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Lowering the Threshold for Refractory Gold Deposits with New Biooxidation Technologies

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ABSTRACT

Biooxidation is now established as a viable commercial process for oxidation of certain refractory sulfide gold concentrates. One of the challenges facing the gold industry is to lower the capital and operating costs of biooxidation and expand the range of refractory sulfide gold deposits to which it is applicable. GeoBiotics has developed a new, lower cost and more widely applicable biooxidation technology. The technology involves thinly coating refractory sulfide gold concentrates onto any one of a number of supports, such as coarse rock, and allowing them to biooxidize in a heap. The biooxidation portion of the incremental operating and capital costs when using this technology have been estimated for a pyritic refractory deposit at processing rates of 2,500 and 10,000 st/day. Biooxidation adds under US$7 MM to the capital and US$1.59 per short ton to the operating cost for a 2,500 st/day mine, and under US$16 MM capital, and US$0.71 per short ton operating cost for a 10,000 st/day mine. This new technology, with these operating and capital costs, now makes biooxidation a viable option for. a wider variety of refractory sulfide deposits.

INTRODUCTION

More than one-third of the gold ore reserves in the United States are considered to be refractory to conventional cyanide extraction or free milling technologies[(1)]. As the near surface oxide gold deposits in the U.S. and the rest of the world are depleted, it is not unreasonable to expect that the percentage of gold produced from refractory ores will increase. Many of the deeper gold deposits that are currently being discovered, including deeper extensions of known oxide deposits, are refractory in nature due to sulfide encapsulation of the gold.

These refractory ores must be oxidized before extraction of the gold, and for many years roasting was the only economical means to process sulfidic ores. More recently, pressure oxidation in autoclaves has been used successfully, and in the past 10 years, biooxidation has been gaining acceptance as an oxidation alternative.

CURRENT BIOOXIDATION TECHNOLOGIES

Biooxidation is simpler, safer and less expensive than roasting or pressure oxidation. For each gram of ore, literally trillions of microorganisms, each smaller than 10 microns, attack the sulfide minerals encapsulating the gold particles in refractory ore. Biooxidation occurs at near ambient pressures and temperatures, whereas pressure oxidation occurs at 200 psig, and roasting at 1,000°F. Inherently, biooxidation processes require less capital and less skilled operating and maintenance personnel.

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Up to now, there have been two fundamental approaches to biooxidation: stiffed tank and whole ore heap. Stirred tank biooxidation involves forming a high grade, sulfide flotation concentrate which is biooxidized as a slurry in a series of aerated and agitated bioreactors. Capital costs are dictated by the size and number of the acid proof tanks, while operating costs are attributable primarily to aeration and agitation of the slurry. Both are governed by the biooxidation reaction rate[2]. Typically, only those sulfides that biooxidize rapidly, such as pyrrhotite and arsenopyrite, are treated in this manner.

Whole ore heap biooxidation has been tested extensively by Newmont and GeoBiotics[3, 4]. Sulfide ore is crushed, agglomerated and placed in a heap configuration. Sulfide oxidizing bacteria are added to the ore and it is allowed to biooxidize for about a year. Then the heap is rinsed, pH adjusted and restocked before the gold is extracted, again in a heap configuration. To date, gold recoveries from whole ore heap biooxidation have been limited to approximately 50 75%.

Oxygen mass transfer limitation is a problem common to both stiffed tank and whole ore heap biooxidation. In stiffed tank biooxidation, the oxygen mass transfer is improved by the use of expensive, high shear, high power agitation. In whole ore biooxidation, a fine crush size is used, often 80% passing 3/8", to increase the biooxidation rate and the subsequent gold extraction recovery[4]. However, the fine crush size compounds limitations in air and liquid transport into and through the biooxidation heap. Agglomeration improves air and liquid flows, but only a limited number of polymeric agglomeration aids are acid stable and the resulting agglomerates are often unstable. Research is ongoing to address these limitations in whole ore heap biooxidation[5].

Stiffed tank biooxidation incurs significant power costs, so it is only applicable to high grade and rapidly biooxidizing sulfide concentrates. It is simple to operate, but requires uninterruptible power to maintain aeration and agitation in the bioreactors. Whole ore heap biooxidation is inexpensive, but the subsequent gold recoveries are low. So far it is only applicable to low grade materials that would otherwise be considered waste.

