestone has been removed quite to the bottom of the cherty limestone formation and the broken ground extends down to the basal member — the Grand Falls chert. This chert is a brittle stratum of flint containing innumerable crevices so that it serves as a ready channel for the circulation of water. On this account much ore has been deposited in it. It is called the "sheet ground." This sheet-ground ore, while of exactly the same composition and origin as the other ore, is distinguished from it notably in several respects. Instead of being in a mass of broken ground along the "soapstone bars" it occurs under the solid original limestone masses. Instead of being in a shapeless irregular mass, it forms a regular flat bed, like a seam of coal. Laterally, its extent is variable, as also is its richness, but the mineralization is pretty uniform over extensive areas, often as much as 2000 ft. wide. It must never be forgotten, however, that the sheet ground is always attached to the *loci* of mineralization — the "soapstone bars." It forms extensive shoots under the limestone bordering the deepest and most strongly mineralized bars or channels. It often extends 1000 ft. from a bar, very rarely over 2000 ft.

Practically all of the successful sheet-ground mining to date has been confined to the great Webb City ore-channel, between Oronogo and Porto Rico. It is generally believed that the sheet ground yields about 3 per cent. of the rock mined in zinc or lead ore. The zinc ore obtained averages not far from 60 per cent. zinc; the lead ore about 80 per cent. lead. The ore is obtained by crushing and washing in concentrating mills, which save about 60 per cent. of the zinc and 90 per cent. of the lead actually contained in the rock. The total saving approximates $66\frac{2}{3}$ per cent.

Exploration

Practically the only method now employed in searching for ore is churn filling. The irregular deposits along the soapstone bars are apt to be quite narrow. The vertical extent is often greater than the width. Consequently, in looking for such ore-bodies it is necessary to drill holes pretty close together. An experienced driller can form a good idea from the kind of ground he encounters of what the chances are of finding ore. If he finds a little ore and open ground, that is, broken rudely stratified material, he will place his following holes not over 50 ft. from the first until he discovers pay ore. Then he will endeavor to follow the ore by drilling along the course of the bar. Where the bars are small and irregular, it is often necessary to drill as many as three or four holes to the acre to explore a tract thoroughly. Since the drilling costs an average of 80 to 90 cents per foot, and the holes will average about 175 ft. deep, we may place the cost of exploring such a tract roughly at $500 per acre.

In the sheet ground no such amount of drilling is necessary. On account of the much greater uniformity of the deposits it is often possible to explore the ground satisfactorily with only one hole to every two acres. Holes to explore this ground are drilled more than 200 ft. and the cost per hole will approximate $200. The actual cost per acre for exploring this ground is probably less than $100, but I think it should properly be about $200.

It is the almost universal custom to appraise the value of the ore only by the eye. The cuttings from the drill come out in the form of coarse angular sand which the driller washes in a bucket of water, and simply forms a judgment as to whether the sand contains pay ores or not. If the cuttings show only small amounts of ore, not enough in his judgment to pay for mining, he records "a few shines of jack or lead." If he thinks the ground doubtful he writes — "shines" or "good lead," or both.

Mining Methods

The mining of this ore will be readily understood from the above description of its occurrence. Owing to the shallowness of the deposits there is no occasion whatever for large expensive shafts. As the extreme depth is only 250 ft., and the average depth in mining perhaps less than 175 ft., it is evident that a single-compartment shaft, except in the unusual contingency of encountering a very large amount of water, can be sunk very cheaply. It is probable that the average shaft of the Joplin district does not cost more than $4000. Hence it is cheaper to open up the ground by numerous shafts rather than by extensive openings underground. It will also be evident that aside from the question of first cost the tramming of ore is cheaper on the surface than underground.

The effect of these considerations is that the accepted method of operating in the district is to have one mill supplied with ore from several shafts, the ore being transported to the mill by inclined tramways.

The hoisting methods of the district are unique and, considering the conditions, exceedingly satisfactory. The ore is shoveled into buckets locally called "cans" which hold about 800 lb. each. These cans are placed upon small trucks underground and run to the shafts, where they are attached to the hoisting rope by a man called the "tub-hooker." The hoist is placed in a derrick or headframe vertically above the shaft, the rope passing over the sheave a few feet above the engine. The hoist man pulls the bucket up so that the bottom of it is slightly above his head. He then attaches to the bottom of the bucket a hook which, when the bucket is again lowered, dumps it into a bin. To do this, hoist his empty bucket back to position, detach the hook, and lower again, is in the hands of an expert hoistman, a matter of only a couple of seconds. In this manner it is possible to average 400 cans per shift, or 160 tons. Only two men are employed, whose combined wages are approximately $5 per day. The hoist itself costs $250. The derrick in which the hoisting is done, together with the bin ore, costs $600 more. It is evident that this method of operating, while having the appearance of crudity, is exceedingly effective and cheap. The actual cost is probably not over 5 cents per ton hoisted.

The mining underground involves the usual requirements of selecting the ground so as to mine out the best of the ore without leaving too much in the pillars and without making the openings too dangerous. In the "upper ground" irregular deposits this selection opens the field for the exercise of skill. In the sheet-ground deposits the work is far more regular and certain. As a general statement, the advantages of the upper deposits in the way of richer ores and softer ground are nearly, if not quite, counterbalanced in favor of the sheet ground by the greater uniformity and persistence of the latter. There is really very little difference in the methods employed in the two kinds of mines. In the upper ground the ore is taken from large irregular chambers and in the sheet ground from flat deposits from 8 to 20 ft. thick that are as regular over considerable areas as a seam of coal. The only differences in mining between the two kinds of mines are of an unimportant nature which will be readily understood. from the above description, and need not be explained.

Milling Methods

The visitor from outside districts is apt to be very much surprised at the crudity of the milling methods employed, and many an engineer has discovered what he believed to be a field for vast improvement by introducing better methods. Thus far nothing whatever has come of such attempts. They have usually been based upon some radical misapprehension of the conditions.

The Joplin mills confessedly only extract about 60 per cent. of the zinc ore. The proportion varies greatly at different mines. The variation, however, is not generally due to the mill practice, but to the character of the ore. The mills are suited to save only the free ore which can be easily separated from the gangue by rather coarse crushing. The remaining zinc which is enclosed in small particles in a secondary growth of flint cannot be saved except by much finer grinding and much more expensive methods for which the resulting ore extracted will not pay.

The ordinary mill consists of no more than three large Cooley jigs supplemented by one or two Wilfley tables. The Cooley jigs are of the Harz type, but contain usually from five to seven cells. The ore after being reduced to about one-half inch is next passed to the rougher jig, which catches some of the coarse lead and makes a rough concentration of the zinc ore. This is drawn as a middling product from the rougher and, after being passed over a second pair of rolls, goes to a second jig called the "cleaner." The tailings from the cleaner jig are sometimes passed over a third or smaller jig for further treatment and a certain proportion of finer material is settled out for treatment in one or two Wilfley tables. The ordinary mill costs from $10,000 to $20,000 and has a capacity of about 15 tons an hour. The largest mills in the district have cost about $50,000 and have a capacity of 35 tons an hour.

Losses in Mining

It must be remembered that the mining of zinc ore was first begun as an incident to lead mining, which was done at or near the surface. At first the zinc ore was sold usually at very low prices. It was cleaned on hand jigs, but later cheap and crude mills were built.

As the lead was found in small irregular patches, at or near the surface, there was no inducement to mine it on a large scale. One or two miners would work at it and pay royalties to the farmers who owned the land. Since two men could not work much land, there was no demand for leases of more than a very few acres. As lead mining gradually changed into zinc mining the small leases continued and the small mills were only expected to handle the richest pockets of "jack." In this way the business has built itself up in ever-increasing volume as a multitude of small leases. The system has all the faults that might be expected of it, but it was the one which the circumstances demanded. That it is attended by frightful losses will appear from the following summary of operating results.

Take 100 tons of ore containing 5 per cent. metallic zinc in the ground, we have the following approximate statement:

Costs and Losses on Zinc Ore

	Costs.	Losses.	Total.
Spelter value 100 tons 5 per cent. ore at 5 cents, St. Louis	......	......	$500.00
Loss in mining, 10 per cent.	......	$50.00	
Mining, 90 tons at $1.05	$94.50	......	......
Loss in milling, 40 per cent.	......	180.00	......
Milling 70 tons at $0.25	22.50	......	......
Loss in smelting, 12 per cent.	......	35.10	......
Smelting and amortization	54.00	......	......
Transportation	9.15	......	......
Total	$180.65	$265.10	$345.75
Approximate profit	......	......	$54.25

This shows a recovery by mining of $450; by milling of $270; by smelting of $234.90. The approximate costs are 36.1 per cent. of the total value; the losses, 53 per cent.; the profit, 10.9 per cent. The profit on recovered value is 23 per cent., and this profit is divided as follows: Smelter, $14.25, or 26 per cent.; royalty, 15 per cent., $23.60, or 43 per cent.; mines, $17.15, or 31 per cent. of the total profit.

Joplin Cost Statements

The cost statements of the Joplin districts are open to a good deal of uncertainty, on account of the lack of accurate information concerning the tonnage handled. The accompanying statement of the Grace Zinc Company illustrates the point. The cans hoisted refers in the local vocabulary to buckets, the greater portion of which are assumed to hold 1000 lb. As a matter of fact, it is known that they do not; some operators estimate that they hold 900 and others 800 lb. On either of these two assumptions the tonnage would be much greater than that taken as the basis for the cost statement. This tonnage estimate is based on the tonnage content of cars holding from 1½ to 2½ tons in which the ore is hoisted to the mill. A considerable amount is rejected as waste. If we were to assume that the cans contained 800 lb. each, our tonnage would be 156,000 and the costs, instead of totaling $1.41, would be reduced to $1.10. If the cans were estimated at 900 lb. each, the tonnage estimate would be almost 180,000, and the cost would fall to 95 cents. The low grade of ore, and particularly the method of leasing and mining which has been adopted, prevent the installation of devices by which a more accurate measure could be taken of the tonnage.

GRACE ZINC COMPANY

PRODUCTION AND COST STATEMENT APRIL 1, 1905, TO JAN. 1, 1908

Cans hoisted	390,346
Tons dirt milled	121,291
Tons mixed ore recovered	5,307

	Per Ton Dirt.	Per Ton Concentrates.	
Breaking ore	$0.40	$9.03	$47,939.43
Tramming	0.21	4.85	25,722.82
Hoisting	0.15	3.32	17,616.19
Pumping	0.10	2.27	12,050.81
Exploring	0.09	2.10	11,160.39
Timbering	....	0.09	452.18
Milling	0.23	5.33	28,304.19
General Expense	0.15	3.56	18,870.34
Construction	0.08	1.74	9,248.40
Total	$1.41	$32.29	$171,364.75
Royalty paid			$38,957.55
Net value of ore			$221,230.21
Total expense			171,364.75
Net profit			$49,865.46

A more accurate statement of costs is based on the tonnage of concentrates produced. The amount of these is, of course, accurately determined. It is probable that the figures given in the accompanying statement give a fair idea of average costs for mining and milling in the Joplin district.

I have not made an estimate of the amortization charge, which should be made against such a plant as that from which the cost statement is taken. The actual cost of such a plant outside of the amounts covered by construction and exploring is probably not over $20,000. All renewals are covered in operating expense. Construction probably more than takes care of the plant itself. It is probable that a sum of $3000 a year in addition to the costs given would be an ample return on the actual plant investment. This would amount in the table to less than $8000, and would increase the total costs per ton of dirt to $1.49, and per ton of concentrates to $34.

Assuming the last figure to represent the complete mining and milling cost, and that a concentrate containing 60 per cent. zinc is smelted at a cost of $14 a ton, with a loss of 12 per cent., we find that 1056 lb. of spelter costs $48, or 4.54 cents per pound. While it is undoubtedly true that some mines at all times, and most mines for short periods, can produce spelter cheaper, I believe that the above figure is a fair average.

Zinc Mining in Wisconsin

Wisconsin has been within the last few years second in the production of zinc in the United States. Its future is thought by many to be exceedingly promising, but I must confess to some doubts as to the ability of the district to maintain a large output for many years in succession. The district is in the extreme southwestern corner of the State.

The zinc ores are associated with iron in the form of marcasites, usually in almost equal quantities. It is impossible by ordinary methods of water concentration to separate this iron from the zinc. The separation must be accomplished electrically either by magnetic attraction or by static repulsion. The magnetic separators are cheap installations costing about $10,000 each for a capacity of some twenty tons of concentrates daily. The process consists of a very light roast which partially oxidizes and magnetizes the marcasite so that by passing the ore thus roasted by a group of magnets, the iron is taken out. This is the usual method employed in the district.

With the exception of the association of zinc with the iron there is no radical difference between the problem of mining in Wisconsin and in Missouri, except that the orebodies have certain different characteristics which I shall presently explain. The mining and milling can be done in approximately the same way, although the costs in Wisconsin seem to average some 20 per cent. higher than in Missouri.

The Wisconsin orebodies fill partial openings in the limestone made by the subsidence of large prism-like masses in the bottom portion of the limestone. The limestone stratum in which the ore occurs is about 150 ft. thick, and is underlaid by a persistent bed of clay shale. It looks as if the limestone might have been dissolved out for a foot or two above the shale along certain channels to such an extent that finally a large irregular prism of limestone detached itself from the solid mass and fell down a distance of perhaps two feet. The result of this subsidence being that the interior of the prism is cracked up to a certain extent and certain openings are made along the top and sides. These openings have served for the deposition of the ores.

The openings thus formed in the cross-section have the shape of a rude arch, usually quite flat at the top, and breaking down in irregular steps along the sides. In the local phraseology, the ores deposited in the level at the top of the arch are called "flats," and those occurring along the sides are called "pitches." The slightly disturbed broken up interior of the prism is called the "core."

These orebodies have precisely the irregularities that one would expect from such an explanation of their origin. In some places the dissolution of the lime, or whatever it was that caused the subsidence, was more extensive than at other places; so that the prisms are both wider and higher in some places than in others. The high places take the shape of long elliptical cones. That is to say, that the roof slopes down both longitudinally and in cross-sections. In some cases these prismatic orebodies have been proved to have considerable persistence in length.. The Empire and Enterprise mines have been worked on one run of ore for a total length of about half a mile, the greatest width being about 120 ft.

It remains to say that the mineralization of the prisms is irregular. Ore sometimes is found on both sides of the arch, but is generally of pay quality on one side only.

These orebodies seem to have an ordinary course of about N. 70° E., but sometimes they make an abrupt turn, and in one well-authenticated case the ore turned at right angles to its ordinary course, and ran for 350 ft. in a course of N. 20° W.

It is believed locally in Wisconsin that the runs of zinc ore will be found to be exceedingly persistent, not always following the same direction, but making occasional turns and then resuming their other course again. It seems to me likely that they will have a considerable degree of persistence, but that they will be persistently payable is a different matter. Very likely the large prisms that have been well mineralized and are payable will be found to be connected only by comparatively small and tortuous channels that will not pay for working them.

The Cost of Zinc Mining in Wisconsin

The actual operating expenses in Wisconsin seem to be about the same or a little higher than in the Joplin field. The only reason for the increased cost is the smaller volume of ore that can be secured from any one shaft. It is usual to pay a royalty of 10 per cent. to the owners of the land.

The cost of mining undoubtedly depends largely on the grade of the ore. Some of the ores in Wisconsin are considerably richer than most of those mined in the Joplin district.

A general idea of the cost of zinc mining from the three principal districts of the central and far West may be had from the following statements:

Generalized statement of the cost of producing spelter from a mine in Wisconsin yielding from its crude ore 10 per cent. of concentrates assaying 40 per cent. zinc:

	Per Ton Crude
Cost of mining, milling, and exploration	$1.40
Amortization of mining and milling plant	.33
Depreciation	.08
Magnetic separation of 40 per cent. concentrates $= \frac{2.00}{10} =$	.20
Saving 90 per cent. and producing 0.6 ton of 60 per cent. concentrate.	
Freight to smelter $= \frac{1.50}{16.6} =$	.09
Smelting, saving $87\frac{1}{2}$ per cent.	.60
Amortization of smelting plant $= \frac{14.00}{166.} =$	.08
Total cost	$2.78

Yield per ton $= \frac{1050}{16\frac{2}{3}} =$ 63 pounds.

Cost per pound spelter, *selling cost*	4.41 cents
Dividend cost	3.76 cents

Estimate of real cost of spelter from Leadville, Colo., sulphide ores averageing 25 per cent. zinc, requiring magnetic separation, and smelted at a plant with capacity of 30,000 tons a year of 45 per cent. concentrates; in Kansas gas belt:

Cost of mining = selling price of ore	$2.57
Cost of separating (extraction 72 per cent.)	2.50
Concentrates produced = 1 ton assaying 45 per cent. zinc from $2\frac{1}{2}$ tons crude ore.	
Freight to Kansas smelter $= \frac{\$3.50}{2\frac{1}{2}}$	1.40
Cost of smelting, less profit on sulphuric acid $= \frac{\$9.20}{2\frac{1}{2}}$	3.68
Carried forward	$10.15

Brought forward	$10.15
Amortization of magnetic separating plant = 15 per cent. on $2.00 cost per annual ton	.30
Amortization of smelting and sulphuric acid plant = 10 per cent. on $14.00 cost per annual ton of concentrates treated $= \frac{\$14.00}{10 \times 2\frac{1}{2}}$	.56
General selling and administration expenses	.40
Total cost per ton crude ore	$11.41

Saving by magnetic separation, 72 per cent., by smelting 80 per cent = 57.6 per cent. = 288 lb.
Cost per pound spelter just under 4 cents.

Generalized statement of the cost of producing spelter from Joplin ore, assuming 4 per cent. of concentrates yielded per ton of crude ore milled, and neglecting royalties and other profits:

	Per Ton Crude.
Cost mining and milling	$1.25
Amortization of mining and milling plant	.33
Depreciation	.08
Transportation to smelter	.06
Smelting, saving $87\frac{1}{2}$ per cent.	.40
Amortization of smelter at 10 per cent. $= \frac{\$14.00}{250}$	.06
General expense	.04
Total cost at smelter	$2.22

Yield $= \frac{1050}{25} = 42$ lb. per ton.

Cost per pound spelter .... 5.28 cents

This is the selling cost, of course. The dividend cost will neglect amortization and may be computed at $\frac{1.83}{42} = 4.36$ cents.

CHAPTER XVIII

OCCURRENCE AND PRODUCTION OF GOLD

Value of gold and transportation — Economic phases of gold mining — Placers — Amalgamation — Cyanide and other recent processes — Economic distinctions of gold ores — Quartz-pyrite lodes — Reasons for variations in costs — Telluride ores and districts — Tables of gold production — Production of various districts — Cost of producing gold per ounce — Profits of gold mining compared with those of other metal mines.

WITHIN recent years gold has become more than ever before the precious metal *par excellence.* Its production has not only increased enormously in amount, but also greatly by comparison with its historic rival, silver. A general description of its qualities has no place here, but it will be interesting to review the more salient features of its occurrence that bear on its production and cost.

A ton of pure gold is worth $602,836. This high value renders the metal, once secured, utterly independent of transportation costs, for it is evident that it can be carried from the remotest corner of the globe for a minute fraction of its worth.

Another equally important fact is that gold occurs to an exceedingly large extent in such form that its extraction from ores is one of the simplest of metallurgical problems, so that it can nearly always be obtained by plants erected on the spot. The cost of such plants per ton treated is moderate. The avidity with which gold has been sought for has resulted in the exhaustion of the mines in the older civilized countries so that at present the output comes from new or barbarous countries where, for the most part, the climate is bad, labor costly, and transportation crudely developed. In the case of gold mines, therefore, the question of transportation has little or nothing to do with moving products *from* the mines, but much to do with moving plants and supplies *to* the mines.

The history of gold mining exhibits three economic phases with reference to mechanical developments: These may be divided chronologically into, (1) The placer period. (2) The amalgamation period. (3) The cyanide and smelting period.

