PRODUCTION COSTS, PORPHYRY COPPER MINES, WESTERN UNITED STATES

by

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Abstract

The cost of copper produced from sulfide concentrates from most United States porphyry copper mines exceeds $0.60 per pound. With rare exception the cost of production from new mines will exceed $0.70 per pound. Only the margin on copper precipitates, molybdenum, and precious metals has kept several mines from slipping into a loss position in the present copper market. An understanding of the effects of geologic factors on production costs has always been very important to achievement of competitive costs, but never more than now. Such understanding is also more essential than ever to evaluation of new projects, expansions as well as new mines, to ensure collection and meaningful compilation of geologic information needed for planning and to make possible an accurate estimate of a project's competitive position.

One of the keys to competitive costs is efficient materials handling from mine through refinery. The system of transportation of ore and waste to beneficiation plants and dumps cannot be well planned without a thorough understanding of the number and distribution of ore types and grade distribution. Inadequate knowledge of ore type and grade distribution, bench by bench, can lead to transportation system bottlenecks which result in very high mining costs per ton of material mined. It can also lead to improper equipment selection with consequent inordinate amounts of walking of shovels and drills and high maintenance costs.

More geologists are needed who can bridge the gap between exploration and planning. The ability to do so will continue to come chiefly from personal initiative, but mining and geology departments of educational institutions should be more active in this discipline.

Introduction

The cost of refined copper produced from western United States porphyry copper ores in almost every case exceeds $0.60 per pound, with the average close to $0.65 per pound. Some mines' costs exceed $0.70 per pound. These costs give full effect to byproduct credits and copper produced from leaching of waste dumps. They include depreciation but do not include any contribution needed, in excess of depreciation, to permit future capital replacement to maintain present levels of copper production or to comply with increasingly burdensome government regulations. They do not reflect the full burden of interest on long-term debt. (The reader is cautioned that the information in this paper reflects 1976 prices and costs. There are substantial differences in 1978 which in the main have caused United States porphyry copper economics to deteriorate.)

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The United States has recently gone through the worst inflation in her history, at least since the Civil War. Regrettably it is clear that unacceptable rates of inflation are still not behind us. Since 1972 the hourly costs of operating, maintaining, and repairing mining equipment have more than doubled. The cost of diesel fuel has more than tripled. Costs have doubled and tripled for a kilowatt-hour of electric power. Grinding balls have doubled in cost. Cans used in the production of copper precipitates have doubled or more than doubled.

Important foreign producers continue to be able to produce refined copper at costs significantly lower than western United States costs. The average cost of production from the Philippines may be as much as $0.10 per pound less than the cost of domestic copper. Moreover much foreign production is under the control of governments some of whom are willing to produce from mines operating at a loss in order to maintain employment goals, modulate social unrest and earn foreign exchange in the short run even though such policies may be destructive of the social order in the long run.

At 1976 copper prices, copper deposits with average grades in the 0.45 to 0.55 percent total copper range are in varying degrees of trouble depending on stripping ratio, metallurgical characteristics, and interest rates. It is obvious that we must do everything possible to hold down production costs if copper deposits in the above grade range are to become profitable, producing mines. Cost control begins with proper mine and metallurgical planning. Proper mine and metallurgical planning in large measure means efficient materials handling from mine through smelter.

Mining Costs

Direct open-pit mining costs per ton of material mined lie in the range of $0.30 to $0.55, with most mines in the $0.40 to $0.50 range. There are two pits that have had costs in excess of $0.70 per ton. These costs do not include depreciation and as used in this paper do not include any payroll burden, taxes or insurance on mining equipment, or any allocation of general and administrative expense.

The cost per pound of marketable copper produced will typically lie in the range $0.140 to $0.175 for an ore that yields 10 pounds of copper through refining and is mined with a 2.5-1 ratio (by weight) of waste to ore. A chalcocite ore with a total copper assay of 0.67 percent or a chalcopyrite ore with a total copper assay of 0.59 percent might yield such a recovery. Stripping ratios near 2.5 to 1 are not uncommon.