A NEW BIOOXIDATION TECHNOLOGY

GeoBiotics has developed a third approach to biooxidation of refractory sulfide gold ores, which is the subject of a number of patents that have been issued or are pending in the U.S. and other countries. This technology combines the high recoveries associated with stirred tank biooxidation with the low costs associated with a heap process. A thin layer of gold-bearing refractory sulfide concentrate is coated onto any one of a number of supports such as coarse rock. The coated support rocks are placed in a heap or vat, inoculated with iron and sulfur oxidizing microorganisms and allowed to biooxidize[6]. After biooxidation several processing options are available, but typically the coating is removed and gold is recovered via traditional cyanide leaching processes.

Figure I depicts a cross section of a coated support rock. The refractory sulfide layer is typically under 0.05 in. thick. Flotation concentrates from ore and mill tails have been tested successfully as sources of the gold-bearing sulfide coating. Generally, the support material has a nominal diameter of 0.5 - I inch. It can be virtually any material that can withstand the low pH biooxidizing environment. Typical materials include barren rock or ore. The dry weight ratio of support to coated material is about 5 to 1.

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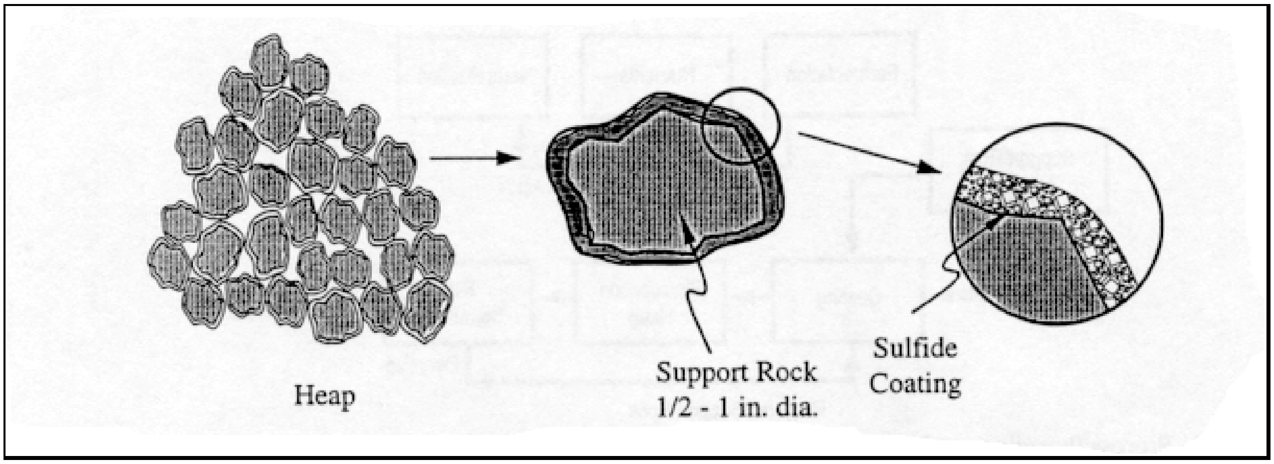

Figure 1
Schematic cross section of refractory sulfide coating on a support rock in a heap configuration. The sulfide layer is usually under 0.05 in. thick and is formed from flotation concentrates.

Figure 2 shows how biooxidation can be used as a pretreatment step in a conventional gold mill. Processing refractory ore involves the addition of flotation, coated biooxidation and neutralization unit operations. The coated biooxidation process is shown in greater detail in Figure 3. Here a sulfide gold concentrate is coated onto support rocks. The coated rocks are then stacked in a heap, inoculated with iron or sulfur oxidizing bacteria such as *Thiobacillus and/or Leptospirillum* and biooxidized. After 3 to 12 weeks, the coated rocks are removed from the heap and the coating is stripped from the support. The coating is then cyanide leached and the support is recycled, processed or discarded.

Oxygen mass transfer limitations into the interior of the heap can be improved with inexpensive air blowers. The large interstitial spaces between the support rocks lead to a large heap porosity and low pressure drops. Short term power outages will not materially affect biooxidation in the heap. As heap operating costs are low, this approach is applicable to those sulfides with slower biooxidation kinetics, such as pyrite, as well as sulfides with fast biooxidation kinetics. After biooxidation, gold recoveries are high, often exceeding 90% (6).