1. From the earliest times down to the present gold has been very largely obtained in a metallic state from the débris of erosion, *i.e.*, from stream gravels. Owing to its great weight gold resists transportation by water and lags behind while the lighter minerals are carried off to the sea. In this way each stream in a gold-producing country is a natural concentrating mill and often retains the metal, or a portion of it, that was once scattered through enormous masses of rock. How great this concentration may be is perhaps not fully realized even by mining men. A stream bed 100 miles long and a quarter of a mile wide and a few feet deep may have gathered gold derived from thousands of cubic miles of eroded rock. The gravel that now contains the gold may equal only a millionth part of the mass that once contained it. Undoubtedly in every such case a very large portion of the original gold has also been removed, but if even one per cent. has remained, the gravel may be ten thousand times as rich in gold as the rock from which the gravel was derived. It is evident, therefore, that streams may contain highly profitable deposits in regions where the gold was originally scattered through a multitude of insignificant veins, all worthless in themselves. The presence of placer gold in payable amounts does not indicate that payable gold will be found *in situ*. Many cases might be cited of important placer mines in regions where there has never been a good mine of any other kind. To be sure quartz mines have been found in Alaska, California, Australasia, and many other regions along with placer deposits. On the other hand, in early times placer gold was obtained in Spain, France, the British Isles, Italy, in fact all over Europe where scarcely a payable quartz mine has been known. It is almost certain that the older civilized countries, Northern Africa, Western Asia, China, India, and Japan, also produced a full quota of this metal from sources now long forgotten.

It is highly probable that by far the greater part of the gold possessed by mankind, even now, came from placer deposits. Nearly all gold was obtained in this way until well into the nineteenth century by the process of mere washing, unaided by amalgamation or any metallurgical process.

2. The properties of quicksilver have been known from very early times, and undoubtedly since about the time of Columbus this metal has been used to a large extent to collect gold out of its gangue in both placer and quartz-mining operations. But it was not until the almost simultaneous discovery of gold in California and Australia at the middle of the nineteenth century that amalgamation came to be the essential process in the recovery of gold. Before the working of extensive quartz mines in those countries amalgamation was used as a useful adjunct in cleaning up the concentrates from gravel washing, but for that purpose it was not vital. But from 1850 to 1890 this process was the only one successfully used by English-speaking people, who have since 1850 produced most of the world's gold, to extract the metal from rocks in place.

The method was found to apply only to ores in which the gold lay in rather loose metallic particles in the rock. It is essential for amalgamation that the gold when it adheres to the quicksilver will be free from adherence to other minerals. In course of time more and more gold ores were found where this was not the case. It was found that most gold veins produced amalgamating ores in the oxidized zones near the surface, but that only selected ones would yield their values in this way after the sulphide zone was reached. Where an extraction of 70 to 90 per cent. was easy in the oxidized zone, the extraction would drop to 60 or 50 per cent. in the sulphides. At the same time the actual assay value of the ore would show some diminution. These two causes were sufficient to render many a mine unpayable. Although some mines continue to be perfectly amenable to amalgamation to great depths, there were found so very many where this was not so that gold mining began to decline, especially during the eighties. This decline was due to the limitations of the amalgamation process.

3. The ingenuity of metallurgists discovered about 1890 several remedies; leaching processes that would extract gold independently or could be used as supplements to amalgamation. These were based on the solubility of gold by chlorine gas and by various cyanides. In one form or another these chlorination and cyanide processes were found to apply to most gold ores. This happened at a time when the world was hungry for gold. Great districts were found like the Witwatersrand where by

amalgamation the ores would pay only in selected cases, but with the additional values saved by the new process would pay handsomely. There was a great revival of the gold industry, which has grown rapidly ever since.

It would be hardly proper to infer that the whole increase of gold production is due to the cyanide and other leaching processes. The old sources of gold supply have not disappeared. Placer mining in Alaska has developed a respectable output. Placer mining in general has been aided by improvements in mechanical appliances, of which by far the most important is the dredge. An increasing amount of gold is also obtained by the smelters as a by-product of lead and copper ores. But it is entirely proper to state that since 1890 the improvements in gold-mining practice have been such as to warrant calling this period a new era in the industry.

Economic Distribution of Gold Ores

On economic grounds we cannot follow with any satisfaction any division according to the processes used. Various processes are often used simultaneously, one supplementing the other. I plan to discuss gold mines under the two general groupings of placer deposits and vein deposits. Of placer deposits nothing more need be said here.

Gold Veins, or Gold Deposits in Situ

By far the most important source of gold known to-day may be called, for want of a better name, the quartz-pyrite lode. In these deposits quartz is always the main constituent. With the quartz there is always a certain proporton of iron pyrite, usually less than 5 per cent. of the mass, but varying from $\frac{1}{4}$ per cent. to 50 per cent. Sulphides of lead, copper, and zinc may also be present, but usually in very subsidiary quantities. The lodes occur in every conceivable attitude and manner. They are of every geological age from the oldest to the youngest. The ores may fill open crevices or fissures caused by shrinking or faulting in the rocks, they may be replacements of other rocks, they may simply fill up the interstices of pebbly beds or conglomerate. In all cases it is highly probable that quartz-pyrite ores were deposited by hot waters of deep-seated origin. In many cases there is reason to believe they came from "magmatic" waters, waters once included in molten rock masses, that escaped when the pressure was released. In almost all cases there is some reason to believe that these deposits have a connection, not always explained, with igneous rocks.

These ores occur in large volume. In many cases millions of tons are in sight. The Treadwell group in Alaska has mined 14,000,000 tons and reports 7,000,000 in sight, averaging $2.40 per ton. The Witwatersrand mines have treated 114,000,000 tons and expect to mine some 500,000,000 tons more, averaging $7 or $8 a ton. Four mines in the Mysore group in India have mined 7,300,000 tons, averaging $18.40 per ton, and have in sight 1,400,000 tons averaging $20. Three mines at El Oro, Mexico, have produced 2,450,000 tons averaging $16 per ton, and have in sight some 900,000 tons averaging $11. The Witwatersrand mines are now treating 20,000,000 tons a year. These figures show that this class of gold mines constitute a great industry carried on under conditions of stability not inferior to those of other kinds of mines. It will be shown later that they are as profitable as any.

In these ores the gold is said to be almost entirely in a metallic state, scattered through the gangue in particles of varying size. Sometimes, for instance, at the North Star mine, in California, 90 per cent. of the gold can be recovered by amalgamation. In other cases, as at El Oro, Mexico, and Goldfield, Nevada, only 10 per cent. or even less will amalgamate. The difference is due not to the state of the metal itself but to its degree of subdivision. In some cases the gold is in such minute particles that, even with the finest grinding, it still remains partly imbedded in particles of gangue. The gold is much more apt to be imbedded in the sulphides than in the quartz, hence it often happens that the alteration of the sulphides by artificial oxidation or roasting sets free a good deal of it. But in this class of gold ores roasting is practically never necessary for a good extraction by leaching processes. It is here that the cyanide process has its great field.

Cost of Mining and Milling Quartz-Pyrite Ores

In both mining and milling the cost is most affected by two dominant factors:

(*a*) The richness of the ore.

(*b*) The size of the deposits.

The richness of the ore affects both departments of the operation through its effect on the elaboration of processes. In the case of low-grade ores the process *must* be cheap, therefore cheapness is secured if necessary by sacrificing part of the ore in both mining and milling. In the case of the Treadwell an ore is mined that assays $2.70 per ton. It is mined, let us say, for $1.15 and milled for $0.35 with an extraction of 75 per cent. by mining and 90 per cent. by milling, making a total saving of 67½ per cent. The profit per ton actually milled is $0.93. Now to save more of the ore, to save 90 per cent., would involve the institution of another method of mining which would certainly be more expensive. Such a method would almost certainly cost over $2 a ton and would therefore wipe out the profits altogether. In the case of milling the only improvement that could be made would be by cyaniding the tailings which only run 27 cents a ton. Under the most favorable conditions this would not pay.

But if we consider the Mysore mines in the same light we get utterly different results. These ores assay $20 a ton. To sacrifice 25 per cent. in mining such ores would be to leave $5 per ton in the ground. To spend $3 or $4 a ton more to secure this would be entirely proper, although such a figure is twice the whole cost of the Treadwell process. In milling a loss of 10 per cent. means $2 a ton, and likewise, to spend say $1 per ton more to save half the loss would be good business. In a word, the cost of $10 a ton for the Mysore ores may be just as sound business as the cost of $1.50 at the Treadwell; and this for no other reason than the greater value of the ore.

Size of Orebodies

With orebodies of the same size we may vary the cost within wide limits at will, as just shown; but human will has no effect on the size of orebodies: we must take them as they are. The size and attitude of the masses to be attacked hedge the cost of mining with limitations even more arbitrary than those imposed by the grade. A uniform bed 6 ft. thick of ore of this character can be handled at a total cost, on average conditions throughout the world, of $3 a ton. A bed 4 ft. thick will cost somewhat more, say $3.50 a ton. Below 4 ft. the cost will rise almost in inverse ratio to the thickness, so that a seam 1 ft. thick will cost $14 a ton, and so on. Now it often happens that most important gold ores do occur in such narrow streaks. In the Witwatersrand the values are usually confined to streaks from 4 inches to 16 inches thick, worth from $20 to $100 a ton. Under the cost conditions ruling in that district a 4-inch seam would cost approximately $60 a ton. This would leave a profit, supposing the ore to assay $100 a ton and that the extraction is 95 per cent., of $35 a ton, equal to 35 per cent. of the assay value. But mining is not conducted that way. Such a seam is mined in a stope at least 4 ft. wide; the ore seam is mixed with an enormous amount of waste, ten or eleven times as much waste as ore. The ore going to the mill will run only $8 a ton and the cost is $5; but the proportion of profit is about the same. Wherever it is possible to mine such seams by themselves, it should be done; but on account of the friable nature of the streaks, in many cases there is so much danger of loss in breaking the ore that it is considered safer to mill most of the stuff broken regardless of its value.

But these considerations do not affect the real cost of mining. In the case cited above the real orebody is only 4 in. thick and the cost is $60 a ton. That the value is diluted and the cost lower is only a matter of convenience. That such orebodies would be worthless if the ore streaks yielded even such apparently attractive assays as $40, $20, to say nothing of $5, a ton is too obvious to argue about. Strange as it may seem, great quantities of money are lost by attempting just such impossibilities.

Other Causes of Variation

Quartz-pyrite ores are metallurgically simple, and outside of the two great factors mentioned above there is nothing to make very great differences in cost. So far as underground operations go the variations are so nearly wholly due to those factors that others may be neglected. In milling, the metallurgical problem, on average ores of say $10 a ton, will cause variations between a minimum of about 75 cents and a maximum of about $2.

The process is in principle uniform throughout the world. It consists of one or all of the following steps:

1. Amalgamation after crushing in stamp batteries.

2. Concentration of refractory sulphides.

3. Leaching of tailings (or, in some cases, the original ore) by cyanide or other solutions.

Where concentration is undertaken, it is only in order to apply some special process to a small fraction of the ore. Such a process may be instituted at the mine, or the concentrates may be shipped to custom plants; but in any case the cost as applied to the crude ore is never very high, because for each ton of concentrates there will be from 10 to 100 tons of crude.

So many examples of the cost of these processes in actual practice will be found in the following chapters, that I shall not discuss them further here.

Other Gold Ores

In the type discussed above the gold in the ore is free, or native, *i.e.*, it is mixed mechanically, not chemically, with the gangue. In Cripple Creek, Colorado; Kalgoorli, West Australia, and in a number of other less important districts, the gold occurs to a large extent as a true ore, namely as tellurides. Here the gold is involved in a chemical combination with tellurium and to a less extent with other elements. Here amalgamation, except to a limited extent in the oxidized zone, is utterly ineffective. Dependence must be had on smelting or on leaching processes of a type inherently more expensive than those applied to quartz-pyrite ores. The reason for this is that in the raw state, the gold, or a large part of it, will not desert its companion minerals to unite with those offered by the leaching solutions. To get around this difficulty it is necessary to break up the tellurides by roasting before attempting to leach. To do this costs $1.50 a ton. This cost is not wholly for the roasting itself, but is due partly to the fact that ordinary wet crushing by stamps is not desirable when roasting is to be done. It is necessary to resort to the much more costly process of dry crushing. After roasting the processes usually proceed so far as cost goes about as in the case of quartz-pyrite ores of pretty high grade; for these tellurides ores are, on account of the high working cost, invariably of fairly high grade. They are often concentrated a good deal by hand sorting, so that when I speak of high grade I mean when they get to the mill or smelter. Referring to the rock actually broken in the stopes, the minimum grade of this type of ore that can be profitably worked is, under present conditions, about $8 a ton.

Gold Production of the World, 1851–1907

Year	Value	Year	Value
1851	$67,600,000	1880	$106,600,000
1852	132,800,000	1881	103,102,000
1853	155,500,000	1882	102,000,000
1854	127,500,000	1883	95,400,000
1855	135,100,000	1884	101,700,000
1856	147,600,000	1885	108,400,000
1857	133,300,000	1886	106,000,000
1858	124,700,000	1887	105,775,000
1859	124,900,000	1888	110,197,000
1860	119,300,000	1889	123,489,000
1861	113,800,000	1890	118,848,700
1862	107,800,000	1891	130,650,000
1863	107,000,000	1892	146,292,600
1864	113,000,000	1893	158,437,551
1865	120,200,000	1894	182,509,283
1866	121,000,000	1895	198,995,741
1867	104,000,000	1896	211,242,081
1868	109,700,000	1897	237,833,084
1869	106,200,000	1898	287,327,833
1870	106,900,000	1899	311,505,947
1871	107,000,000	1900	258,829,703
1872	99,600,000	1901	260,877,429
1873	96,200,000	1902	298,812,493
1874	90,800,000	1903	329,475,401
1875	97,500,000	1904	349,088,293
1876	103,700,000	1905	378,411,754
1877	114,000,000	1906	405,060,969
1878	119,000,000	1907	412,556,136
1879	109,000,000	1908	444,382,312

(See tables on pages 334 and 335.)

The following table is designed to show the approximate yield of some of the important gold-mining districts of the world in tonnage and value:

QUARTZ PYRITE DISTRICTS

Name of District	Country	Tons Milled per Year	Value of Annual Yield
Witwatersrand	Transvaal	20,000,000	$150,000,000
Various districts	Rhodesia	1,650,000	12,000,000
	British W. Africa	500,000	5,000,000
Kolar	Mysore, India	600,000	10,000,000
Various districts excluding Kalgoorlie	W. Australia	—	18,000,000
El Oro	Mexico	600,000	9,000,000
San Juan	Colorado	500,000	6,000,000
Black Hills	S. Dakota	1,700,000	7,000,000
Juneau	Alaska	1,300,000	3,250,000
Nevada County	California	225,000	2,000,000
Goldfield	Nevada	300,000	10,000,000
Thames district	New Zealand	500,000	6,000,000
Oriental Consolidated	Korea	250,000	1,300,000

TELLURIDE MINING DISTRICTS

Name of District	Country	Tons Milled per Year	Value of Annual Yield
Cripple Creek	Colorado	500,000	11,000,000
Kalgoorlie	West Australia	1,650,000	16,500,000

DISTRICTS PRODUCING GOLD AS AN IMPORTANT CONSTITUENT OF SMELTING ORES

Name of District	Country	Tons Milled per Year	Value of Annual Yield
Leadville	Colorado	—	1,000,000
Tintic	Utah	—	2,250,000
Park City	Utah	—	1,600,000

PLACER DISTRICTS

Name of District	Country	Value of Annual Yield
Butte & Yuba Counties	California (principally dredging)	4,500,000
Nome	Alaska (drifting and hydraulicking frozen gravels)	7,000,000
Fairbanks	Alaska (drifting and hydraulicking frozen gravels)	8,000,000
Dawson	Yukon Territory (drifting, hydraulicking, and dredging frozen gravels)	3,300,000
Various districts in Siberia	About	24,000,000

GOLD PRODUCTION OF THE WORLD

Countries	1906			1907			1908		
	Oz. Fine	Kilograms	Value	Oz. Fine	Kilograms	Value	Oz. Fine	Kilograms	Value
America, North:									
United States	(*a*) 4,565,333	142,001	$94,373,800	(*a*) 4,374,827	136,075	$90,435,700	(*e*) 4,659,360	144,933	$96,313,256
Canada	(*b*) 581,709	18,093	12,023,932	(*b*) 399,844	12,437	8,264,765	(*b*) 462,467	14,384	9,559,274
Newfoundland	4,475	139	92,500	4,315	134	89,191	(*e*) 4,400	137	90,948
Mexico	896,615	27,889	18,534,700	(*a*) 903,672	28,108	18,739,181	(*a*) 1,182,445	36,779	24,518,548
Central America	(*b*) 92,431	2,875	1,910,725	(*b*) 101,980	3,172	2,096,911	(*e*) 110,000	3,422	2,273,875
America, South:									
Argentina	(*b*) 257	8	5,317	(*b*) 4,983	155	103,013	(*e*) 5,000	155	413,428
Bolivia	890	28	17,403	1,209	38	25,000	(*e*) 1,300	40	26,873
Brazil	(*b*) 116,254	3,616	2,403,194	146,218	4,548	3,022,326	(*e*) 150,000	4,670	3,100,650
Chile	(*a*) 36,490	1,135	754,321	(*a*) 61,310	1,907	1,267,278	(*e*) 60,000	1,871	1,240,200
Columbia	(*b*) 105,966	3,296	2,190,522	(*b*) 157,471	4,898	3,255,311	(*e*) 170,000	5,289	3,514,073
Ecuador	(*b*) 14,242	443	294,417	(*b*) 12,924	402	267,169	(*e*) 12,000	374	248,052
Guiana, British	79,682	2,478	1,647,031	59,796	1,859	1,234,988	62,406	1,941	1,289,948
Guiana, Dutch	38,162	1,187	788,820	35,494	1,104	733,718	38,790	1,210	810,829
Guiana, French	108,924	3,388	1,765,312	(*b*) 89,923	2,797	1,858,886	(*e*) 90,000	2,800	1,860,300
Peru	(*a*) 40,091	1,247	828,756	(*a*) 24,981	777	516,394	(*e*) 25,000	778	516,500
Uruguay	(*b*) 1,542	48	31,901	(*b*) 2,508	78	51,839	(*e*) 2,500	78	51,650
Venezuela	(*b*) 1,222	38	25,255	(*b*) 1,093	34	22,596	(*e*) 1,100	34	22,737
Europe:									
Austria	(*a*) 4,035	125	83,401	(*a*) 4,437	138	91,719	(*e*) 4,400	137	90,948
France	(*a*) 24,754	769	511,665	(*a*) 40,991	1,275	847,290	(*e*) 35,000	1,088	723,450
Hungary	(*a*) 120,176	3,738	2,484,275	(*a*) 112,557	3,501	2,326,765	(*e*) 110,000	3,422	2,273,815
Germany	3,890	121	80,400	3,220	100	66,460	3,220	100	66,460

Italy	(*b*) 1,990	62	41,205	(*b*) 1,928	60	39,876	(*e*) 1,900	59	39,273
Norway	(*a*) 261	8	5,400	—	—	—	(*e*) 250	8	5,165
Portugal	48	1	1,000	48	1	1,000	(*e*) 40	1	827
Russia	1,087,056	33,812	22,469,432	1,282,635	39,895	26,512,065	1,497,076	46,565	30,944,561
Spain	226	8	5,500	322	10	6,645	(*e*) 300	9	6,201
Sweden	(*a*) 643	20	13,292	(*a*) 900	28	18,590	(*e*) 900	28	18,603
Turkey	(*b*) 289	9	5,981	(*b*) 225	7	4,652	(*e*) 250	8	5,165
United Kingdom	(*b*) 1,415	44	29,242	(*b*) 1,415	44	29,242	(*e*) 1,400	43	28,938
Africa:									
Madagascar	56,585	1,760	1,169,608	54,012	1,680	1,116,428	(*e*) 55,000	1,712	1,136,850
Rhodesia	(*a*) 457,115	14,218	9,647,581	(*a*) 512,791	15,959	10,589,385	(*a*) 594,407	18,488	12,276,394
Transvaal	5,786,617	179,988	119,609,373	6,431,384	200,041	132,936,707	7,054,621	219,429	145,819,016
West Coast	199,432	6,203	4,122,260	272,277	8,468	5,627,970	279,320	8,688	5,773,544
Asia:									
Borneo, British	(*b*) 70,087	2,180	1,448,828	(*b*) 75,520	2,349	1,561,145	(*e*) 80,000	2,488	1,653,600
China	(*e*) 217,688	6,771	4,500,000	(*e*) 217,688	6,771	4,500,000	(*e*) 250,000	7,778	5,165,000
East Indies, Dutch	(*b*) 60,699	1,888	1,254,765	(*b*) 79,636	2,477	1,646,214	108,641	3,379	2,245,609
India, British	(*a*) 525,527	16,346	10,852,546	(*a*) 495,965	15,426	10,251,494	504,309	15,686	10,424,067
Japan (*d*)	132,979	4,135	2,748,920	164,753	5,090	3,403,378	(*e*) 155,000	4,824	3,203,850
Korea	(*b*) 110,434	3,435	2,282,901	(*b*) 105,002	3,266	2,170,584	108,502	3,385	2,250,000
Malay Peninsula	16,933	527	350,000	15,627	485	325,000	(*e*) 15,000	467	320,385
Australasia (*c*)	3,984,538	123,927	82,358,207	3,659,693	114,132	75,849,349	3,557,705	110,632	72,509,200
Other Countires	(*e*) 72,570	2,257	1,500,000	72,570	2,257	1,500,000	(*e*) 75,000	2,332	1,550,250
Total	19,620,272	610,261	$405,551,022	19,988,144	618,898	$411,294,458	21,529,300	669,651	$444,382,312

(*a*) Official statistics of the country. (*b*) U. S. Mint report. (*c*) Six states and New Zealand. (*d*) Exclusive of Formosa. (*e*) Estimated.