The principal geologic factors affecting open-pit mining costs are the level-by-level distribution of ore types, ore grades and waste, and structures affecting slope stability. Without good level maps showing these features it is not possible to really plan well the system of transportation of ore from point of loading to the crusher. Waste-to-ore ratios at a given future time cannot be accurately predicted. Mining faces cannot be planned with the most advantageous orientation. Adequate planning for ore-type blending cannot be done.

A good grade and ore-type distribution model permits reasonably accurate estimation of preproduction stripping requirements, yearly waste-to-ore ratios, and availability of ore of different grades and metallurgical types. Good level maps and estimates of the above factors make possible a good haulage plan, which is the key to low mining costs. They permit selection of the equipment best suited to the orebody. Inaccurate stripping estimates can lead to inability to meet debt service requirements with the need for very costly refinancing of obligations. Improper equipment selection can lead to excessive tramming of shovels and drills with increases in hourly operating and maintenance costs of 20 to 40 percent. As shovels increase in size, the importance of an individual unit in achieving production goals become more and more pronounced. A faulty mining plan, due to a lack of good level maps, may lead to many nonproductive hours of shovel walking and downtime and to idle expensive concentrator capacity.

With good geologic level maps and some simple testing it is also possible to predict the extent of rock types with significantly different drillability. Different rock types found in pits in the Twin Buttes district may result in penetration rates with the same drill that differ by a factor of two.

Good grade distribution maps are invaluable in judging the relative merits of shovels and loaders or a combination of the two for a particular orebody.

Milling Costs

Direct milling costs lie in range of $1.20 to over $2.00 per ton of ore milled. Most frequently the costs are in the range of $1.35 to $1.60. The cost per pound of marketable copper for an ore yielding 10 pounds per ton will be $0.135 to $0.160. Inaccurate level maps and consequent poor planning and underachievement of tonnage goals can push the cost over $0.20 per pound.

Since mineralogy affects total recoverable pounds, it can have a drastic effect on all costs from mining through smelting. To clarify the effect on milling costs, three situations might be considered:

1. Do we have a clean chalcopyrite ore? Is the sulfide ore liable to be diluted with oxidized material in fault zones or in caving, for example, toward the end of draw of a block?

2. In the case of a chalcocite ore does the chalcocite occur almost entirely as thin coatings on pyrite? Does it extend down into cleavage planes to the extent that substantial copper is still locked up in pyrite at any reasonable grind?

3. If the ore is a mixed oxide-sulfide ore is the oxide mainly chrysocolla, malachite, or a film on chalcocite?

Assuming a direct milling cost of $1.50 per ton of ore milled and a total copper assay of 0.60 percent, the above ores could yield a wide range of costs per pound of copper produced.

The clean chalcopyrite ore might give a recovery through refining of 86 percent with a cost per pound of copper of $0.145. If a significant amount of oxidized material were present, recovery might drop to 84 percent with a cost of $0.149 per pound. A chalcocite ore with the chalcocite as exterior coatings on other sulfide grains might yield a 75 percent recovery with a cost of $0.167 per pound. With a substantial amount of the chalcocite on unexposed cleavage planes at a fine grind, final recovery could drop to 68 percent with a milling cost of $0.184 per pound. Mixed oxide-sulfide ores might give 75 percent recovery after treatment, costing, for example, $3.65 per ton to recover both oxide and sulfide copper. The cost per pound would be $0.405.

General and Administrative Costs

These costs include such items as the unit general manager, accounting, purchasing, safety and welfare, pension plan, insurance, general maintenance, and as used in this paper, payroll taxes. There is no category of costs that comes in for more diverse definition and treatment than general and administrative expense. These costs when allocated to mining, milling, leaching, smelting, etc. may be referred to as indirect mining costs, indirect milling cost, etc.

Indirect costs may range from 30 to 100 percent of direct costs but more commonly are in the 40-60 percent range. Thus, if an operation has a direct mining cost of $0.45 per ton of rock, a 2-to-1 stripping ratio and a direct milling cost of $1.50, the general and administrative costs might be expected to be 40 to 60 percent of $2.85, or $1.14 to $1.71 per ton of ore milled. For an ore with 10 pounds of marketable copper per ton, this represents $0.114 to $0.171 per pound of copper.

Vat or Tank Leaching

Geologic factors that affect the cost of copper recovered by vat leaching include ore and gangue mineralogy and the tendency of the ore to yield fines when mined and crushed.