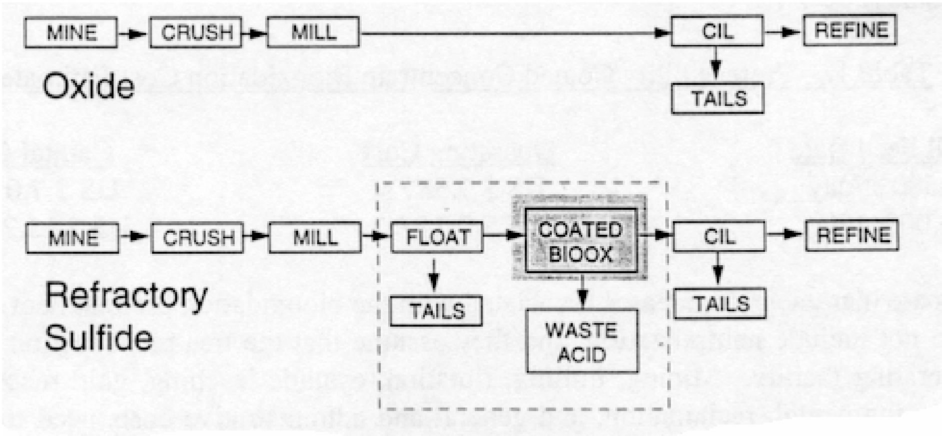

Figure 2
Addition of biooxidation processing to a conventional gold mill. The dashed box represents added processing steps. The reported biooxidation capital and operating costs are for the shaded area.

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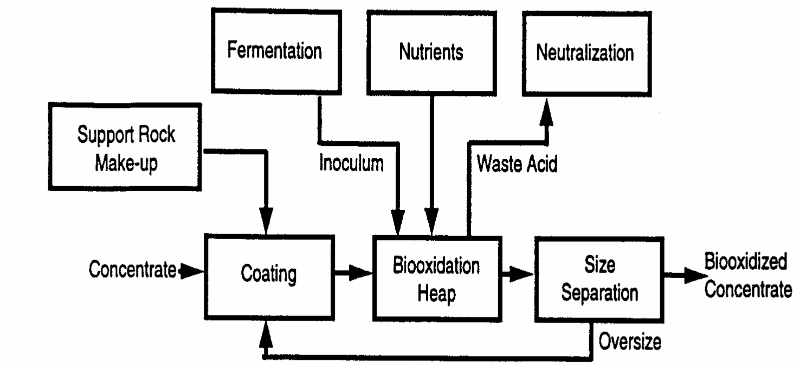

Recycled Support Rock

Figure 3
Process flow diagram for coated biooxidation step for a hypothetical refractory deposit

Pilot scale testing of this technology is currently underway. Successful coating and stripping tests, at rates that could handle the production from a 500 st/day mill, were completed in the second quarter of 1996. At the end of August, 1996 a pilot scale biooxidation test in a 4 feet diameter, 13 feet tall column was completed and another column test initiated.

CAPITAL and OPERATING COSTS

The material handling equipment associated with the coated concentrate technology are well characterized in the minerals processing industry and consist primarily of a lined pad, conveyors, stackers and loaders. GeoBiotics commissioned Davy International to conduct a prefeasibility study of the biooxidation portion of the process (denoted by the shaded area in Figure 2). Capital costs were estimated to ±30% 'and operating costs to ±20%. A hypothetical sulfide refractory gold deposit located in central Nevada was examined at two different processing rates. The sulfides were assumed to be pyritic and capable of forming a sulfide flotation concentrate representing 10% of the weight of the milled ore. Biooxidation was projected to occur over a 9 week cycle during which 50% of the sulfides were biooxidized.

Table I shows the operating and capital costs for the biooxidation step from the Davy International study.

Table 1
Prefeasibility Coated Concentrate Biooxidation Cost Estimates

Mill Feed Rate	Operating Cost	Capital Cost
2,500 st/day	US $ 1.58 / st	US $ 7.0 MM
10,000 st/day	US $ 0.71 / st	US $ 15.7 MM

These costs are incremental increases associated with the biooxidation pretreatment of the refractory ore, do not include neutralization, and they assume that the treatment section is associated with an operating facility. Mining, milling, flotation, cyanide leaching, gold recovery, tailings disposal, environmental, reclamation, and general and administrative costs need to be added in order to get a complete cost estimate.

The major component of the biooxidation operating cost is labor. A complete breakdown of the operating cost is shown in Table 2.

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Table 2
Biooxidation Operating Cost Details (US$/short ton mill feel

	2,500 stIday		*10,000 stIday*	
	US$/St	**%**	**US$/St**	**%**
Labor (operations and maintenance)	1.06	67	0.31	44
Maintenance supplies (4% direct capital)	0.21	13	0.12	17
Consumables (lime, nutrients, floc)	0.20	13	0.20	28
Power (US$0.05 / kWh)	0.06	4	*0.05*	7
Operating supplies (I% direct capital)	0.05	3	0.03	4
Total	**1.58**	**100**	**0.712**	**100**
Number of employees		21		25

Biooxidation operations were assumed to be 24-hour coverage on 12-hour shifts. Coating and biooxidation heap stacking occur on one shift each day and reclaim and stripping occur on the other shift. There is only a small incremental increase in staffing requirements at the larger processing rate, because the size and capacity of the equipment are greater. Consequently, the unit operating cost decreases significantly with scale.