Note. — Fine gold is valued at $20.67 per oz.: which is equivalent to $664.60 per kilogram.

Cost of Producing Gold per Ounce

It is to be remembered that fine gold is worth $20.67 per ounce. In order to gain some idea of the proportion of profit in gold mining as compared with other metals we may conveniently take the cost per ounce as an index. It is a current statement that gold costs more than it is worth. If one were to charge up against it the fruitless explorations and unprofitable enterprises of which it is the object it is impossible to conjecture how near true this statement might prove to be. Very likely those responsible for the statement and who believe it have never gone beyond the point of making a guess. In my judgment the statement is not any more true with reference to gold than with any other metal. Just as the selling price of copper is determined in the main by the costs obtained by the successful enterprises which are responsible for the major portion of the output, so the value of gold is established by the correspondingly successful properties and districts which yield the greater part of it.

In the Transvaal the proportion of total yield of gold that has been paid in dividends is almost exactly 25 per cent. The cost of gold, therefore, in this district which is yielding one-third of the world's output has been to date three-quarters of $20.67, or about $15.50 an ounce. This proportion is holding good at present, the record for the year 1908 showing dividends equal to 28 per cent. of the gross value produced, indicating a cost per ounce of about $14.85.

We might compare the record of the Robinson, at present the world's most profitable gold mine, against the Calumet & Hecla, the world's most profitable copper mine. The comparison is approximately as follows:

The Calumet & Hecla: gross value of yield about $312,000,000; dividends $108,500,000, which is 35 per cent.

The Robinson mine: gross value of yield $60,000,000; dividends $32,000,000, equal to 54 per cent.

In Cripple Creek, Colorado, I estimate the cost of gold to have averaged about $17 per oz. or 82 per cent. of its value, while the principal mine — the Portland — has secured gold at a cost of $14.50 per oz. or 70 per cent. of its value.

In Kalgoorlie, West Australia, I have no figures for the district at large, but seven or eight of the leading mines have paid dividends equal to approximately 40 per cent. of the yield in gold, so that the cost per ounce is only $12.40. These mines have furnished so large a proportion of the total yield of that district that it seems safe to conclude that the cost of the entire yield has not exceeded $15 per oz.

In the Kolar district of India, the four leading mines responsible for nearly all the output paid dividends equal to 44 per cent. of the gross value. Hence we conclude that the cost of gold has not exceeded $12 for those mines, and probably not over $14 for the entire district.

At El Oro, Mexico, the record of the three leading mines shows profits of 40 per cent., indicating cost of gold of only $12 per oz. It is not at all probable that the fruitless prospecting in that district would bring the total cost up to more than $14.

While it is not probable that such favorable showings for gold-mining districts can be extended to cover the whole list of districts, it is evident that the successful gold mines are fully as profitable as successful copper mines. The value of gold produced in the world is almost twice the value of the copper production, so that I feel warranted in saying that the current belief that copper mining is the most profitable form of mining enterprise, and that gold mining is one of the least profitable, is far from justified. It is to be remarked, however, that in the United States copper is a more important product than gold and it is in the hands of a smaller number of much larger concerns, which have paid larger dividends than any individual gold mine. In the world at large the reverse is true.

CHAPTER XIX

QUARTZ-PYRITE GOLD MINES

Treadwell group in Alaska — Exhibit of conditions and costs — Homestake — San Juan region in Colorado — Camp Bird — Liberty Bell — El Oro district in Mexico — Esperanza and El Oro mines — Kolar district in Mysore, India — Details of cost factors — Records of the mines — A question of bookkeeping — Witwatersrand — Average results — The Robinson mine — Generalizations on the price of labor and costs.

Included in the class of quartz-pyrite mines are all of the properties of the Witwatersrand in the Transvaal, in fact all the gold mines of South Africa, nearly all the mines in eastern Australia, those of the Kolar district in India, of El Oro in Mexico, of California, Nevada, and Douglas Island, Alaska. In general, these ores are a light-colored or whitish quartz containing from 0.25 to 10 per cent. of iron pyrite and other sulphides in varying but usually subsidiary amounts. The quartz and pyrite may fill open fissures, or they may be replacements of country rock, or the cementing material of beds of conglomerate. Deposits of this kind have proved to be extensive, often persistent to great depths, and are worked on a grand scale.

Treadwell Group

The group of mines on Douglas Island, Alaska, known as the Treadwell, Mexican, and Ready Bullion, furnish ore for 780 stamps at the rate of 1,200,000 tons a year. This work with good reason stands at the head of the list of quartz-pyrite operations, furnishing an example of the simplest metallurgical problem, the lowest costs, and, I believe, the best management to be found in this class of mining. The external and internal factors which affect the results obtained are of great interest to the student of mine economics.

Robert Kinzie, now superintendent of all the mines, published in *Trans.*, A. I. M. E., Vol. XXXIV, a detailed account of

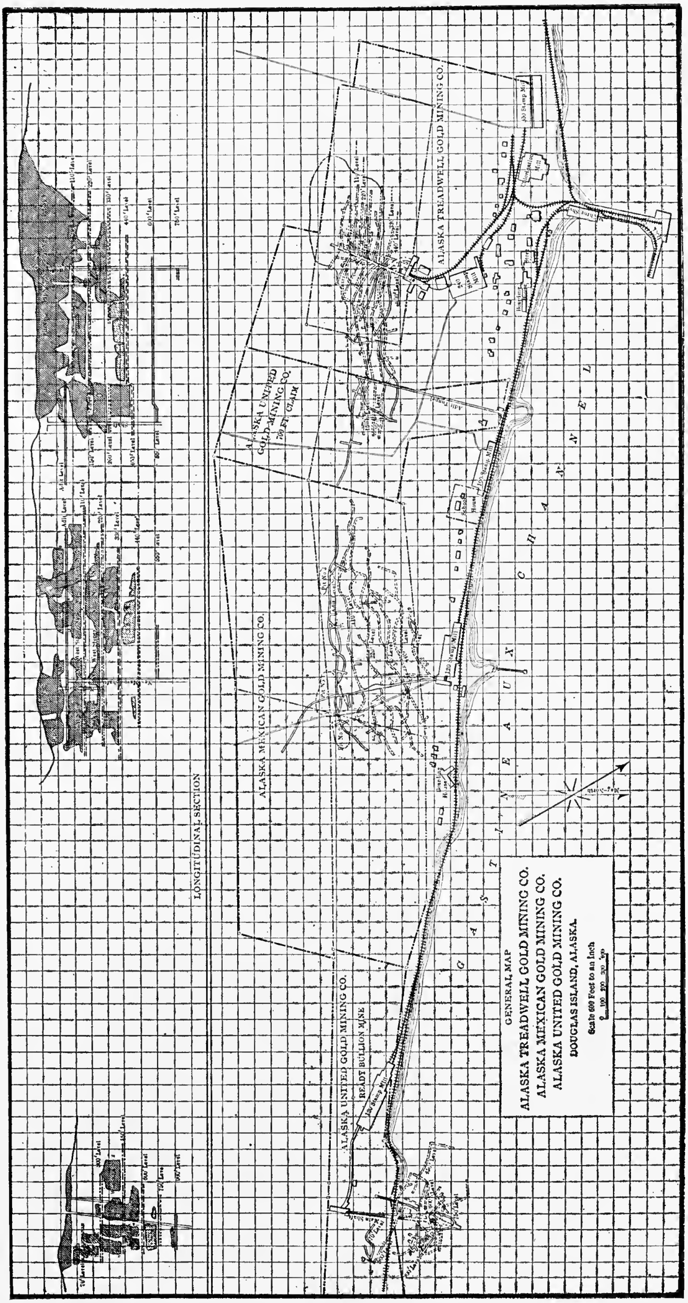
GENERAL MAP
ALASKA TREADWELL GOLD MINING CO.
ALASKA MEXICAN GOLD MINING CO.
ALASKA UNITED GOLD MINING CO.
DOUGLAS ISLAND, ALASKA.
Scale 600 Feet to an Inch
ALASKA TREADWELL GOLD MINING CO.
ALASKA UNITED GOLD MINING CO. 700 FT. CLAIM
ALASKA MEXICAN GOLD MINING CO.
ALASKA UNITED GOLD MINING CO.
READY BULLION MINE
LONGITUDINAL SECTION
GASTINEAUX CHANNEL
120 Stamp Mill

FIG. 18.

these properties up to 1902; in addition to this we have the full and excellent reports issued by the companies. On the whole the information available is definite and satisfactory.

Along a great porphyry dike which cuts the black slate of Douglas Island, there are three or four large lenses or ore shoots where the dike has been profoundly altered and silicified by the action of magmatic waters. The largest and most northerly of these is the Treadwell orebody, which was 400 ft. wide and 1000 ft. long at the surface. The Mexican and Ready Bullion orebodies are approximately 20 ft. thick and from 500 to 1000 ft. long in horizontal section. These orebodies are situated within a stone's throw of a splendid harbor on a sheltered waterway, which extends for 1000 miles from Puget Sound to Skagway. The most convenient and cheapest transportation facilities are thus provided for coal, timber, and other supplies. Concentrates, in the shape of auriferous iron pyrite, are shipped 800 miles to the Tacoma smelter at a cost of $1.72 per ton. The climate, though rainy, is mild and pleasant, corresponding to that of Scotland or southern Norway. While wages are not low, according to some standards (averaging about 32 cents per hour in actual cost), I believe that labor, owing to its efficiency, is really cheap. In addition to these advantages an abundance of water power is available. Little pumping is necessary in the mines. These external factors are so favorable as to be quite exceptional, perhaps unrivaled.

Internal Factors

The internal factors are also exceptional. The orebodies are large and firm; standing nearly vertical between pretty solid walls, they came up under the glacial drift in large masses that could be attacked in open pits. The metallurgical problem is the simplest.

Mining these orebodies, therefore, presented to the management the following factors: Several million tons of ore favorably situated for cheap handling, but containing less than $3 per ton. To make the maximum profit, or to make profits at all, required cheap methods both of mining and milling.

These conditions as to mining were met at the beginning by the "milling" method in an open pit; and as to treatment by the adoption of a large, simple, water-actuated stamp mill in which ore could be amalgamated and concentrated in wholesale quantities and at minimum cost. The simple metallurgical treatment proved amply effective, for the ore is thus treated at a cost of 17 to 27 cents a ton with an apparent extraction of 90 per cent.

As the mining proceeded it became increasingly difficult and finally impossible to maintain the required output from open pits and it became again imperative to devise a method of mining, this time underground, that would be cheap enough. It was a broader problem than the first because it involved the question of how much ore could be sacrificed on the one hand and how cheap the mining could be done on the other. It was discovered that about 75 per cent. of the ore could be mined without timbers from large chambers kept full of broken ore, only enough being drawn off at the bottom to afford room for the miners at the top. In the widest deposit this process costs $1 per ton and in the narrower bodies $1.20 per ton.

No change being required in milling methods on account of increasing depth the inauguration of the method of mining described seems to have solved the problem of making these ore-bodies pay to an indefinite depth as long as they maintain anything like their present size and value.

The milling of the Treadwell ores, its results, the collection and shipment of concentrates, are all shown up to 1902 in the accompanying tables given by Mr. Kinzie. It is well to note that in each of the mines the value recovered is about equally divided between free gold saved by amalgamation, and auriferous pyrite which constitutes 2 per cent. or less of the original ore. The shipment and treatment of these concentrates costs about $6.75 a ton and when spread over the original ore milled costs from 10 to 14 cents a ton.

Alaska Treadwell Gold-Mining Company

RECEIPTS AND EXPENDITURES IN DOLLARS PER TON. ALSO CONDITIONS AFFECTING OPERATING COSTS

Year	Total Gross Bullion and Concentrate Yield per Ton	All Expenses per Ton: Douglas Island: Supplies	Douglas Island: Labor	San Francisco, London, Paris, and Consulting Engineer	Total	Profits per Ton: Operating	Other	Total	Per Cent. Ore from: Surface Pits	Underground	No. Feet: Shaft Sunk	Other Development Work	Pounds Powder Used Per Ton Ore	Per Cent. Ore Milled by: Water Power	Steam Power	Per Cent. Indian Labor	Average Daily Pay all D. Island Employees	Concentrates: Per Cent.	Value per Ton	Grand Total: Tons Ore Milled	Profit	Year	Remarks
1890–1...	$3.49	$0.73	$0.85	$0.13	$1.71	$1.71	$0.10	$1.89	100	....	...	.....	1.01	79.11	20.89	....	....	2.66	$40.65	220,686	$418,208.90	1890–1	
1891–2...	2.95	0.65	0.78	0.07	1.50	1.45	0.08	1.51	100	....	...	.....	0.93	73.29	26.71	....	....	2.10	32.08	239,633	361,980.16	1891–2	
1892–3...	2.94	0.72	0.56	0.07	1.35	1.59	0.04	1.63	100	....	...	.....	0.76	70.18	29.82	....	....	1.80	41.42	237,235	385,613.79	1892–3	
1893–4...	3.21	0.52	0.75	0.09	1.35	1.86	0.10	1.96	100	....	...	1607	0.73	64.37	35.63	21.34	$3.00	1.84	46.45	220,043	429,948.86	1893–4	
1894–5...	2.60	0.59	0.71	0.07	1.37	1.23	0.06	1.29	100	....	116	1076	0.60	71.34	28.66	15.84	3.15	1.75	50.52	241,278	309,534.56	1894–5	
1895–6...	2.97	0.45	0.65	0.07	1.16	1.81	0.07	1.88	99	1.0	50	1091	0.76	80.56	19.44	13.63	3.10	1.66	57.73	263,670	497,342.22	1895–6	
1896–7...	2.80	0.75	0.75	0.07	1.57	1.23	0.11	1.34	95.1	4.9	...	2162	0.97	74.66	25.34	14.47	3.25	1.92	48.14	242,027	323,034.95	1896–7	
1897–8...	2.32	0.57	0.82	0.08	1.48	0.84	0.12	0.96	89.5	10.5	458	2208	0.84	62.73	37.27	8.36	3.23	1.70	44.33	254,329	243,260.82	1897–8	
1898–9...	2.71	0.48	0.74	0.07	1.28	1.43	0.12	1.55	85.1	14.9	48	3805	1.08	68.46	31.54	12.13	3.13	1.96	48.11	250,408	386,792.34	1898–9	
1899–0...	2.07	0.44	0.45	0.03	0.92	1.15	0.06	1.21	67.0	33.0	...	3455	0.80	79.97	20.03	5.71	3.02	1.76	38.78	557,960	673,961.18	1899–0	
1900–1...	1.88	0.54	0.62	0.03	1.19	0.69	0.08	0.77	47.7	52.3	...	4767.5	1.14	79.29	20.71	5.33	3.25	1.78	41.92	457,802	352,558.89	1900–1	
1901–2...	1.91	0.49	0.78	0.01	1.28	0.63	0.05	0.68	56.0	44.0	231	5327.5	1.65	77.39	22.61	5.00	3.26	1.82	50.48	682,893	463,489.93	1901–2	
1902.....	1.88	0.46	0.54	0.01	1.01	0.82	0.05	0.87	58.3	41.7	113	2583.0	1.34	84.93	15.07	4.8	3.18	1.88	49.79	508,636	442,513.32	1902	Six months

Alaska United Gold-Mining Company — Ready Bullion Mine

RECEIPTS AND EXPENDITURES IN DOLLARS PER TON. ALSO CONDITIONS AFFECTING OPERATING COSTS

Year	Total Gross Bullion and Concentrate Yield per Ton	All Expenses per Ton: Douglas Island: Supplies	All Expenses per Ton: Douglas Island: Labor	All Expenses per Ton: San Francisco, London, Paris, and Consulting Engineer	All Expenses per Ton: Total	Profits per Ton: Operating	Profits per Ton: Other	Profits per Ton: Total	Per Cent. Ore from: Surface Pits	Per Cent. Ore from: Underground	No. Feet: Shaft Sunk	No. Feet: Other Development Work	Pounds Powder Used per Ton Ore	Per Cent. Ore Milled by: Water Power	Per Cent. Ore Milled by: Steam Power	Per Cent. Indian Labor	Average Daily Pay all D. Island Employees	Concentrates: Per Cent.	Concentrates: Value per Ton	Grand Total: Tons Ore Milled	Grand Total: Profit	Year Ending Dec. 15
1898	2.42	$0.71	$0.55	$0.03	$1.29	$1.13	$0.07	$1.19	100.0	.....	602	2112	2.69	.....	100	....	$3.34	2.03	$72.00	19,612	$23,412.13	1898
1899	2.72	0.90	1.04	0.03	1.97	0.75	....	0.75	37.98	62.02	47	4272	1.32	.....	100	9.23	3.08	1.93	38.10	162,107	121,339.75	1899
1900	2.15	0.78	0.83	0.03	1.67	0.48	....	0.48	8.42	91.58	259	3552	1.19	.....	100	8.50	3.09	2.07	31.57	179,410	86,418.18	1900
1901	1.94	0.88	0.90	0.03	1.86	0.08	....	0.08	4.17	95.83	165	2370	1.28	.....	100	2.33	3.05	1.97	33.14	170,642	14,476.61	1901
1902	1.48	0.70	0.78	0.02	1.56	0.02	....	0.02	1.43	98.57	58	2787	1.19	.....	100	1.00	3.10	2.04	32.95	226,522	Loss 5,385.70	1902