For an oxide ore assaying 0.65 percent total copper, a good situation would be represented by a high percentage of true chrysocolla or of malachite with a recovery of 70-80 percent of the copper (probably closer to the lower figure), a relatively small percentage of fines to the vats, and a low acid-consuming gangue. The cost of vat leaching under these circumstances could be $1.60-$1.75 per ton of ore leached, resulting in a leaching cost per pound of recovered copper of $0.154-$0.192.

A difficult situation with the same total copper assay would be represented by refractory mineralogy, high fines, and high acid consumption. Recovery could be 45 to 65 percent of the total copper content. The leaching cost could be $3.50 to $4.00 per ton of ore leached, with a leaching cost per pound of copper recovered by leaching of $0.414 to $0.684.

Smelting, Refining, and Freight Costs

For nonintegrated producers the 1976 costs of concentrate freight, smelting, converting, anode casting, anode freight and refining will be in the range of $0.22 to $0.27 per pound of marketable copper in 1977 with the average in the $0.24-$0.26 range.

For integrated producers the costs will be from about $0.140 to about $0.220 per pound.

Financial Costs

A new plant in the western United States to mine and mill 60,000-80,000 tons of ore per day and a smelter to treat the concentrate could cost $500 million or more to engineer, construct, and start. Depending on the amount of debt capital employed, repayment of principal and interest could exceed $75 million in a peak repayment year. If 80,000 tons of ore were milled per day, 350 days per year, with a marketable copper recovery of 10 pounds per ton of ore milled, the principal and interest in such a year would be about $0.27 per pound of marketable copper.

In view of the numbers, it is clear that everything possible must be done to ensure a more-than-adequate available ore supply at and after mill startup. An erroneous conception of the geometry of the top of the ore zone could lead to refinancing $50 to $60 million and add $15 million to the cost of capital. Good grade distribution maps are cheap insurance against such an eventuality. With good level maps and good planning it may be possible to open up the mine to produce at peak capacity without interruption and to high grade to the extent possible without incurring unreasonable costs. This could permit acceleration of debt repayment with savings of tens of millions of dollars.

It should be recalled that a fair return to equity shareholders on their investment is a very real financial cost. In fact the cost of equity capital is normally higher than the cost of debt. The fact that relatively less debt is used in one project than another is not a valid reason for devoting less time and money to careful planning.

What We Can Do

To help keep production costs at an acceptable level the following suggestions are offered. It will be noted that geologists should play a very important role in planning many aspects of a modern porphyry copper operation.

1.   From the outset of the drilling program, work toward preparation of bench maps, level by level, that will show the distribution of ore types, ore grades, and waste and geologic structures. Ore type may be defined by a few simple variables: flotation recovery, grindability, pyrite content, and others. Values of such variables may be nearly as important to post to the level maps next to drill-hole intersections as the grade of the drill-hole bench composites. Remember it is not just the orebody and what is within pit limits that affect costs. Structures hundreds of feet behind originally contemplated pit limits may affect pit limits sooner than expected. Prepare two sets of vertical sections, perpendicular to each other, and reconcile them in plan to get good geologic level maps.

2.   Many geologic features that influence grade and ore type have steep walls. The only reasonable way to get an accurate picture of the size and orientation of these features is by angle hole drilling. I would not suggest angle hole drilling as a method of reducing total footage needed for an accurate grade estimate. I do suggest it for outlining of waste zones inside the pit.

3.   Once a preproduction stripping plan is made, drill some holes behind long ore faces that you are counting on for initial production. There is little excuse for letting a $600 million investment operate at 50 percent of capacity while you catch up on stripping when 10 drill holes would have saved the day.

4.   Also recall that you need dumping room. Provide the information on a timely basis for selecting dump areas.

5.   Ore type is becoming very important. Not by grade alone does man live. Oxidized or partially oxidized zones of substantial size can penetrate hundreds to more than a thousand feet into chalcocite blankets and chalcopyrite orebodies, leading to substantial quantities of ore with a high acid-soluble copper content. Be alert to the probability (not possibility) of the need to blend for best recovery. Prepare some level maps with ore-type distribution.