Table 3 details the capital cost estimate. It is interesting to note that, although the cost estimates for the two sizes of operations were estimated separately and independently, the final capital cost estimates scale at a 0.58 exponential factor, close to the 0.60 rule-of-thumb. As most of the equipment is idle for one half of the day, throughputs could be doubled, and unit operating costs lowered slightly, with only a small increase in capital cost.

Table 3
Biooxidation Capital Cost Details (US$ 000s)

	2,500 st/day	10,000 st/day
Support rock sizing & concentrate coating	98	934
Biooxidation pad (US$2/sq ft)	773	2,990
Stacking, reclaim, solution management	2,590	5,705
Stripping, biooxidized concentrate thickening	859	1,306
Engineering, procurement & construction management	723	1,640
Freight	175	350
Contingency (18% of above)	1,029	2,327
Sales tax	204	406
Total	**6,951**	**15,658**

Depending how the coated concentrate biooxidation process were to be integrated with an existing mine operation, a number of cost reductions could be anticipated, including fuller utilization of existing equipment and employees.

Not addressed here is a major processing cost associated with oxidizing any sulfide ore: the treatment of acid effluent generated during oxidation. Production of waste acid is not unique to biooxidation. Roasting and pressure oxidation of sulfide ores generate significant quantities of acid which must be concentrated or neutralized. For biooxidation, this effluent is dilute and laden with iron ions, so it is typically neutralized. Neutralization costs are strongly influenced by site specific factors. For example, when the flotation tails contain sufficient carbonates, neutralization costs will be minimal as the waste acid can be combined with these tails prior to disposal. Other alternatives include neutralization with lime or limestone. Neutralization costs will vary depending on the acid generating characteristics of the ore, the extent of biooxidation required to liberate the gold, the neutralization method selected and the availability of neutralization reagents.

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IMPLICATIONS of LOW COST BIOOXIDATION TECHNOLOGY

The new GeoBiotics technology is capable of achieving similar gold recoveries from refractory sulfide gold ores as roasting, pressure oxidation and stirred tank biooxidation at significantly lower capital and operating costs. The only significant environmental issue is the generation of waste acid which must be neutralized, but this is a problem common with the other oxidation technologies.

A further attribute of the coated concentrate technology is that all of the equipment is standard material handling equipment and a biooxidation pad similar to a heap leach pad. The biooxidation facility is relatively simple to operate, maintain and manage with little requirement for skilled labor. It is flexible in operation, lending itself to be scaled up or down at any time.

The implications of this coated concentrate biooxidation technology for the international gold mining industry are many fold. This technology:

- lowers the threshold of size and grade of refractory sulfide gold deposits, allowing smaller, lower grade deposits to be developed;
- facilitates expansion of reserves at existing refractory sulfide gold deposits by lowering the cut-off grade;
- is well-suited for use in remote locations, especially regions with limited availability of skilled labor, because the facilities are relatively simple to construct and operate;
- is well-suited for countries with elevated political risk because of low capital component;
- provides for flexible operations that are capable of surviving equipment failures, process upsets, and power outages (and allowing use of interruptible power at lower unit rates);
- can expand the throughput of existing autoclaves by functioning as a pre-treatment step to partially oxidize sulfides;
- has low capital and operating costs, making it suitable for tailings treatment projects in which existing refractory sulfidic gold tailings are biooxidized;
- reduces the acid rock drainage potential of leach tailings; and
- permits throughput to be easily scaled up or down.

Finally, this technology lends itself to the development of custom biooxidation plants which could purchase and treat refractory sulfide gold concentrates from gold mines which are too limited in reserves or annual production to justify having an on-site, dedicated oxidation plant. This will permit development of deposits which would otherwise be uneconomic.

CONCLUSION

Biooxidation has been a commercially viable oxidation option for certain refractory sulfide gold concentrates for several years. The advent of GeoBiotics' new, lower cost, more flexible biooxidation technology expands the horizons for biooxidation and makes biooxidation a viable alternative oxidation process for a wider variety of refractory sulfide deposits. Smaller, lower-grade deposits, which would not have been economic with any of the existing oxidation technologies bear a fresh look. Large, higher grade deposits which would be economic with one or more of the existing oxidation technologies now have a lower cost, more profitable alternative.

The economic threshold for the treatment of refractory sulfide gold deposits has been lowered.

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