700-Foot Claim

Year	Total Gross Bullion and Concentrate Yield per Ton	Supplies	Labor	San Francisco, London, Paris, and Consulting Engineer	Total Expenses	Operating	Other	Total Profits	Surface Pits	Underground	Shaft Sunk	Other Development Work	Pounds Powder Used per Ton Ore	Water Power	Steam Power	Per Cent. Indian Labor	Average Daily Pay all D. Island Employees	Concentrates Per Cent.	Value per Ton	Tons Ore Milled	Profit	Year Ending Dec. 15
1899	1.72	$0.54	$1.10	$0.03	$1.68	$0.04	....	$0.04	73.02	26.98	...	1621	1.11	100.0	....	1.87	$3.04	1.94	$37.87	85,065	$3,405.88	1890
1900	1.81	0.69	0.84	0.03	1.56	0.25	....	0.25	49.89	50.11	72	486	1.24	58.42	41.58	3.37	3.01	1.73	34.91	125,612	31,571.05	1909
1901	1.50	0.90	1.05	0.03	1.97	0.48	....	Loss 0.42	23.14	76.86	312	1396	1.03	54.16	45.84	1.32	3.11	1.71	28.13	89,450	Loss 42,797.49	1901
1902	1.33	0.52	0.63	0.02	1.17	0.16	....	0.16	....	100.0	...	382	0.78	81.82	18.18	...	3.10	1.84	48.46	118,541	19,362.64	1902

Alaska Mexican Gold-Mining Company

RECEIPTS AND EXPENDITURES IN DOLLARS PER TON. ALSO CONDITIONS AFFECTING OPERATING COSTS

Year	Total Gross Bullion and Concentrate Yield per Ton	Supplies	Labor	San Francisco, London, Paris, and Consulting Engineer	Total Expenses	Operating	Other	Total Profits	Surface Pits	Underground	Shaft Sunk	Other Development Work	Pounds Powder Used per Ton Ore	Water Power	Steam Power	Per Cent. Indian Labor	Average Daily Pay all D. Island Employees	Concentrates Per Cent.	Value per Ton	Tons Ore Milled	Profit	Year Ending Dec. 15
1894	$2.79	$0.84	$1.00	$0.13	$1.97	$0.82	....	$0.82	41.37	58.63	110	795	1.07	53.33	46.67	18.75	$3.70	2.02	$35.45	73,141	$59,639.65	1894
1895	2.85	0.85	1.03	0.07	1.95	0.90	....	0.90	48.37	51.63	236	2946	1.08	57.42	42.58	19.48	3.47	2.01	44.84	79,439	71,391.78	1895
1896	2.42	0.77	0.98	0.06	1.81	0.61	....	0.61	46.37	53.63	62	2333	1.21	43.39	56.61	26.08	3.49	2.18	42.49	101,702	61,650.43	1896
1897	2.12	0.69	0.84	0.05	1.57	0.55	....	0.55	37.76	62.24	...	2130	1.18	62.68	37.32	23.91	3.28	1.81	37.77	158,005	87,101.46	1897
1898	2.31	0.75	0.90	0.05	1.70	0.62	....	0.62	34.55	65.45	...	2081	1.25	55.50	44.50	16.46	2.95	2.07	34.80	162,457	100,663.07	1898
1899	2.09	0.72	0.96	0.03	1.73	0.36	$0.01	0.37	28.84	71.16	302	1910	1.36	48.47	51.53	15.59	2.93	1.98	37.85	166,054	62,333.42	1899
1900	1.89	0.68	0.97	0.04	1.69	0.20	....	0.20	16.30	83.70	107	2987	1.24	42.10	57.90	11.49	3.05	1.64	26.07	166,449	33,821.02	1900
1901	1.90	0.75	0.98	0.03	1.76	0.14	....	0.14	0.53	99.47	112	5329	1.00	43.97	56.02	0.76	3.07	1.78	39.30	178,960	24,709.63	1901
1902	2.06	0.62	0.99	0.03	1.64	0.41	....	0.41	....	100.00	218	4988	1.32	50.60	49.40	....	3.12	1.83	59.51	207,455	86,025.51	1902

The actual results and average costs up to the end of the reports for 1907 for the various mines are as follows:

	Treadwell	Mexican	Ready Bullion
Tons milled	8,485,085	2,447,063	1,841,079
Tons in sight	4,982,883	794,924	1,378,651
Feet development work, 14 years	74,717	59,960	27,362
Tons developed per foot approximate	120	54	100
Total value recovered per ton	$2.44	$2.55	$1.89
Profits, operating, per ton	1.16	0.77	0.25
Total operating cost per ton	1.28	1.78	1.64
Last depreciation figures per ton	0.21	0.23	0.35
Total estimated cost	1.49	2.01	1.99

From the above it appears that the Treadwell and Mexican mines have been very profitable, but that the Ready Bullion has not as yet earned enough to justify the investment, but the improvement in grade at the bottom is such as to be very promising for the future. It further appears that the combined mines have treated 12,773,227 tons of quartz worth $30,446,947 or $2.38 per ton for a total operating cost of $1.43 per ton, to which is to be added 24 cents a ton as a fair estimate (it seems very liberal) of the value of the plants employed; the total to be estimated for cost being $1.67 per ton and the profit 71 cents or 30 per cent. of the gross value recovered.

Below are given, more in detail, the costs of these remarkable mines, for the Treadwell in the year ending May 31, 1907, and for the Mexican and Ready Bullion for the calendar year 1907, the ore all coming from underground stopes except 12 per cent. of the Treadwell ore which came from an open pit. In each case the costs, while not the lowest on record, are quite near the average. I believe in the case of the Treadwell that the costs are overstated, certain sums being credited to the receipts which might logically be deducted from the costs, but I have made no attempt to change the figures given.

	Treadwell	Mexican	Ready Bullion
Tons milled	702,953	214,263	213,370
Cost mining and development	$1.00	$1.19	$1.00
Milling	0.17	0.27	0.36
Shipping and smelting concentrates	0.12	0.12	0.11
General expense	0.04	0.09	0.07
Construction	0.04	0.01	0.01
Total operating	$1.37	$1.68	$1.55
Depreciation	0.21	0.23	0.35
Grand total	$1.58	$1.91	$1.90

Homestake

From the Treadwell group one naturally turns to the Homestake mine in the Black Hills, South Dakota, to make comparisons. This is the greatest gold mine in the world in point both of tonnage and of gross value produced. In eight years out of the last nine the output has been as follows:

		Per Ton
Tons milled	9,383,114	
Gold recovered	$34,638,518	$3.69
Cost	28,587,300	3.04
Profit	6,051,218	0.65

It is to be observed that the costs are nearly twice as high as at the Treadwell group. Why the difference should be so great does not appear. One is tempted to suspect that the management may have had something to do with it, although nothing is more dangerous than to jump at such a conclusion.

The external conditions are not so favorable as at Douglas Island. The wages are about the same, but there is not such a good supply of water and timber, and transportation is more costly. The cost of water alone is approximately 10 cents a ton at the Homestake.

The internal factors would appear to be about the same. A vast body of silicified slate has been followed from the surface to a depth of nearly 1600 ft. The thickness is several hundred feet. The metallurgical problem seems to be simple; 4.7 tons are crushed per stamp per day. Amalgamation is followed by cyaniding the tailings at the very moderate cost of 18 cents per ton stamped.

The finer slimes receive a further treatment not described in the reports.

There are 1000 stamps employed on Homestake ore in six different mills. The whole milling process in 1907 cost as follows per ton:

Milling and amalgamating	44c.
Cyaniding	18c.
Slime treatment and construction	24c.
Total	86c.

The recent cost for mining and development is $2 a ton. For mining at the rate of 4000 tons a day from a single orebody this seems high. Possibly the methods are too good; a more wasteful one might be more profitable. Assuming that with the methods that have been used the profit now averages 75 cents a ton, it is demonstrable that the adoption of a method that would reduce the mining cost from $2 to $1.25 per ton at a sacrifice of 25 per cent. of the ore now saved would increase the value of the mine 60 per cent. If on the present basis 20,000,000 tons would be mined in fifteen years at a profit of $15,000,000, the present value, figuring interest on deferred payments at 4 per cent., would be $11,111,000. On the other basis, 15,000,000 tons mined in eleven years at a profit of $22,500,000 would give a present value of $17,700,000.

Mines of the San Juan Region, Colorado

The external conditions at the Camp Bird property are unfavorable. The altitude of the mine is 11,200 ft. in steep and snowy mountains. Two years ago a snow slide destroyed the mill and delayed operations six months. Wages are about average for the Rocky Mountain region, but it is not to be supposed that men are capable of sustaining their best exertions at such an altitude. Supplies have to be hauled several miles from the railroad station, Ouray, over a steep mountain road often blocked with snow.

The internal factors are as follows: The ore occurs in extensive shoots in a nearly vertical quartz vein 3 to 10 ft. thick, in a horizontal formation of bedded porphyries. In a total length of 4500 ft. explored there are four ore shoots aggregating 1700 ft. long. This has involved an expense for development of 76 cents a ton.

Stoping is done as at the Treadwell by breaking the whole vein upward from the levels and drawing out only enough to make room for the miners. Up to April, 1907, about 489,000 tons had been taken out and milled; 112,000 tons remained broken in the stopes.

Camp Bird Mine for the Year Ending April 30, 1908

Blocking out ore	$0.64
Ore breaking	.60
Timbering	.69
Loading and tramming	.78
Hoisting	.18
Lighting and pumping	.15
Engineering, sampling, and assaying	.10
Foremen and bosses	.17
Power	.32
Maintenance	.44
Total mining, 78,966 tons	4.08
Transportation to mill	.28
Stamp milling 80,087 tons	1.19
Cyaniding	.61
Shipping and selling concentrates	1.42
General expense, consulting engineer, administration, taxes, etc.	1.50
Depreciation average five years	.78
Survey of unpatented claims	.06
London office expense	.35
Total cost per ton	$10.27

Total values recovered were $25.90 per ton; of these 74.76 per cent. was obtained by amalgamation; 16.02 per cent. by concentration, and 9.22 per cent. by cyaniding. The extraction of the gold is given at 93.84 per cent. Adopting this as a rough estimate or the total extraction of all metals, we get $27.60 as the orginal value of the ore, so that the mill losses are approximately $1.70 per ton.

It is interesting to compare this record with that of the Mysore mine in India, which extracts a somewhat lower grade of ore without any expense for the treatment of concentrates, and mined ore during the same year at a cost of $9.25 a ton, although the wages at the Mysore mine seem to have averaged only 36 cents a day. The number of men employed at the Camp Bird is approximately 300 for an output of 80,000 tons, while at the Mysore 8334 are employed for an output of 234,000 tons.

It appears that the operations for the year given above were cheaper than for former years, an explanation being found in the fact that some 17,000 tons of ore were withdrawn from the stopes more than were broken in the stopes, and because the tonnage treated during the year was greater than ever before without any increase in the amount of general expense. During the past three years 184,605 tons were treated, averaging $28.90 per ton, and the earnings were $16 a ton, leaving $12.90 as the actual cost. It is stated that the extraction reported for 1908 was the highest on record. If we assume that the extraction has averaged 92 per cent. the performance of the mine may be calculated as follows:

Assay value of ore	$31.40
Loss in milling	2.50
Yield	28.90
Total operating costs, including construction, development, and London expenses	12.90
Total costs and losses	15.40
Profit per ton	16.00
Percentage of profit	51.00

These costs are much higher than those of the Liberty Bell mine a few miles away. The reason undoubtedly is the higher grade of the Camp Bird ores; this accounts for higher costs in taxes, freight, and treatment, etc., and furnishes the excuse for pretty liberal fees and management.

Results of Operations at the Liberty Bell Mine

Tons mined and milled		510,729
Net receipts per ton		$7.20
Costs:		
General expense	$1.05	
Mining and development	2.65	
Tramming to mill	0.42	
Milling	1.70	
Shipping concentrates	0.36	
Total operating		$6.34
Depreciation		0.30
Total		$6.64
Profit per ton		0.56

At this mine 26,446 ft. of opening work has been done in nine years, resulting in mining and developing about 900,000 tons of ore, or 34 tons to 1 ft. The cost per foot of development seems to be about $10, and per ton developed, $0.30. The stoping width is about 5 ft.

Analyzing roughly the difference between the costs of the Camp Bird and the Liberty Bell it appears that the former is more expensive, as follows:

	Per Ton
Underground cost	$1.46
Milling	0.15
Treatment charges	1.45
General expense	2.00
Depreciation of plant	0.55
Total	$5.61

It may be fairly said that the higher cost at the Camp Bird for milling and treatment charges are entirely justified by the higher grade of the ore. As to other expenses one may doubt their necessity.

Other mines in the San Juan region whose reports are available are the Tomboy and the Smuggler Union. I have not investigated these reports, but in a general way the costs at these mines are not greatly different from those of the Liberty Bell. These mines have each reported costs lower than those given, for a single year, but it is doubtful if they would be lower if figured upon a long term of years.

In general mining in the San Juan region costs about $7 a ton. The external factors of a rough surface, a severe climate, costly transportation and a debilitating altitude are all unfavorable. The internal factors are such that only a small tonnage can be maintained. Metallurgically the ores are only fair, and while not markedly difficult, do not seem to permit of full treatment at a cost of less than $2 a ton. The explanation, therefore, of the big jump in costs from $1.50 at the Treadwell and $3 at the Homestake to $7 in the San Juan is the cumulative effect of a variety of both external and internal factors.

El Oro, Mexico

The mines at El Oro, Mexico, are well managed; they pay good dividends and issue good reports. The two principal mines are the Esperanza and El Oro on the San Rafael vein and the Dos Estrellas on a parallel vein to the westward. The Mexico mine just north of the Esperanza on the San Rafael lode is promising. The veins are large mineralized shear zones in slate or shale. There are numerous cross faults. The veins are for the most

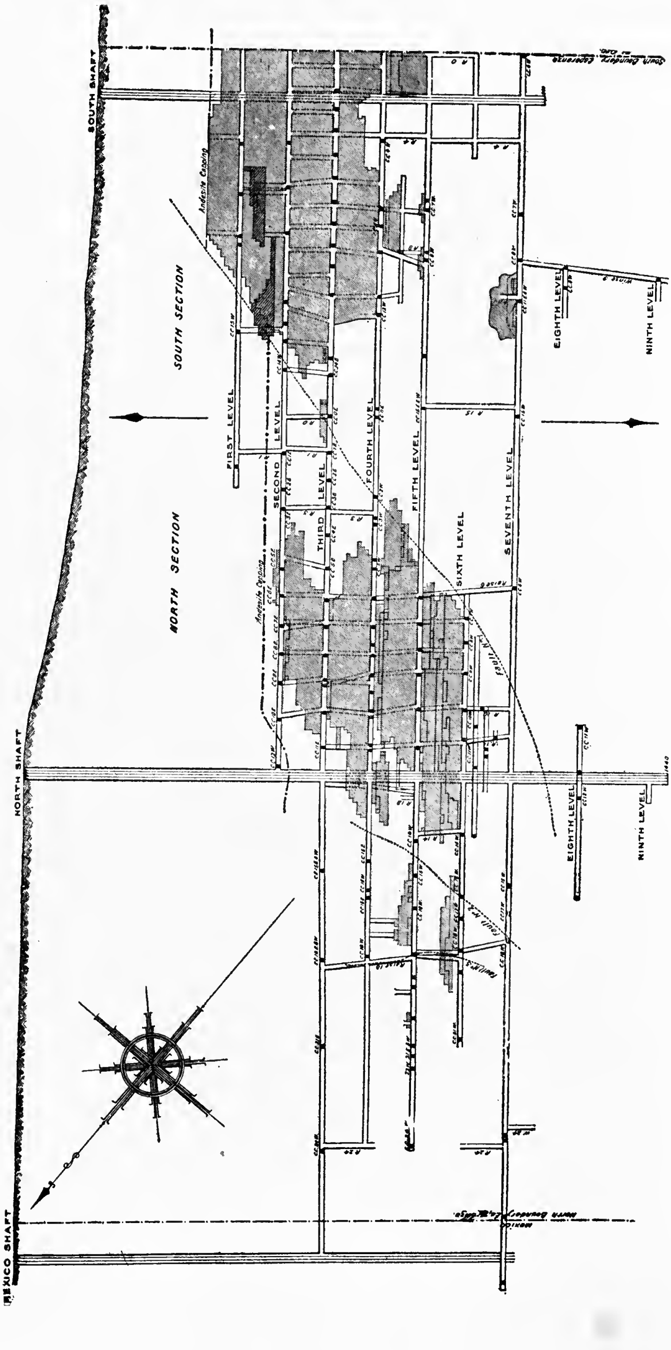

FIG. 19.—Longitudinal section of Esperanza mine, illustrating ore shoots such that 1 foot of development work is required for mining 16 tons of ore.

part obscured by a later flow of andesitic lava which covers the important orebodies to a depth of several hundred feet. The ore is quartz with pyrite sprinkled through it. The gold is very finely divided, and will yield by amalgamation only about 15 per cent.

Grade of Ore and Output

It appears that the Esperanza mine up to the end of 1908 produced 1,176,117 tons averaging $19 per ton, and El Oro 1,080,000 tons to the end of 1907 averaging $11.39 per ton, in both cases by actual yield. Probably these figures indicate average ores produced by the principal mines in the district. If so, we get a yield of $16.33. It is probable that the extraction has averaged something like 88 per cent., so that the assay value of the ore as mined must be about $18.50 per ton. Two distinct types of ore have been worked: an oxidized cyaniding ore averaging about $13 a ton by assay value, by extraction about $11.40 as stated above for the material mined; and a narrower vein of sulphides discovered and worked on the Esperanza, and lately on the Mexico mine, the ore from which has been treated mainly in the smelters and has been of high grade, much of it running three or four ounces per ton. Below are given the figures for mining and milling at the El Oro and Esperanza up to the end of 1907, since which time the reports indicate nothing to warrant changing them.

In general, the milling ores of the district may be described as follows:

Assay value	$13.00
Loss in milling	1.60
Yield	11.40
Costs mining and milling	7.00
Profit	4.40
Percentage of profit	34.00

Smelting ores produced by the Esperanza in 1906 were:

Value per ton	$74.50	
Freight treatment and deductions		$18.75
Cost of mining per ton		5.00
Total cost		23.75
Profit		50.75
Percentage of profit		68.00

The external conditions are probably about average for gold mining. The wages for natives are low and their labor inefficient. Water-generated electric power is furnished to the mine. The El Oro company owns a railroad, timber land, and a sawmill, and presumably supplies the other mines as well as its own with timber and transportation.

The walls are heavy, and where broken by cross-faults become very soft. Ordinarily the square-set rooms can be kept open to a hight of 40 to 50 ft.; then they must be filled. The mines are pretty hot. The ore while forming in good-sized bodies is separated into streaks in different parts of the shear zone. The development of these requires considerable crosscutting and drifting along the intersected streaks. Work is also done on entirely distinct veins separated by some hundreds of feet of waste. The experience to date has shown the requirements in the way of development to be as follows:

	Feet	Tons Mined	Tons Developed
El Oro	88,803	820,000	605,000
Esperanza	60,640	875,000	142,000
Total	149,440	1,695,000	747,000

About one foot of opening work to 16 tons discovered.

COSTS

	El Oro	Esperanza
Tons mined	1,080,788	450,000
Tons milled	1,027,282	333,330
Mining	$1.99	$2.80
Development	0.74	0.80
Milling	0.77	2.63 (Milling and Cyaniding)
Cyaniding	1.11	
Water	0.02	—
Other	0.13	—
General	0.90	1.08
Construction	0.36	0.19
Total	$6.02	$7.50

The recovery of metals at the two mines is reported for 1906–7 as follows:

	Gold Per Cent.	Silver Per Cent.	Total Value Per Cent.
Esperanza	90.64	57.33	86.20
El Oro	90.28	68.55	86.63

Costs at the Esperanza have always been higher than at the El Oro both for mining and milling. There is nothing in the reports to explain why this should be so.

Kolar District, Mysore, India

In Vol. XXXIII, Part 1, of the "Memoirs of the Geological Survey of India," F. H. Hatch gives an excellent practical description of the Kolar mines as they were in 1900. Since that time certain changes have been introduced, notably water-generated electric power; the scale of operating has increased, and the costs diminished, but no specific description of these changes has come to my attention. The reports of the various companies give abundant information about output, costs, mine developments, etc. It is possible that something might be changed by Mr. Hatch if the descriptions were to be brought down to the present day, but on the whole the sources of information are satisfactory. One feels particularly like complimenting Messrs. John Taylor & Sons, who manage most of the mines, on their complete and detailed annual reports to their stockholders.

The principal mines are the Mysore, Champion Reef, Ooregum, and Nundydroog: other mines are not very profitable. The district has been opened since 1882. The output has been steadily increasing, but the maximum seems to have been reached. The climate is tropical; the rainfall averages 30.13 in. per year, but is variable.

This Indian gold-field is one of the most instructive examples to be found anywhere in studying the basic principles of mine economics. The center of the field is 183 miles from the important seaport of Madras; the freight rate for various articles being as follows (presumably per long ton):

Coal in carloads	$1.40
Timber less than 17 ft. long	1.90
Timber more than 17 ft. long	2.24
Steel, cast iron pipes, machinery, and kerosene	3.40
Wire ropes and galvanized iron pipes	4.45
Machinery in small lots	5.87
Explosives	16.67

Indian coal is delivered at the mines for $6.50 per ton; English coal for $9.75, and fire wood for $2.56. Ordinary mining timber costs from $20 to $45 per M., a large proportion being of the more expensive kinds. Dynamite costs about 27 cents per pound and blasting gelatin (93 per cent. nitroglycerin) 35 cents. These supplies, it will be observed, are all more expensive than in the United States in the proportion of perhaps two to one.

Labor at Mysore

When we come to labor the situation is interesting. Men are employed in the following proportions:

Europeans	2.2 per cent.
Eurasians	1.6 per cent.
Natives	96.2 per cent.

I have no means of computing, except approximately, the average wages earned by three classes. Europeans are paid by the month, on contract usually for three years. Transportation is provided by the companies to and from Europe, and quarters, furniture, fuel, lights, and servants also. Men laid up by sickness draw full pay. The salaries vary from $30 a month for some of the miners to $100 for smiths and machinists, and $250 to the highest paid chemists and foremen. Considering the debilitating effect of the climate and the loss of time during illness, voyages, and holidays, it does not seem improbable that the work done by these men costs at least twice as much as work done in the United States would cost if done by men paid the same wages. Indeed I believe this estimate is too low.

Wages of natives are as follows in cents per day.

Carpenters	12 to 50
Smiths	8 to 48
Timbermen	16 to 43
Engine drivers	20 to 33

Trackmen	20 to 41
Gang bosses	24 to 33
Machine men	20 to 33
Hand miners	16 to 24
Blasters	16 to 24
Landers	16 to 20
Trammers	16 to 18
Muckers	14 to 16
Firemen	12 to 16
Surface coolies	8 to 12

It is, of course, impossible to obtain from these details an exact estimate of the wages paid, but on the assumption that the wages of miners are somewhere near the average for natives and that Europeans average $5 a day including expenses, and Eurasians $2, we have:

2.2 Europeans at $5 equals	$11.00
1.6 Eurasians at $2 equals	3.20
96.2 Natives at $0.23 equals	22.12
100.0	$36.32

This means an average wage of 36 cents or thereabouts, for all employees.

Factors in Mining

The internal factors are a single marvelously persistent quartz vein, with a few branches, developed for a length of 17,500 ft. The vein occurs in a belt of schists which I suppose, from the presence of beds of quartzite, are undoubtedly in part metamorphosed sediments. The belt seems to be a syncline, but it is invaded on both sides by intrusive granites. The bulk of the schist consists of altered traps or lavas. There are some later dikes of a basic character. The vein corresponds both in strike and dip, which is about 50 to 55 degrees west, with the foliation of the schists. The ore is a clean quartz containing 0.25 per cent. of pyrite. The quartz occurs in a number of shoots along the vein. Some of the shoots occur in sharp anticlinal folds where something like the saddle reefs of Bendigo, Australia, has been developed in the vein. The direction of other ore shoots along the plane of the vein seems to be about parallel to the axes of these folds. The extent of the shoots is variable; some of the largest are known to be more than 4000 ft. deep along the slope, and as much as 800 ft. wide, measured at right angles to the long axis. It is difficult to ascertain the thickness of the vein stoped; the average is probably between 3 and 4 ft. Taking the vein at large, the poor with the good, the average thickness of mill ore developed on the Mysore property in 1907 was 1.8 ft.

Although these mines, particularly the Mysore, are looking exceedingly well in the bottom, the thickness and grade of the ore show some diminution. The greatest vertical depth reached is about 2400 ft. in the Edgar shaft of the Mysore. In earlier years, when the mines were less than 1000 ft. deep. vertically, the ore shoots on the Mysore and Champion Reef mines seem to have averaged nearly 5 ft. in thickness.

Method of Treatment

The milling practice is simple. The ore, when properly sorted, yields a clean quartz with very little clayey matter in it. The process consists of amalgamation in a stamp battery followed by cyaniding the tailings. A special cyanide process is used for the comparatively small proportion of slimes. The only distinctive fact is that the crushing duty per stamp is low, being only 2.25 tons per day per 1050-lb. stamp. The pulp is put through screens averaging about 1600 apertures per square inch. The low stamp duty is made necessary by the high grade of the ore. In the Transvaal and at the Treadwell the duty per day is about five tons per stamp.

A few years ago a striking and uneconomical feature of the metallurgical practice was that the work was done in a number of small mills instead of in a central large one on each property. This bad feature has been, I believe, largely corrected.

It will be seen from the following table that the conditions and costs are fairly uniform for the four properties. Consequently it does not seem worth while to give details for more than one.

For this purpose the Mysore mine serves excellently. It is an extraordinarily good and profitable property, situated at the south end of the district and covering 7700 ft. along the lode. It is developed to an extreme vertical depth of 2600 ft., equal to 4000 ft. along the incline. The ore is derived from three independent shoots of which the central one is the more prominent, but all three have proved persistent to the lowest workings. In

Output and Valuation of Ore Produced by the Four Principal Mines of the Kolar District of India Reduced to Short Tons and American Currency.

Name and Date	Tons Mined	Tons Ore in Sight	Yield from Ore Mined	Average per Ton	Dividends	Average Dividends per Ton	Cost per Ton
Mysore 1884–1898	2,484,562	1,085,000	$52,624,000	$21.18	$27,252,000	$10.96	$9.22
Champion Reef 1892–1908	2,130,748	—	40,340,000	19.00	17,148,000	8.05	10.95
Nundyroog 1888–1908	1,029,700	133,000	17,763,000	17.24	7,163,000	6.96	10.28
Ooregum 1888–1908	1,660,781	172,000	23,580,000	14.20	7,852,000	4.74	9.46
Four mines 1884–1908	7,305,791	1,388,000	$134,300,000	18.40	59,655,000	8.18	10.22

Note. — There is reason to believe that the dividends are larger than the real profits because they include sums obtained from stockholders, for premiums and new stock issued to cover new construction and developments. This practice, however, has now been stopped and it may be that the costs estimated are not far from the truth, on the theory that the money heretofore spent on plant will serve for the future operation of the mines, or at least for the ore in sight.

1907 the record was as follows, expressed in short tons and American currency:

	Currency
Tons mined and treated	233,825
Assay value of ore	$20.00
Yield of ore	17.12
Loss in milling	2.88
Extraction in mill	85.51 per cent.

	Costs per Ton
Plant and equipment, including a proportion of the development work, average for eleven years	$1.87
Administration	.20
Mining	4.68
Milling	.63
Cyaniding tailings	.23
Repairs to buildings, machinery, and plant	.90

	Costs per Ton	
Surface costs	.10	
Pumping charges	.05	
Transport and insurance of gold	.15	
Kolar Central Metallurgical Establishment	.01	
Medical Establishment	.04	
Survey department	.01	
Police and detective force	.01	
Traveling expenses of employees	.04	
Kolar Gold Field Electricity Department	.01	
Telegrams, postages, and incidental expenses in India	.02	
Directors' fees	.11	
Salaries and bonuses to managers and clerks	.15	
Telegrams, postage, stationery, etc.	.03	
Total costs equalizing small differences in details	9.25	
Net profit per ton	7.87	
Profit on gross value of ore mined	39	per cent.
Total costs and losses	12.13	

A Question of Bookkeeping

To charge improvements to capital account, even if they are absolutely new, is a bookkeeping error into which nearly all mining companies fall. This error is, of course, in most cases theoretically rectified by writing off a certain amount of depreciation. While in the case of these Kolar mines it appears that the depreciation has kept pace with the increase of capital (for eleven years the Mysore company received from stockholders about £60,000 a year), this does not alter the fact that the money thus written off did not come out of the mine. To some extent, of course, the money thus provided was used to make a real increase in the company's resources, and to this extent it will be paid back in the shape of increased profits, or lower costs, in later years. But it should never be forgotten for a moment that there is always some work going on about a mine in the shape of permanent improvements, and that for a period of years the average amount thus expended should not be written off the balance sheet; it should be charged to operating. To pay operating expenses out of new capital is either a fraud or a bookkeeping sophistry. It is always a mistake more or less complete. It may be partly justified but never wholly.

The accompanying table prepared by Mr. Hatch shows the distribution of costs for the year 1899. These costs are a little higher than the average, but not so much as to give a seriously false impression.

Within the past year or two considerable economy has been effected by the introduction of water-generated electric power from the Cauvery falls. In 1899 steam power cost $150 per horse-power year and the cost per ton for the power used was more than $3. Electric power is now furnished for $90 a year, reducing the power cost more than $1 per ton.

I will not go into details regarding all the mines, but will give some further facts regarding the Mysore, the largest and best mine in the district. This property in the years 1902–1907, inclusive, did 163,691 ft. of development work, mined and milled 1,210,000 tons of ore, and increased its reserves from 380,800 tons to 1,012,480 tons. The actual ore developed during the period was 1,841,500 tons, being a trifle more than 11 tons per foot of development work. This development with approximate costs was made up as follows:

Drifts and crosscuts, 117,912 ft. at $10 equals	$1,179,120
Raises, 24,041 ft. at $40 equals	960,000
Winzes, 12,291 ft. at $40 equals	490,000
Shafts, 9,447 ft. at $100 equals	944,700
Total	$3,574,000

The costs are approximations from Hatch's report.

High Development Cost

If these costs are anywhere near the actual, and I believe that they are, we have an average cost per ton developed of about $1.94 and per ton milled of $2.95.

In the abstract of Hatch's figures for various kinds of work it is to be observed that the development accounts for about half the cost of mining. In this connection, however, it is well to point out that a considerable portion of the development work does not appear in the working costs, but is charged to capital account. The only place where this expenditure appears is in the balance sheet where certain sums are "written off" for depreciation, etc. These sums amount in six years to $2,122,000 on machinery, plant, etc. Of this a good deal must represent the cost and equipment of Edgar's and other shafts.

To show how this bookkeeping works, let us take the revenue account for the year 1907. Here we find that administration and working costs, including directors' fees, insurance, and all general expenses, amount to $8 per ton. To this we must add from the balance sheet, in order to get the management's real estimate of the costs, the sum of $1.76 per ton for depreciation, this being the average for the last six years. With this addition the total cost is $9.76. This, it will be observed, is very close, both to Mr. Hatch's figures in 1899, and to my own estimate based on the output and dividends.

Mr. Hatch comments as follows:

COSTS AT THE MINES OF MYSORE IN 1899, ACCORDING TO HATCH

	Mysore	Champion Reef	Ooregum	Nundydroog	Balaghat	Coronadel
Mine costs	$5.79	$7.15	—	$7.02	$12.12	$4.87
Mill	1.28	1.68	—	1.41	1.41	1.60
Wheeler pans	—	0.69	$9.46	0.21	—	—
Cyanide	0.69	0.89	—	0.75	0.50	0.47
Administration	0.28	0.27	0.44	0.51	0.79	0.76
General charges	0.75	0.61	0.49	0.48	0.31	0.49
Total	$8.79	$11.29	$10.39	$10.38	$15.13	$8.19
Royalty on gold ore	1.58	1.51	0.86	1.12	0.63	0.21
Depreciation	0.41	0.26	0.14	0.40	2.20	0.50
London office	0.39	0.30	0.33	0.65	0.88	0.74
Grand total	$11.17	$13.36	$11.72	$12.55	$18.84	$9.64
Reduced to short tons	$10.00	$11.93	$10.47	$11.21	$16.82	$8.61

"The working costs are high, but there is not much difficulty in accounting for this. First, the nature of the ore deposit dictates a high cost of working, as, for instance, the occurrence of the pay-ore in shoots, which, though of high grade, are of comparatively limited extent. This leads to a heavy expenditure in development, as much sinking, driving, and crosscutting must be done in waste rock in order to open up pay or shoot ore. The cost of this development work is included in the figures given for working costs. Then again the heaviness or instability of the ground in parts of the mines necessitates a big expenditure on timber to secure the stopes, shafts, and levels.

Cost and Grade of Ore

"Further, it must not be forgotten that the cost of working a high-grade ore is of necessity greater than that of a low-grade ore, and the reason for this is plain. In mining low-grade stuff the main object is to obtain a large tonnage at a low cost; consequently the stopes are carried as wide as possible and the whole mass of the orebody is, as a rule, exploited, the exploratory or dead work being at a minimum. With high-grade stuff, on the other hand, the stopes are kept as narrow as possible, and great care is exercised only to extract the payable portions of the orebody. Much exploratory work in waste rock is, therefore, necessary in order to locate the pay ore. Similar factors influence the metallurgical treatment. With low-grade stuff the ore is passed quickly through the mill, a high stamp duty being maintained by the use of coarse screening and a low discharge, and the cyanide process is relied upon to catch the gold that escapes amalgamation. Whereas with high-grade ore the usual practice is to crush fine, and to catch as high a percentage of the gold as possible by amalgamation.

"For these reasons it is impossible to compare the working costs of high-grade mines, such as those at Kolar, with the low-grade mines of other countries, as, for instance, those of the Witwatersrand in the Transvaal. At the same time, it must be admitted that a reduction in working expenses at Kolar could no doubt be effected by improvements in milling plant, and by the substitution of automatic mechanical means for native labor in the handling of the ore delivered at the shaft top, and of the tailings leaving the mill. The substitution of a large centrally-placed mill with heavy stamps for several small and scattered mills with light stamps, which at the present moment is being carried out on the Champion Reef, and is in anticipation at Ooregum, will decrease the cost of milling at these mines. The introduction of mechanical haulage, automatic sorting tables, tailings, wheels for elevating the tailings, and pointed boxes for classifying and filling directly into the cyanide vats, all these improvements would no doubt have a similar effect. So also will the introduction of water power transmitted by electric current, as it is proposed to do by the Cauvery power scheme."

Details of Development Costs, Hatch

Cost of Raising (10x5 ft.) 15.6 ft. per month

Labor, white	$8.25
Labor, native	4.50
Explosives	6.25
Supplies	4.90
Compressed air	21.00
	$44.90

Cost of Driving

Hand .... $9 per ft., rate 15 ft. per month.
Machine .... $11 per ft., rate 30 to 35 ft. per month.

Stoping in 4½-ft. vein without timbering costs about $1.25 per ton.

Cost per Foot of Shaft-sinking in Kolar Goldfields

	Nundydroog 12 x 6 ft.	Oakleys' 16 x 8 ft.	Champion Reef 16 x 8 ft.	Edgar's Mysore circ'r 18 ft.
Labor	$31.27	$32.68	—	—
Timber	7.88	25.22	—	—
Explosives and supplies	13.40	24.20	—	—
Compressed air	32.84	33.88	—	—
Hoisting	10.93	4.84	—	—
Drill sharpening	0.49	—	—	—
	$96.81	$120.82	$145.91	$120
Speed per month	15 ft.	25 ft.	28 ft.	20 ft.

Equivalent work in the United States may be estimated as follows:

Sinking large working shafts (Lake Superior, Butte, Cœur d'Alene, or Cripple Creek), average rate per month 50 ft., cost per ft.	$100
Raising with complete timbering, 10x6 ft.	25
Drifting in average ground, 5x8 ft.	9

Wages and Cost of Labor

I have given many details about the Kolar mines because I wish to illustrate the extraordinary lack of correspondence between the wages paid and the costs. There does not seem to be any detail in which work at these mines is done cheaper than in the United States. In Cripple Creek, or Butte, or the Cœur d'Alene, where wages average ten times as high as at Kolar, work can be done just as cheaply. This is true of drifting, of crosscutting, of raising, of shaft sinking, of stoping, of everything on which I can find data for comparison.

It is true that supplies cost more than in the United States; nevertheless out of working costs of $8.96 per ton I find that labor must account for about $5.50 or 60 per cent. This is the usual proportion in the United States. We find that the number of men employed to mine and mill 217,770 tons of rock in 1907 at the Mysore mine was 8334 or 26 tons per man per year. At the Camp Bird mine in Colorado, where external conditions are unfavorable, the ore being of higher grade and the costs nearly the same, the wages are ten times as high and the output per man ten times as great.

It is inconceivable to me that the energy expended by a miner in Colorado is ten times as great as that expended by the Indian miner. The true explanation of the wonderful difference in performance lies in the industrial efficiency of the community by which the men are surrounded.

Witwatersrand

The great gold-mining field, Witwatersrand, produces one-third of the world's annual yield of gold, and is so well known to the mining public, and even to the public at large, that any general description of it, other than such as will serve my purpose of illustrating the factors governing the cost of mining, is unnecessary.

The occurrence of the ores here bears a resemblance to that of two important districts described elsewhere, *i.e.*, to the copper conglomerates of Lake Superior and to the Kolar mines in India. Like the Calumet conglomerate the banket beds of the Transvaal are mineralized sedimentary beds, and the value of the material worked is not far from equivalent, but the "Rand" beds are thinner, more persistent, and workable over much greater areas. The Kolar mines, while on a vein of different geological origin and producing ores of much higher value, bear a considerable resemblance in the persistence and abundance of the mineralization.

Two recent papers by distinguished American engineers throw excellent light on the present condition of the industry. Ross E. Browne has written an exhaustive discussion of "Working Costs on the Mines of the Witwatersrand" (republished in the *Mining Journal* of London, in the issues of July, 1907) and Thomas H. Leggett (*Trans.* A. I. M. E., February, 1908), describes the "Present Mining Conditions on the Rand."

Mr. Browne sizes up average conditions for the whole district as follows:

	Per Ton Milled
Working cost	$5.85
Capital redemption	1.22
Total expense	$7.07
Yield	8.71
Profit	1.64

By capital redemption, I suppose, Mr. Browne means all capital, including probably large sums paid for mining claims. By the theory of costs used in this article such sums are profits paid to somebody by the working of ore from the land and are not, therefore, costs. Accordingly, Mr. Browne's estimate of the cost of capital redemption is somewhat high.

A summary of the record of the Witwatersrand is as follows:

Tons milled (1884–1908)	113,600,000
Value recovered	$1,049,000,000.00
Dividends paid	273,655,000.00
Yield per ton	$9.23
Dividends per ton	2.41
Cost per ton	6.82

In 1908 the figures were as follows:

Tons milled	18,000,000
Value recovered	$144,600,000.00
Dividends paid	41,800,000.00
Yield per ton	8.03
Dividends per ton	2.30
Cost per ton	5.73

It is probable that the dividends in these tables include sums that should properly be charged to redemption of capital, *i.e.*, amortization of plants, and that the costs should be estimated a little higher. On the other hand, it is certain that these costs include all current construction, or depreciation charges, and are a much better exhibit of the real dividend costs than the "working costs" ordinarily published. Almost all the production comes from dividend-paying mines.

On nine representative mines in the district Mr. Browne finds the following average working conditions:

Number of stamps operating	111	
Working costs per ton milled	$5.19	
Percentage rejected by sorting (probably at surface only)	13	
Ratio of tons developed to tons mined	0.90	
Width (thickness) of stopes in inches	69	
Continuity of reefs, normal for the Rand, unrivaled elsewhere.		
Average depth of mining in feet	1200	
Dip of reef	30	degrees
Hardness of ground, solid quartzite and slate.		
Cost of timber per ton of ore mined	4 cents	
Cost of coal per ton delivered at plant	$3.41	
Gallons of water pumped from mine per ton of ore milled	313	
Duty of stamp, tons milled per 24 hours	4.85	

With the above average conditions the average costs are as follows:

Development cost per ton	$0.37	
Other mining costs	2.63	
Total cost per ton hoisted		$3.00
Milling, crushing, and amalgamating		0.69
Cyaniding		0.64
General expense at mines		0.25
General expense at head office		0.18
Total		$4.76

These figures represent the costs as they would be if all the ore hoisted were milled, but as 13 per cent. is rejected by sorting, the cost as divided by the tonnage actually milled is brought up to $5.19.

A Comparison of Records

I cannot believe that these figures make a disadvantageous comparison with costs of similar operations elsewhere. This opinion is somewhat at variance with the general idea among mining men, and, as I have never been in South Africa, it is perhaps well to explain that I am going wholly upon the consideration of the basic principles involved.

Mr. Browne sees hope of reducing costs to about $3.75 per ton by increasing the efficiency of white labor, by better direction of colored labor, and by reducing the cost of supplies. With this hope I certainly have no quarrel and it is probably not altogether extravagant. Considerable improvements are brought about by necessity and by long-continued effort. As the grade of ore diminishes the cost is inevitably diminished by the simple process, among other things, of refusing to work ores that present difficulties beyond a certain limit. But as a matter of practical experience, taking into consideration all the ins and outs, good luck, and bad accidents, it seems to me that the performance of the Rand mines is fully as good as that of other mines.

To judge better of this let us look up the life history of the greatest of the Transvaal mines, the Robinson, and see how it compares with other great mines of which we have the records.

Robinson Gold Mining Company, to End of 1906

Tons milled		2,657,768
Total value, $46,535,000	Per ton,	$17.50
Working cost per ton		6.36
Construction and improvements		0.78
Total cost per ton milled		7.14
Profit $27,680,000	Per ton,	10.36
Dividends and cash in profit and loss		24,219,000
Real estate, securities, and cash on loan		3,461,000

Nearly 60 per cent. of the entire gross revenue is shown as clear profit. Few mines of this grade can equal this showing of costs.

It would be an exceedingly laborious compilation to get the average costs in detail, so I shall content myself with giving the details in a year of which the costs approximate the average. Such a year is 1897 when the total cost was $6.90 divided between working cost at $6.65 and construction at $0.25. In this year the tonnage hoisted was 203,597 of which 23,197 was sorted out on the surface. In addition the amount sorted out underground was estimated at 60,000 tons, making the total stoped about 263,500 tons. Since the sorting out of this waste underground serves no useful purpose in protecting the safety of the workings, it was sorted out entirely to avoid the expense of milling. It is probable that the sorting on the surface and stowing of waste underground cost fully as much as the tramming of ore for the mill. For comparing the work done here with certain other mines it is necessary to make these corrections.

MINING COSTS, ROBINSON GOLD MINING COMPANY

Tons		Per Ton
263,500 stoped	$443,694	$1.68
263,500 trammed	21,882	1.08
203,597 hoisted	19,671	0.10
263,500 mine maintenance and pumping	47,306	0.18
320,000 developed	178,334	0.56
		$2.60

These figures are as low as those of the Portland mine at Cripple Creek, figured on the same basis; they are not far above those of the Tamarack, or the Calumet & Hecla, where the volume of material in the same area is more than double, and lower than equivalent work in the Mysore mine. It is to be remembered that the mining is done at the Robinson on two beds, the Main Reef Leader of a payable width of 18 in. and the South Reef of a payable width of 42 in., on which there is not room for working. The effort is to carry the stopes as narrow as possible.

MILLING COSTS

	Tons	Total	Per Ton
Crushing and sorting	203,597	$18,134	$0.09
Transport to mill	180,400	5,465	0.03
Milling and maintenance	—	78,548	0.43
Power	—	40,094	0.22
			$0.77

SECONDARY TREATMENT

Vanning, concentration	14,966	$0.07
Cyaniding, chlorination	126,470	0.70
		$0.77
Total treatment		1.54

Here we have ore worth $20 a ton treated with an extraction of 89.3 per cent. at a cost that seems low enough. A certain correspondence obtains here as elsewhere between the value of ore treated and the cost of treatment, even by the same process.

ROBINSON, GENERAL EXPENSE, 263,500 TONS

	Total	Per Ton
General maintenance	$21,071	$0.08
General charges	73,918	0.28
Machinery, plant, and buildings	95,716	0.36
Special charges	23,531	0.09
Construction	46,038	0.18
		$0.99

If all the rock broken, therefore, were treated, we should find the following comparison with the costs as given:

	Per Ton Milled (as given)	Per Ton Mined
Mining	$3.90	$2.60
Treatment	1.57	1.54
General expense	1.18	0.81
Construction	0.25	0.18
	$6.90	$5.13

The gradual diminution both of costs and the grade of ore is shown as follows:

	Yield per Ton	Working Costs per Ton
1890	$46.20	$10.02
1906	13.84	5.30

At the end of 1906, 2,180,000 tons of ore were blocked out, of which the development had been paid for by mining operations to date. The average assay value of the reserves was $14.50 per ton, and the extraction being realized was 93 per cent.; so that a net yield of $13.50 can be expected. It seems plain from the steady reduction of costs that these reserves can be mined for all working and construction costs for $5 a ton, leaving a net profit of $8.50 per ton, or $18,500,000.

Not a Record of Extravagance and Carelessness

I feel that this record of the Robinson mine shows, in a general way, the achievements and tendencies of the Rand industry; and that it is a monument, not of extravagance and carelessness, but of excellent engineering and of broad-gaged and honest management.

With this view of the cost problem on the Rand, Thomas H. Leggett is in full accord. I quote from his paper on the "Present Mining Conditions on the Rand," as follows:

"As the mining camp grows older the working costs almost invariably decrease, providing the camp maintains a healthful activity with advancing years, and this has been the case on the Witwatersrand, the result being as follows:

1898, average working costs of 65 companies	25*s.* 1.3*d.*
1899, average working costs of 42*a* companies	25*s.* 2.7*d.*
1906, average working costs of 58 companies	22*s.* 1.0*d.*
1907, average working costs of 56*b* companies	20*s.* 8.0*d.*

a The Boer war broke out in October, hence the records are incomplete.

b Two less than in 1906, due to exhaustion of the Bonanza mine and incomplete records from one other mine.

"These costs include mining, development, crushing, and sorting, milling, cyaniding, maintenance, and general expense, but they do not cover depreciation and amortization, these items being more properly dealt with by the directors at the end of the year. These results show the very material decrease of 4*s.* 6*d.* per ton since 1899, and are, therefore, approaching now to the 6s. reduction predicted by John Hays Hammond in 1901, but it has taken time to attain this result, as I then pointed out it would do. A comparison of the costs in 1907 with those of 1906 shows a decrease of 1*s.* 5*d.*, or 34 cents per ton, due chiefly to decreased wages and increased efficiency of both white and colored labor, including the Chinese in the latter category, though increased crushing capacity through the use of heavier stamps (up to 1670 lb. per stamp) and regrinding in tube mills have also aided.

"In 1906 fifty-eight companies mined and milled 13,065,624 tons of ore at a total cost of £14,411,219, while in 1907 fifty-six companies milled and mined 14,861,234 tons at a total cost of £15,351,749, being an increase of 1,795,610 tons for an increased cost of only £940,530.

"Most of these economics were attained during the latter half of 1907, after the white miners' strike, and some mines made startling reductions, as, for instance, the Robinson, which reported costs of 14*s.* 9*d.* for November, and the Glencairn, of 15*s.* 1*d.* per ton.

"Such strenuous and successful efforts are now being made to reduce still more the working costs on the Rand, that I think it safe to anticipate another large decrease for the year 1908."

Labor Cost not Excessive

I have expressed the opinion that costs on the Rand are not essentially different from those that would be obtained were the properties situated in the United States. What about wages? The only direct information I have is the statement of Mr. Browne that whites average $4.60 a day and colored laborers $0.66 per day, and are employed in the proportion of 9.2 colored men to one white man.

Average wages about $1.18 per day; as the percentage of colored men varies, so the average wages will vary from time to time.

In my judgment the figures demonstrate that the Rand is another proof of the fact that the rate of wages does not determine the cost of labor. Criticism of the Rand has been to the effect that costs are higher there than in the United States. Mr. Browne believes that California labor paid California prices on the Rand would be cheaper than the labor actually employed by about 15 per cent. In California wages are approximately $3 per day. I have estimated average development costs at various places as follows:

	Per Foot
Rand, average for shafts, drifts, raises, etc.	$20
Kolar, average for shafts, drifts, raises, etc.	22
Cripple Creek, average for shafts, drifts, raises, etc.	14

Wages

	Per Day
Rand	$1.18
Kolar	0.36
Cripple Creek	3.40

An exact comparison cannot be made, because the rocks and conditions are different. In the Rand the rock is harder than at Cripple Creek, and the openings probably average larger, but on the other hand, there is less water to pump.

Effiency of Labor a Function of the Cost

The point I am seeking especially to bring out is that criticism has been applied to the inefficiency of Rand labor as if it were a special case, and that because wages average low on the Rand costs ought to be correspondingly low. I contend that this assumption, if carried beyond certain narrow limits, is an incorrect one, and if established it would be in opposition to a general economic law.

President Roosevelt's great work has often been called a reaffirmation of the Decalogue. I am afraid that the conclusions I have arrived at are of the same class. You will remember the scriptural phrase, "The laborer is worthy of his hire," and the common proverb that the "Workman is known by his tools." These statements contain the essence of the problem of the cost of labor, always the fundamental and final element in the cost of anything. The gist of the whole subject was tersely stated by the first Lord Brassey, the great English contractor, who said that the same work costs the same money anywhere regardless of the price of wages. The workman, the tools, and the wages go hand in hand. Good wages command through competition, effective workers. Good workmen create efficient tools.

On the other hand, it is a truism to say that high-class tools and machinery can only be used by men who have intelligence enough to secure the wages their efficiency justifies. Where a man's idea of moving dirt is to fill a basket with his hands and carry the basket on his head, his wages correspond with the fruitfulness of his idea; he earns 10 cents a day. Where dirt is moved by the complex organism of modern civilized industry which applies external power through the agency of railroads and steam shovels, the men who operate the tools are better paid. The master of the industrial enterprise, which may be described as the greatest tool of all, a mechanism fashioned by the combined efforts of countless brains to direct the united efforts of men and energy to useful work, is pretty sure to be a millionaire; the man who runs the steam shovel gets $5 a day; the laborer who moves the ties in front of the steam shovel gets $2 a day. In the world's market the product is worth the same thing whether it is the result of an industrial miracle or of infinite but stupid human labor. When mankind produces efficiency it gets a due return for it, a return which is expressed pretty accurately in wages.

A Rule Without Exceptions

The only reason why these conclusions are not accepted as truisms is that people are suspicious of each other and are accustomed to doubt the fairness of the distribution of wealth. That this distribution is a matter the fairness of which can only be guaranteed by ceaseless vigilance, it is a folly to doubt; but on the whole I believe everybody concerned *does* exert vigilance, a vigilance made instinctive by the fundamental laws of the evolution of life, and on the whole the distribution is pretty fair. To avoid possible errors, however, we had best perhaps not apply this generalization to work of an ephemeral character, but only to permanent or semi-permanent industries where labor has time to adjust itself to competition.

But here we have to meet the question, Are not modern methods employed in South Africa and India? Have we not sent there our best engineers, our most modern machinery, and our best methods? If so, then why are not the men more efficient and the wages higher? I answer that it is indeed true that we have sent many civilized appliances to those places, but not all. Among the things we have not sent are the surroundings, point of view, ambition, and energy of a civilized community. The few hundred or few thousand Europeans who operate mines in Africa or India are immersed in an ocean of black humanity, upon which the small foreign community has an influence, true enough, but not such an influence as to revolutionize the habits, aims, and expectations of the natives.

An enterprise so situated must take into account at the beginning the state of mind of its future employees, and it would be silly to make such plans as might run counter to their prejudices; and, even if the managers had hopes of making the natives eventually as effective as Europeans, he would have to plan his operations on a different basis. As a matter of fact, such an expectation is hopeless; an individual Kafir or Hindoo may fill a certain position as effectively as an European, but to expect a large body of such people to become collectively as effective as a body of Europeans whose ideas had been trained for generations along lines making for an entirely different standard of effort is quite absurd. A considerable body of whites may indeed supply a certain amount of mental and nervous energy to the natives which the latter could not supply for themselves, but in so doing the white men must use up energy in the direction of others that they might otherwise use in their own labors.

If a body of colored men in a colored man's country is going to turn out work under the direction of white men as cheaply as the white men can do it themselves in their own country, they must do it by working for lower wages. This is exactly what happens in every case. It is a rule to which there are no exceptions.

CHAPTER XX

CRIPPLE CREEK, KALGOORLIE, AND GOLDFIELD

Development of Cripple Creek and Kalgoorlie — The geology of Cripple Creek — Estimate of aggregate results — Portland Mine — Kalgoorlie — The costs of five prominent mines — Comparison of Cripple Creek and Kalgoorlie — Goldfield, Nevada — Goldfield Consolidated Mines Co. — Estimate of costs.

Cripple Creek and Kalgoorlie

These two important gold-mining districts were discovered and opened on opposite sides of the globe at about the same time, shortly after 1890. Their appearance added greatly not only to the output of the yellow metal but also to the interest in mining enterprises. It was confidently believed for a number of years that they represented a type of ore deposits that had before been overlooked on account of their refractory nature and their elusive non-spectacular appearance; in other words, because they were hard to treat and hard to find, and that many other similar ones would be discovered. This expectation, though natural, has not been borne out by events; for no important new districts of the same type have been discovered since, and the original camps after a history of less than twenty years find themselves already old and declining in real and comparative importance. Nevertheless, their development and exploitation have been exceedingly interesting episodes in the history of gold mining and the men who took part have added much to the science of mining and metallurgy not only in gold but in other metals.

The parallelism between the two districts is, I believe, more apparent than real. About the only point in common is the occurrence of tellurides of gold, but even in that particular the similarity is not by any means complete. At Kalgoorlie only a part of the gold is associated with tellurium, while at Cripple Creek it nearly all is. The result is that in the two camps the metallurgical problem is different; at least it has been worked out differently.

When we come to geological and structural relations there is little similarity. At Kalgoorlie the veins are in a volcanic formation, apparently of great geological age, that has been subjected to severe and deep-seated dynamic action, resulting in the formation of strong lodes in shear zones.

Cripple Creek Mines

Cripple Creek, on the other hand, presents deposits in an extinct but geologically recent volcano. The rocks have not been subject to dynamic or metamorphic action, except those incident to the formation of the veins. The productive area is elliptical in outline with a length of about five miles from N.W. to S.E. and a width of three miles from N.E. to S.W., and contains numerous veins throughout, but the most valuable ones seem to be near the periphery of the volcanic mass, many being in the enclosing granites at or near the contact.

The veins are apparently all of the same age and of the same character, being deposits in fissures that result from adjustments following the cooling of the volcano. There was very little faulting along the veins either preceding or following the mineralization. The deposits vary in character according to the intensity of the mineralization along the fissures and according to the character of the rocks traversed by the fissures. In some cases a vein will be merely the quartz filling of an open crevice with very little impregnation of the wall rocks. In other cases, the deposit of quartz in the fracture planes is minute in quantity, but extends out into innumerable joint planes along which there has been a limited impregnation of the wall rocks. In this case the workable ores have the form of a stock-work. In still other cases the walls of a fissure are altered considerably for several feet on each side of the crevice by the introduction of new quartz replacing certain minerals in the original rocks. This occurs more commonly in the granite, but sometimes in basalt dikes, and wherever it happens the ore becomes a homogeneous mass.

Speaking generally, the ore deposits are either too small or too imperfectly mineralized to allow of the mining of merchantable ore in mass. A large amount of waste must be broken, of such character that it can better be rejected by hand sorting than by any other means. While it is not possible to give exact figures on this point it is a fair estimate that only 40 per cent.

of the material stoped is shipped to the mills. The amount of development work required is very great. Up to 1903 it appears that some 2,300,000 ft. of shafts, drifts, crosscuts, raises, and winzes had been dug for a total output of some $3\frac{1}{2}$ million tons of shipping ore and some 9 million tons of ore stoped.

Since the development work may be estimated to average some $14 a foot, it appears that it must have cost at least $8 a ton for all ore shipped from the district up to that time, for development alone. The cost of stoping the same ores must have averaged not less than $8 a ton more. The cost of freight and treatment in mills and smelters may be estimated at an additional $9 or $10, so that the total cost, exclusive of plant, was $26 per ton shipped and certainly more than $10 per ton stoped. If we add the plants, the total estimate for all ores will not fall far short of $30 per ton shipped, and $12 per ton stoped. The ores averaged probably $36 a ton, leaving a profit of about $6 a ton or less than 18 per cent. of the gross value. These figures being for the district as a whole, they naturally include a good many failures. Some of the mines have secured lower costs throughout their history, and many are securing much lower costs now. The dominant factor, however, in lower costs is the lowering grade of the ore. In 1899 the ore shipped averaged $36.73 per ton. In 1906 the average had fallen to $20.35 per ton.

Portland Mine

This is the best mine in the district and it presents good examples of all the types of deposit known in Cripple Creek. Most of the ore has come from an area of some 60 acres in which there have been done up to the end of 1908 above the 1500 ft. level no less than 212,593 ft. of development work. This development was necessary to open up a great number of veins, some of which were independent and others had a mineralized connection with other veins. The total production of shipped ore was 949,382 tons, valued at $29,430,842, giving an average of $31 per ton. The total amount stoped may be estimated at 2,400,000 tons, so that we may estimate that it required one foot of development work for every $4\frac{1}{2}$ tons shipped and for every 11 tons stoped.

The dividends paid amounted to $8,227,800 and the quick assets to approximately $500,000 more, making total earnings

$8,727,000, equal to $9.30 per ton shipped. A rough estimate of average costs is as follows:

	Per Ton, Shipped	Per Ton, Crude
Development	$3.00	$1.20
Plant	1.50	.60
Stoping	8.00	3.20
Freight, treatment, and deductions	9.20	3.68
Total	$21.70	8.68

The recent history of the mine shows much lower costs largely due to a diminution of the grade of the ore and of the amount of development work done, and also to the fact that the company has been milling its own ores. In 1903 the mine was shipping ores at averaging $30 per ton and doing one foot of development work for $4\frac{1}{2}$ tons shipped. In 1908 the grade of the ore had fallen to $19.45 per ton shipped and the development work was only one foot to 16 tons shipped.

The last report that gives operating costs in detail is that for 1905, from which I get the following data:

The costs were as follows:

Tons shipped	109,232
Average yield per ton after deducting mill losses	21.96
Development work accomplished	21,073 feet equal to one foot to $5\frac{1}{4}$ tons.

	Per Ton, Shipped	Per Ton, Stoped Estimated at $2\frac{1}{2}$ Times Amount Shipped
Stoping	$7.85	$3.14
Construction at mine	.29	.12
Development	1.22	.49
Transportation to mill	1.37	.55
Milling and construction	3.49	1.40
Amortization of mill	1.00	.40
General expense	.08	.03
Total cost	$15.30	$6.12
Profit per ton	6.66	2.26

Grouping the costs per ton shipped it appears that the expenses at the mine were $9.36 and those at the mill, including transportation, $5.94. The extraction of the mill was 95.82 per cent.

When we consider that the ore thus treated is obtained by rejecting at the mine a large part of the ore stoped, and that the rejection means a loss of some low-grade ore which must be computed to average some $2.50 per ton, we find that the losses from sorting, assuming that 60 per cent. is rejected, must equal $1.50 per ton stoped. On this basis it appears that the grade of ore that can be mined under the conditions exhibited is approximately $8 per ton where sorting can be practised, and where the ore can be shipped without sorting it must be $10 per ton.

With the still lower grade ores which have been mined since 1905 a certain lessening of cost is obtained by diminishing the proportion of development work and on account of the lower transportation cost for lower grade ores. The freights from the mine to the mill are based on a sliding scale according to the grade of the ore.

Milling

The mill in which the ores are now treated was built in 1901 at Colorado Springs, some forty-five miles from the mine. The cost of the milling plant is given at $910,000. Owing to the steady diminution both in volume and in grade of the ore it does not seem unfair to expect the practical exhaustion of the mine within a few years. The amount of ore treated in the past by the mill is approximately 600,000 tons and it does not seem unreasonable to charge the ore with $1 per ton for the amortization of capital in the mill. It must be remembered that this capital was obtained by withholding dividends from the stockholders, and the ore now being treated is enjoying the value thus created.

The mill treatment consists of dry crushing, followed by careful roasting of all the pulp; chlorination in barrels and concentration of the tailings. The concentrates shipped amount, I believe, to about 1 per cent. of the ore.

The Portland mine while representative in a way of the whole Cripple Creek district is decidedly a better mine than most of the others. Its costs are undoubtedly below the average, although there may be some like the Strong and the Golden Cycle, which have enjoyed lower mining costs on account of having a more

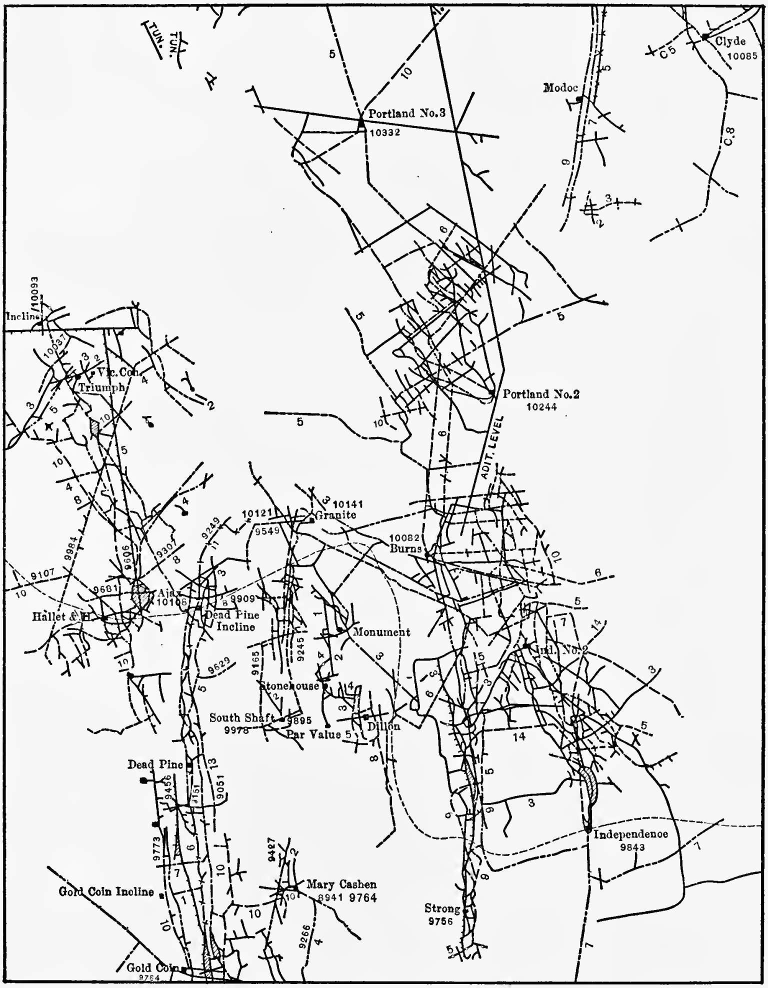

FIG. 20.—Illustration of the development work in the Portland mine and vicinity, where 1 foot of opening work has been necessary for mining 4½ tons of shipping ore.

homogeneous ore. Its history is fairly indicative of the district in which variation in costs is probably due in the main to development work. Many properties that have produced just as good ore on the average as the Portland have not been profitable because their output has been spasmodic and the earnings from an occasional bonanza have been absorbed in prospecting.

The Portland mine has been well and energetically managed from its very beginning. It has created its plant out of earnings and has consistently made money for its stockholders. From time to time there has been criticism of its management and methods, but I am convinced that such criticism has on the whole been ill-considered, being based largely on comparisons with other properties that have issued only partial statements of costs for limited periods.

Cripple Creek is a good example of a mining camp where results have not been fully understood. For instance, it is, or was, commonly believed that labor in Cripple Creek was exorbitantly paid and ineffective. In my opinion the truth is the exact contrary of this. The miners of Cripple Creek have always been an exceedingly intelligent and effective lot of men. The wages average, it is true, some $3.40 for the eight-hour shift, but competition for the places has allowed operators to work with selected men. While the climate is fairly healthful the altitude of 10,000 ft. above the sea certainly diminishes one's endurance as compared with sea level conditions; but to clinch the argument as to comparative efficiency of the highly paid labor of Cripple Creek with that of other places I will give the following figures on the cost of development work in the Portland mine for the first half of 1903.

896 Ft. Drifts Averaging 5 Ft. by 7 Ft.

	Labor Costs	Per Foot
Tramming	$898.38	$1.00
Pipe and trackmen	125.12	.14
Machine men	1,686.	1.88
Total labor	$2,709.50	$3.02
Other Costs:		
Use of machines, air, etc.	$867.57	$0.97
Repairs, cars, etc.	69.98	.08
Explosives	1,279.76	1.43
Hoisting	414.53	.46
General expense, surveying, assaying, bosses	515.20	.58
Grand total	$5,556.54	$6.20

1229 FT. CROSSCUTS 5 FT. BY 7 FT.

Tramming	$1,138.87	$0.93
Pipe and trackmen	149.37	.12
Machine men	2,473.49	2.02
Total labor	$3,761.73	$3.07
Other Costs:		
Use of machines, air, etc.	$1,191.24	$0.97
Repairs, cars, etc.	111.28	.08
Explosives	2,044.65	1.66
Hoisting	656.67	.53
General expense, surveying, assaying, bosses	819.26	.67
Grand total	$8,684.83	$7.07

112 FT. RAISES AND WINZES

Tramming	$105.76	$ .094
Pipe and truckmen	3.37	.03
Timbermen	133.17	1.19
Machinemen	354.50	3.17
Total labor	596.80	$5.33
Other Costs:		
Use of machines, air, etc.	$186.25	$1.66
Repairs, cars, etc.	6.84	.06
Explosives	158.52	1.41
Lumber and timber	170.65	1.51
Hoisting	44.41	.40
General, bosses, assaying, etc.	50.37	.45
Grand total	$1,213.84	$10.84

The grand total cost for all underground labor was $7.068 for 2237 ft. of development work, equal to $3.11 per ft. While it is not possible to pretend that these figures are an average for the history of the mine, it is evident that they exhibit a good record of labor efficiency. The rocks through which these openings were made might be classed as eruptive rocks of average hardness, being andesites and granites. There was no pumping charged against these costs.

This is another evidence of the lack of correspondence in mining costs between rate of wages and the cost of labor. If the same kind of work is done cheaper anywhere I have not been able to find the place.

Kalgoorlie Mines

As remarked above, the resemblance of Kalgoorlie to Cripple Creek is more apparent than real, being based largely on the occurrence of telluride ores in both places.

The external factors at Kalgoorlie are much less favorable on account of a dry hot climate and long distances from populous centers. The internal factors are more favorable than those of Cripple Creek.

The lodes in Kalgoorlie are much larger, more persistent, and better mineralized. Instead of being split up into a multitude of small veins containing short and inconstant ore shoots, Kalgoorlie mines have only a few lodes which present ore shoots of an average stoping width of 11½ ft. The lodes have been found to be payable to a depth of 2600 ft. Comparing the two districts at large, it is probable that Kalgoorlie has one capital advantage in having a much smaller proportion of development work to do. Recollecting that all Cripple Creek mines seem to require one foot of development work for every four tons stoped, making a cost of more than $3 per ton for that account alone, it seems that Kalgoorlie enjoys a considerable advantage in that particular. I have, however, no means of obtaining full figures for the whole district of Kalgoorlie, upon which to base an exact comparison, but am compelled to draw conclusions from the records of some individual mines as compared with the Portland mine.

In stoping the Kalgoorlie mines have a marked advantage in being able to avoid sorting. The ore is sent to the mills practically as it is broken in stopes of considerable width. There is no evidence, however, that the cost per ton of rock handled is any lower in Kalgoorlie than it is in Cripple Creek.

When we come to milling we find that the figures are somewhat in favor of the Australian district. The ores are milled on the spot, thus avoiding railroad transportation charges. The processes themselves are slightly cheaper than those employed at Cripple Creek, but the extraction of the gold is somewhat less perfect, being from 85 per cent. to 93 per cent. as against about 96 per cent. in the Colorado camp.

Two distinct methods are employed about equally. The first method is wet crushing in stamp mills followed by amalgamation, by concentration and cyaniding of sands and slimes, the concentrates alone being roasted and then treated by a special cyanide process. This process effects a saving of from 85 to 93 per cent. of gold at a cost of from $2.21 to $3.92 per ton, varying according to the size of the mills and the grade of ore.

The alternative process consists of dry crushing in ball mills followed by roasting the entire pulp and then cyaniding. This process saves from 90 per cent. to 92 per cent. of the gold at a cost which seems to average somewhat higher than the other processes, averaging for two mines $4.20 per ton in 1905. The largest mills in Kalgoorlie have a capacity of more than 20,000 tons a month as against 10,000 tons for the Portland mill. It is possible that if Cripple Creek ores were milled on the same scale, the costs would be lower than they are. When we come to consider the difference in natural advantages between the two points, it is evident that the Kalgoorlie ores are at a disadvantage. They have to be treated under the most unfavorable conditions: water, coal, and all supplies being extremely expensive, while in Colorado the mills pay little or nothing for water and are situated in proximity to coal mines.

The following is given as a characteristic analysis of ore:

Silica	60 per cent.
Alumina	11 per cent.
Ferrous oxide	$5\frac{1}{2}$ per cent.
Pyrites	7 per cent.
Calcium carbonate	$7\frac{1}{2}$ per cent.
Magnesium carbonate	6 per cent.
Soda and potash	$1\frac{1}{2}$ per cent.
Water	$1\frac{5}{10}$ per cent.

The following table illustrates the diminishing grade of ore with increasing depth in the Great Boulder mine:

300–400	$29.60
400–500	39.90
500–600	49.50
600–700	18.80
700–800	28.70
800–900	27.20
900–1000	27.30
1000–1100	24.60
1100–1200	19.70

1200–1300	19.80
1300–1400	13.40
1400–1500	14.60
1500–1900	12.70

Calculated average $22.00 per ton.

If we assume that this ore is worked with an extract of 90 per cent., the actual yield would be somewhat less than $20 per ton. These figures are quoted from an article by Mr. G. W. Williams on "Mining Practice in Kalgoorlie," in the *Engineering and Mining Journal* of January 25, 1908.

Our English friends have been disposed to believe that their practice in Kalgoorlie has been superior to that of Colorado. It is possible that they may be right in this contention, but it must be remembered that they do not secure as high an extraction as the Colorado mills, and in making comparisons of costs they may overlook some of the dominant factors. In order to convey in general terms a comparison of the operations in the two camps I present the following tables showing the results in 1905 at five of the principal properties of Kalgoorlie, trying in each case to present the figures as nearly as possible in the same manner as those given for Cripple Creek, and reducing all statements to short tons and American currency.

Kalgoorlie Mines—Where Ores are Crushed Wet in Stamp Mills and only Concentrates Roasted. Record for 1905 — Short Tons

	Ivanhoe	Oroya-Brownhill	Golden Horse-shoe
Tons	196,569	112,713	249,800
Assay value per ton	$15.50	$30.21	$14.87
Loss in milling	2.36	2.11	1.65
Yield	13.14	28.10	13.22
Feet development for year	6,808	12,285	8.047
Cost development per ton	$0.82	$1.43	$0.49
Current construction	0.65	2.17	1.08
Working Costs:			
Breaking ore	1.50	0.83	—
Filling stopes	.24	0.28	—
Tramming and hoisting	.40	0.58	—
Total mining	2.12	1.69	2.24
Rock breaking	.09	.16	
Ore transport	.03	.12	1.32
Milling	.50	.51	
Concentrating	.12	.13	
Roasting concentrates (1 ton concentrates to 18 crude)	.10	(1 in 16) .12	
Cyaniding concentrates	.06	.07	.10
Fine grinding concentrates	.02	.09	
Fine grinding sands	.16	.31	
Cyanide by percolation	.21		.98
Cyanide by agitation	.60	1.70	
Filter pressing	.15	.40	
Precipitation and smelting	.11	.11	.13
Re-treating	.01	.22	—
Maintenance	—	—	.06
Total treatment	2.21	3.92	2.59
General expense London and Kalgoorlie	.51	.64	.42
Realization of bullion	.14	.25	.02
Deduct profit on stores	.10	.14	—
Net working costs	4.94	6.36	—
Taxes	0.30	0.80	0.31
Freight and treatment on ore shipped (Golden Horseshoe = $22.79 per ton)		—	2.11
Total estimate of cost	6.45	10.76	9.26
Losses in milling	2.36	2.11	1.65
Total costs and losses	8.81	12.97	10.91
Profit per ton	6.69	17.24	3.96
Percentage profit	43	57	27

KALGOORLIE MINES WHERE ALL ORES ARE ROASTED

	Great Boulder Proprietary	Great Boulder Perseverance
Tons	147,900	165,465
Assay value	$20.56	$13.94
Loss in milling	2.47	1.30
Yield	18.09	12.64
Development feet incl. diamond drilling	7,373	14,163
Costs per ton treated	—	—
Plant expense	1.41	0.51
Development	1.07 (average 3 yrs.)	1.60
Mining — Ore breaking	2.07	2.20
Treatment — Sulphides	2.13	3.81
Cyanide plant (tailings)	1.01	.95
Tailings distribution	—	.12
Tailings transport	—	.35
Realization of bullion	.05	.16
Purchase tailings	—	.04
Insurance	—	.10
General expense — London	.31	.24
Kalgoorlie	.39	.29
Taxes Australia	.49	.11
Grand total cost per short ton	8.93	10.48
Mill losses	2.47	1.30
	$11.40	$11.78
Profit per ton	9.16	2.16
Percentage profit	44.5	15.5

Casting up an average of the ore produced by these mines we find that the assay value of all five was about $17.60 per ton. It may be interesting to make a sort of comparison between these mines and the Portland of Cripple Creek in order to observe the difference in results obtained on an ore of equivalent value in the two districts. In order to avoid the labor of averaging costs let us take the results of the Ivanhoe mine, which produces ores nearest the average in grade, and assume that the Portland mine were producing the same grade of ore, using the costs reported by each for the year 1905.

Comparison of results at Ivanhoe and Portland mines, assuming that each produces ore averaging by assay $15.50 per ton, but that the Portland mine rejects by sorting 60 per cent. of ore stoped and that the waste rejected averages $2.50 per ton:

Ivanhoe		Portland	
Tons mined per foot development	27	Tons mined per foot development	13
Cost development	$0.82	Cost development	$0.49
Cost for current construction mine and mill	0.65	Current construction mine only	.12
Mining	2.12	Mining and sorting	3.14
Sorting losses	0.00	Sorting loss 60 per cent. of $2.50	1.50
Transportation to mill	.03	40 per cent. of $2.00	.80
Milling	2.18	40 per cent. of $3.50	1.40
Amortization of mill (included under construction)	0.00	40 per cent. of $1.00	.40
General expenses	.85	(included in costs mainly)	0.03
Loss in milling	2.36	4 per cent. of $35.00	1.40
Total costs and losses	9.01		9.28
Deduct profit on stores	.10		0.00
Net cost	8.91		9.28
Profit per ton	6.69		6.22
Percentage profit	43		40

The Ivanhoe is stated by Mr. J. H. Curle ("Gold Mines of the World") to be the best managed mine in Kalgoorlie. Furthermore, it is one in which the wet crushing method is used. Undeniably it is the one with which the Portland can least afford to compare itself. Were we to take the Great Boulder and the Perseverance for comparison we should find the figures very much in favor of the Colorado property. Those properties show milling costs of $3.19 and $5.39 respectively, and exhibit the following comparison (using the same figures for the Portland as before).

	Great Boulder Proprietary	Great Boulder Perseverance	Portland
Assay value of ore	$20.56	$13.94	$15.50
Total operating costs	8.93	10.48	6.38
Loss in milling and sorting	2.47	1.30	2.90
Total costs and losses	11.40	$11.78	$9.28

It is plain that there is no ground for making a comparison favorable to one district and unfavorable to the other; and that if the managements in the two districts were to be exchanged the stockholders would not have much cause to worry.

Since 1905 the mines have undoubtedly succeeded in lowering their costs somewhat, as in the case of Cripple Creek, in proportion to the diminishing grade of the ore. The Golden Horseshoe mine in the years 1907 and 1908 treated 554,131 tons with an average yield of $10.95. The dividends paid were $2,405,600, equal to $4.34. Assuming that the dividends equaled the actual profit, the cost figures out at $6.61 per ton. This compares with the total of $7.15 for the same mine in 1905. It is to be remarked that in the tables given above the Golden Horseshoe ships 7 per cent. of its ore to smelters in the form of concentrates and high-grade ore. This imposed a further cost of $2.11. This mine is still securing a profit of 40 per cent. of the gross value of gold produced. Its complete record for eleven years' operation shows an output of $33,154,000 in gold, from which $13,468,000 have been paid in dividends, equal to 41 per cent. of the gross yield. The total number of tons treated is not given, but it will approximate two million, so that the yield for the life of the mine has been about $16.70 per ton and profits $6.70, leaving $10 as the cost of operating, including all plant and development. The records of the mine, however, do not indicate the expenses and deductions incurred for shipping ore to the smelters, simply reporting the sums received net from such shipments. If these expenses were included it is probable that they would make an addition of something more than $2 per ton both to the costs and to the yield of gold, making the total costs something more than $12, and the yield of gold approximately $19 per ton. If the extraction averaged 90 per cent., the gross assay valuation of the ores mined would be about $21, which approximates very closely to that of the Great Boulder.

No mines in Cripple Creek have produced anything like such quantities of ore of this grade, nor have they earned such large dividends. The fact is that the Kalgoorlie camp contains only nine or ten mines of first-class importance, but these have produced nearly all the gold and all of the dividends of the district. In them the values have been concentrated into a much smaller space than in the case of Cripple Creek, where the output has come from a large number of comparatively small producers, and where payable values have practically ceased at a depth of 1200 ft. This group of dividend-paying properties are therefore better and higher grade mines than any in Cripple Creek. Their outlook for the future is also far more attractive. The Ivanhoe reports reserves of 934,000 tons, averaging $11.75 per ton, and good ore at the 1970 ft. level; the Golden Horseshoe 1,065,000 tons averaging $12, with $15 ore on the 2000 ft. level; the Great Boulder 731,000 tons, averaging $16, and good ore on the 2600 ft. level; the Associated 483,517 tons, averaging $10 per ton; in each case assuring the product for 3 to 4 years, and an average profit of 40 per cent. of the gross value. It would not be surprising if they proved payable to much greater depths.

Goldfield, Nevada

This district was discovered in 1903 about twenty miles south of the somewhat older camp of Tonapah, the success of which had served to attract many prospectors to the comparatively old mining regions of Nevada. The discovery in that year of some rich ore on the Jumbo and Combination mines started a considerable excitement during 1904 followed by comparative quiescence during the latter part of 1905; but the discovery of an extraordinary bonanza on the Mohawk claim in April, 1906, encouraged the recrudescence of the mining boom not only in Goldfield but in other parts of Nevada, until the excitement reached by the end of 1906 a degree of extravagance for which it would be hard to find a parallel. About that time the owners of the Mohawk, pursuing their good fortune with commendable intelligence and energy, secured most of the promising ground in the camp and formed the Goldfield Consolidated Mines Company, which has to-day, after a period of reorganization and development, the most productive and profitable gold mine in the world.

The Goldfield district is in a region of volcanic rocks of doubtful but probably rather recent geological age. A series of great quartz veins, or rather zones of silification is found, indicated by a series of bold outcrops which have a strike usually nearly north and south. It seems probable that the gold belongs to a later mineralization, because the quartz masses are nearly or quite barren. The rich ore shoots seem confined to smaller fissures that traverse the great quartz masses in various directions and have produced a considerable amount of brecciation in them. These later fissures often cut the great quartz reefs at right angles and the ore shoots seem rather more apt to occur along the flanks than in the interior of the reefs. There have been discovered a number of rich bonanzas, probably due in considerable measure to a process of reconcentration near the surface, but exploration has not proceeded deep enough to establish this as more than a probability.

The grade of the ore is already diminishing rapidly owing to causes that are universal in such districts. Owing to lack of treatment facilities on the ground, and to the high cost of transportation, at the beginning, only high-grade ores could be shipped. In 1906 the Mohawk bonanza produced in eight months upwards of 70,000 tons of ore averaging $120 per ton. With the institution of milling plants on a large scale, lower grade ores can be treated so that at present the Goldfield Consolidated is mining 20,000 tons a month of ore averaging $40 a ton. That such values will be maintained is an unreasonable expectation that has never been indulged in by the management. I am led to believe that the actual developments indicate about one-half a million tons of ore that will average between $20 and $25.

During the past two years the efforts of the management have been directed towards the completion of a satisfactory organization, the prosecution of development and the construction of a new mill. This was done so successfully that at the beginning of 1909 the property was ready to begin extensive operations on a new basis. A magnificent modern mill was built with a capacity of 600 tons a day with a railroad to provide for transportations of ores to it, together with some additions to the mining plant at a total expense of $900,000.

During 1908 17,460 ft. of development work was done by the company at an average cost of $17.60 a foot and 20,463 ft. were done by leasers. The amount of ore developed by this work is not stated, but the lessees shipped only 25,600 tons and probably did not put much ore in sight, so that this portion of the development work only seems to have opened up to 1¼ tons per foot. What the cost for development will average is a question that probably will only be determined after several years' experience, but judging from the large amounts done to date, it is hardly likely that the cost per ton will be less than $2 from this item.

The cost of stoping will undoubtedly vary according to the extent to which ore must be sought in narrow seams, but experience to date seems to indicate that ore of the milling grade will be found in fairly wide stopes, so that the cost of stoping will probably be about $2. In addition to this the report for 1908 seems to indicate that general expenses will approximate 30 cents per ton on an output of 240,000 tons a year. It would seem, therefore, that the cost of mining might be calculated at about $4.30.

Milling

Mr. J. H. MacKenzie, manager, describes the milling process briefly as follows:

"Crushing in gyratory rock breakers and stamps, with regrinding to slime and tube mills; amalgamation over copper plates both before and after milling; concentration by means of Deister slime tables; cyanidation of tailings from concentrators with the aid of Pachuca adjutators and Butters filters and zinc dust precipitation. Concentrates are treated in an auxiliary plant by means of a modification of the cyaniding process, and products from all departments of the mill are refined and shipped directly to the mint as gold bullion."

This process is very similar to that employed at Kalgoorlie and it is very probable that the costs will be approximately the same. Experience in actual operation has not gone far enough to demonstrate exactly what it will be, but it is worth remarking that the mill is an extremely good one and works with the greatest precision, giving an extraction of about 94 per cent. gold. If we assume that the costs will be the same as at the Ivanhoe in Kalgoorlie, which is a modern mill of the same size, namely, 100 stamps, we may calculate the cost of treatment at $2.20 a ton including transportation from the mines.

It is to be remembered that the cost of the plant is approximately $900,000. Owing to the erratic character of the ore it would seem wise to amortize the plants in five years, which would make a calculation for amortization of 75 cents a ton. We may also calculate that current construction will amount to about 25 cents a ton, making a total plant cost of $1 per ton treated. On this basis we might calculate the costs as follows:

Mining	$4.30
Milling	2.20
Construction	.25
Total current costs	$6.75
Add for amortization	.75
Total cost per ton	$7.50

With an extraction of 94 per cent. these costs indicate that the minimum assay value of a payable ore should be $8 a ton.

While the above figures are given only as approximations it is nevertheless true that they are made with some reference to the figures unofficially given out by the company for the present year and they may be accepted with some confidence.

For the present year the yield of gold from this property promises to be enormous, perhaps $8,000,000 gross, on which net profits upwards of $5,000,000 may be realized. Such an output will be a new record among the gold mines of the world.

CHAPTER XXI

SILVER MINING AT COBALT AND GUANAJUATO

Phenomenon of the sudden decline of the price of silver compared with gold — Present inferior position of silver mining — Cobalt as an example of high mining costs — Logic of costs — Guanajuato.

Silver Mining

By far the greater portion of the silver of the world is now obtained as a by-product from mines that are operated chiefly for lead, copper, or gold; and in this connection the metal has been frequently touched upon in preceding chapters. There are only a few conspicuous districts now where silver is the primary object of the mining industry. Some remarks on two of these, Cobalt, Ontario, and Guanajuato, Mexico, are sufficiently interesting to warrant insertion.

The present obscure position of silver mining is due to one of the most remarkable economic revolutions in history. In the course of twenty-five years in the latter part of the nineteenth century silver declined in value from $1.30 to about 55 cents per ounce, and in so doing suddenly lost, apparently forever, a position of importance as the companion of gold that it had held in the estimation of mankind for thousands of years. It is no wonder that such a violent and unprecedented fall astounded the generation that beheld it, and put in play that instinct which attributes any mysterious unpleasant happening to design, and which, in this instance, took the form among the half-informed of an accusation against financiers of a gigantic "conspiracy." It is infinitely more probable that the financiers of the world understood the reasons for the fall of silver as little as other people. It is no part of the present work to offer an explanation; merely to point it out as the most conspicuous example of a great commodity suddenly taking a price level radically different from its traditional one.

The comparatively unimportant position now held by silver mines would be very different had not the fall in prices taken place, for with silver at \$1.29 an ounce, many of the important mining districts would be more valuable for their silver than for

Fig. 21. — The drop in value of silver.

anything else. The Cœur d'Alenes, Park City, Tintic, and many other districts would be so changed in the relative importance of the metals they produce that they could safely be called silver-mining camps producing lead, gold, and copper as by-products.

Cobalt District, Ontario

Colbalt is unique not only on account of the geological occurrence of its ores, but also because it is an example of the absolute inconsequence of high costs per ton in precious metal mining. So far as I know the Cobalt ores are mined at the highest cost of any ores of importance in the world, yet their silver contents are secured at the lowest cost, with the largest margin of profit. The district belongs to the same series of pre-Cambrian rock formations that has proved so prolific in iron, copper, and nickel near the shores of Lake Superior; but at Cobalt the orebodies instead of having the grandiose character so universal in Lake Superior, are exceedingly small, disconnected, and rich. The geological resemblance to Lake Superior extends to the character of the surface, which is highly glaciated and covered with swamps and lakes with low rounded knobs of more resistant rocks forming occasional eminences above the generally level country. The rocks consist of the ancient greenstone schists, usually called the Keewatin, with some troughs of Huronian quartzites and conglomerates, the latter invaded by dykes, and sills of biabase. The veins occur in all of the rocks to some extent, but chiefly in the sedimentary formations.

FIG. 22.

The superficial extent of the district is several thousand acres, but the individual orebodies are so small that they might almost be described as minute. They are usually only from one inch to six inches wide and from a few feet to 150 ft. long, and ordinarily of no great depth. This at least applies to the ore shoots. Some veins that are barren on the surface contain ores at greater depth. While the absolute bottom of the district has not been reached, the hopes of the operators are more fixed on discovering new veins than on following old ones in depth. The vein filling is largely calcite with some quartz. The ore consists largely of native silver, but associated with it are some of the richer sulphides, dyscrasite, argentite, pyrargyrite. With the silver occurs cobalt, nickel, and arsenic in smaltite, niccolite, and other minerals.

The problem of mining such ores consists largely in finding them. Once found the principal problem is to extract them cleanly — no concentrating process being so efficient for the purpose as hand sorting. The ores once secured are shipped to the smelters at a cost for freight, treatment, and deductions of over $50 a ton.

But the ores thus mined contain 750 oz. of silver per ton, so that $50 for all treatment charges only means 7 cents an ounce. The cost of mining in the whole district, outside of treatment charges, seems to have averaged about $145 a ton, probably divided about equally between development and extraction. Even this high figure only means 20 cents an ounce.

It is almost amusing to speculate on the surprise that a Lake Superior miner must feel at such tremendous costs per ton; nevertheless, there is not the slightest ground for supposing that these high costs do not represent just as good mining practice as any in Lake Superior. It is for the purpose of illustrating this fact that the mines at Cobalt are interesting in a work on the cost of mining.

Let us neglect the question of finding ores and assume that it costs $75 a ton to get them out of the ground. What does this mean in comparison with the cost of say $1 a ton for mining the ore at the Wolverine? Simply that it takes seventy-five times as much work to get it out. That this should be so is a direct result of the size and thickness of the orebodies. In the case of the Wolverine the thickness is 15 ft. or 180 in. and the ore is placed on surface for $1 per ton. It is probable that if the orebody were only 4 ft. thick and as continuous as it actually is, the mining cost at the Wolverine would be about $2 a ton. Now since an opening 4 ft. wide is about the least that can be made, a cost greater than $2 a ton will be simply an inverse ratio of the actual thickness to 4 ft. If the cobalt ore is to cost $75 per ton we might calculate the thickness of it at 48 in. $\div \frac{75}{2}$ = 1.28 in.

A continuous seam, then, of ore 1.28 in. thick ought to cost $75 a ton for mining. It means exactly the same thing if a series of bunches, averaged up, amount to a mean of 1.28 in.

In the light of the figures there is no mystery in the fact that an orebody 1.28 in. thick may be a bonanza. It is worth $400 a ton. If this value were scattered through 4 ft. of a continuous orebody, it would give a value to the whole mass of $11 a ton, equal at average prices to 75 lb. of copper, which every one would recognize as a bonanza. Such an orebody would give, under the costs prevailing among Lake Superior amygdaloid mines, figures something as follows:

Mining per ton	$2.00
Surface expense, transportation, and milling	.90
Construction and amortization	.50
Smelting, refining, and marketing	.80
Total	$4.20

Cost per pound copper about 5.6 cents.

At fifteen-cent copper the profit would be 63 per cent. of the gross value.

If we scatter the values through a mass 15 ft. thick, there would be the equivalent of 20 lb. copper per ton, and the costs would be:

Mining	$1.00
Surface, expense, transportation, and milling	.65
Construction and amortization	.30
Smelting, refining, and marketing	.22
Total	$2.17

Cost per pound copper, 11 cents.

Profit on gross value, 27 per cent.

In the case of the 4-ft. orebody the costs per ton would be approximately twice as high as in the case of the 15-ft. orebody containing the same copper, but the cost of copper would be only half as great and the profit more than twice as much.

This makes it plain enough that the concentration of values is a great economic advantage.

In the case of the Cobalt orebody 1.28 in. thick (always neglecting the question of prospecting), on the theory of a continuous seam, the results are as follows:

Mining per ton	$75.00
Smelting and marketing	50.00
Total cost per ton	$125.00

Value per ton, $400; profit, 69 per cent.

But in Cobalt there is no continuity. The ore must be looked for at an additional cost of $70 a ton so that the actual profit is reduced to 52 per cent. Nevertheless it is quite simple to show that a natural concentration in values involving enormous increases of cost per ton is a distinct economic advantage.

Record of Cobalt as a Whole

	Tons	Ounces Silver	Value	Dividends
1904–1908......	48,545	35,083,300	$19,495,000	$10,000,000 ±

$$\text{Cost per ton} = \frac{9,495,000}{48,545} = \$195$$

Value per ounce, 55.7 cents
Cost per ounce, 27 cents

Nipissing Mine

1904–1908	8,449	8,145,834	$4,540,000	$2,640,000 600,000

$$\text{Cost per ton} = \frac{\$1,300,000}{8449} = 154 \pm$$

Cost per ounce, 16 cents ±

Nipissing Mine, 1908

Tons shipped, 3505; ounces silver, 2,893,931; ounces per ton, 826

Costs	Dollars	Per Ton	Per Ounce, Silver
Operation................	$361,274.85	$105.46	$0.13011
Depreciation	44,631.66	13.03	.01607
Marketing ore............	174,775.66	51.02	.06294
Legal, etc.	22,292.51	6.50	.00803
Less income..............	$27,761.61	$8.10	$.01000
Total....................	$575,213.07	$167.91	$0.20715

There is good reason to believe that the above figures for 1908 are ample. They include a depreciation charge on plant and buildings of 24 per cent. It appears that the cost of "prospecting" "exploration," and "development" (whatever they may separately mean) amounts to some 37 per cent. of the total cost of "operation."

Kerr Lake Mining Company

For the year ending August 31, 1908, this company showed the following record:

Tons mined, 528; ounces silver, 1,473,712; ounces per ton, 2790.

Costs		Per Ton	Per Ounce
Production and development	$139,530	$264.25	$0.0947
Shipping and smelting	76,093	144.30	.0516
General expense	32,904	62.30	.0223
Plant and machinery	57,419	108.75	.0390
Total	305,946	579.44	$0.2076

This is probably a new record for high costs per ton, yet silver was produced for less than 21 cents per ounce and the profit was nearly 70 per cent. of the gross value.

Not all of the Cobalt ores are of such high grade, several of the mines being now equipped with mills for concentrating, but the mills only handle a small tonnage and it is safe to say that if Cobalt had to depend on the low-grade ores that it would never have been heard of.

Guanajuato, Mexico

Guanajuato has the reputation of having been the most productive silver-mining district in the world; its total output exceeding one thousand million ounces. It is the very reverse of the Cobalt district in geological structure, ore deposits, and methods. The rocks, instead of belonging to the ancient Algonkian series, belong to the comparatively recent Cretaceous. Instead of the multitude of small veins there are four or five very large fault fissures carrying a strong mineralization of quartz and silver sulphides. The mining methods, instead of depending on the careful sorting of small streaks of rich smelting ore, are designed to extract large quantities, and finally, the treatment, instead of being smelting as at Cobalt, is confined almost entirely to cyaniding. In the early days (and by early days I mean the period of more than two hundred and fifty years following 1550, during which an occasional bonanza was discovered) it is probable that Guanajuato bore a much closer resemblance to Cobalt than it does to-day. It is likely that a very large amount of high-grade ore was then mined and that the lower grade ores of the present day have become valuable more because the rich ores of former times are no longer to be had than for any other reason. In other words it is probable that if the high-grade ores of former times were now available the ores being mined at present would not excite much attention. It has often been remarked that Guanajuato bears a close resemblance to the Comstock lode in Nevada, and its history has been similar; but its life has been longer and its output greater. The longer life of the Mexican camp has been chiefly due to the fact that until recently it has not been worked with American appliances and energy, the result being that at Guanajuato, after a life of three hundred and fifty years, the deepest mines have reached a depth of only 2000 ft., while on the Comstock lode explorations reached a depth of over 3000 ft. within thirty years after the first discovery.

The present mining activity of Guanajuato is chiefly in the hands of Americans and is extremely recent, dating back only to 1904 when it was first satisfactorily demonstrated that the ores could be economically worked by the cyanide process. Since that time the output of the camp has increased very rapidly. It has now reached an annual output of about ten million ounces, divided among some eight or ten producing mines. The average ore is probably worth some $7 or $8 per ton, the values consisting of about 13 oz. of silver and .05 oz. of an ounce of gold.

The economics of the districts are somewhat as follows: Labor is very cheap and just as poor as it is cheap; miners earning from $1 a day down. There is no evidence here any more than in India or South Africa that low wages means cheap operating. Water-generated electric power has been brought into the district by American enterprise from a distance of some 110 miles. This power was first used by the mines in 1905 and its introduction proved a great advantage and has much to do with the success of the mining enterprises. Electric power is sold at $75 per horse-power per year, which is a very moderate price; before its introduction steam power cost some $200 a year.

Cost of Cyaniding, Guanajtato Development Company's Mills

Mill	Period 1908	Wet Tons Milled Per Month	Crushing			Concentration	Classifying	Treatment		Filtering and Precipitation	Pumping Solution	Water Supply	Surface Expense	All Costs				
			Coarse	Fine	Regrind			Sand	Slime					Labor and Bosses	Supplies	Power	Miscellaneous	Grand Total
Peregrina	Average of 4 months	12,356	$0.079	$0.395	$0.185	$0.061	$0.011	$0.346	$0.253	$0.189[1]	$0.067	$0.022	$0.020	$0.453	$0.748	$0.415	$0.003	$1.619
	Minimum monthly tonnage	11,324												0.485	0.910	0.425	0.005	1.825
	Maximum monthly tonnage	13,593												0.440	0.665	0.380	—	1.485
Pinguico	Average of 8 months	6,188	$0.075	$0.305	$0.235	$0.080	$0.020	$0.460	$0.405	$0.415	$0.050	$0.080	$0.040	$0.720	$1.090	$0.355	—	$2.165
	Minimum monthly tonnage	5,820												0.825	1.140	0.365	—	2.330
	Maximum monthly tonnage	6,168												0.675	0.975	0.325	—	1.975
San Próspero	Average of 7 months	4,014	$0.055	$0.340	$0.100	$0.050	$0.025	$0.390	$0.360	$0.310	$0.065	$0.040	$0.015	$0.470	$0.875	$0.395	$0.010	$1.750
	Minimum monthly tonnage	5,820												0.510	1.100	0.470	—	2.080
	Maximum monthly tonnage	6,168												0.465	0.860	0.335	—	1.660
Nayal	Average of 6 months	1,347	$0.115	$0.600	—	$0.135	$0.205	$0.595	$0.430	$0.290[1]	$0.045	$0.035	$0.045	$1.020	$1.045	$0.420	$0.010	$2.495
	Minimum monthly tonnage	1,168												1.065	1.350	0.535	—	2.950
	Maximum monthly tonnage	1,477												0.950	0.915	0.285	—	2.150

[1] No filtering plant at this mill.

A number of good mills have been built and are now operating in the district, the results of which are given in an accompanying table. It will be seen that the operating costs vary from $1.62 per ton for a mill of the capacity of 400 tons a day to $2.50 a ton for one having a capacity of only 50 tons.

I have found the plant expenditures stated for only one mine — the Pinguico — at which the total cost for plant and equipment, including mill, mill site, storehouse, supplies, etc., was $680,000, providing for a treatment capacity of some 80,000 tons a year. If this mine may be taken as an average for the district, we may calculate that the plant costs somewhere around $8.50 per ton of annual output. Since there is every reason to believe that these mines will be fairly long-lived, it seems rational to amortize the capital over a period of fifteen years so that in round numbers the capital employed is worth 10 per cent., or $0.85 per ton. Calculating the usual amount for depreciation, 6 per cent., we get 51 cents a ton for this item. It is stated that mining costs in the principal mines are about $2.25 per ton.

The entire minimum cost of operating at Guanajuato may be tabulated as follows:

Mining	$2.25
Milling	1.60
Milling	1.60
Amortization	0.85
Depreciation	.51
Total	$5.21

With an extraction of 85 per cent. these costs mean that the minimum grade ore that can be handled must have an assay value of some $6.50 per ton, which means in round numbers some 10 oz. in silver and $1 per ton in gold.

The higher grade ores, as in other districts, are more costly. The Pinguico mine in 1908 produced 82,750 tons of ore worth $1,088,000 or $13.16 a ton. The profits were $425,705, or a trifle over $5.14 a ton, so that the total costs were $8.02. The extraction is stated to be 85.56 per cent. of the gross value of the ore. In this case, therefore, the minimum value that will stand working is in the neighborhood of $10 a ton.

It seems that up to the present the profits of the Guanajuato mines have been very moderate. Pinguico, just mentioned, is probably the most prosperous. It produced silver in 1908 at an approximate cost of 35 cents an ounce. It is probable that for the district at large the present cost of silver is approximately 50 cents an ounce against 27 cents at Cobalt.

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