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GEOCOAT™ Biooxidation Demonstration at Ashanti Goldfields' Obuasi Operations, Ghana, West Africa

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ABSTRACT

Facing lower gold prices, gold mine operators throughout the world are seeking ways to reduce costs for treating refractory sulfide ores. Many gold mines, currently producing oxide ores, have underlying refractory sulfide deposits and the operators could extend the mine life by processing these sulfides. Fortunately, oxidation technologies for refractory ores need not be complex nor costly. GeoBiotics, Inc. has developed heap biooxidation technologies (GEOCOAT™) for treatment of refractory gold ores and concentrates. GEOCOAT™ uses simple low cost unit operations common to heap leaching of gold and copper ores. The cost effectiveness and flexibility of GEOCOAT™ heap biooxidation allows mining companies to expand operations to include refractory ore. In addition, GEOCOAT™ can be utilized to supplement or replace existing oxidation processes such as roasting, autoclaving, or agitated tank biooxidation, and to treat a lower resource grade than is currently economic.

The GEOCOAT™ technology involves coating sulfide concentrates onto sized support rocks and biooxidizing the sulfides in a heap configuration. After biooxidation the concentrate is stripped from the support rock, neutralized and leached in conventional cyanidation facilities.

Ashanti Goldfields Company Ltd. (AGC) produces over 885,000 ounces of gold per year from oxide and refractory ores at its Obuasi operations in Ghana. Refractory flotation concentrates are treated in roasters and in the world's largest stirred tank biooxidation facility.

In August 1998, AGC and GeoBiotics jointly constructed and operated a field demonstration heap of the GEOCOAT™ process at the Obuasi operations. The heap contained 1082 tonnes of support rock and 125 tonnes of concentrate. The heap was approximately 19 meters square at the base and 3.8 meters high, and ran for 88 days after which the concentrate was reclaimed. Average gold recovery after biooxidation was 91.5% with a NaCN consumption of 8.6 kg/t. Baseline gold recovery by direct cyanidation of the concentrate was 53.8%.

The field demonstration project was completed in December 1998 and successfully demonstrated that the GEOCOAT™ process is a technically and economically viable low cost alternative for treating concentrates and ores at the Obuasi operations. A second demonstration heap, using low-grade sulfide ore as the support rock, is currently being constructed.

The potential integration of a GEOCOAT™ heap biooxidation technology at Obuasi provides numerous opportunities to increase gold production, reduce cut-off grade, and reduce operating costs

INTRODUCTION

As free milling, oxide gold deposits are depleted, refractory deposits must be developed in order to maintain gold production. Unfortunately, refractory processes often incur prohibitively high operating and maintenance costs, and require exotic materials of construction, highly trained operating and



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maintenance personnel, and substantial capital investment. These disadvantages, coupled with lower gold prices, have hindered development or expansion of refractory gold projects.

GEOCOAT™, a proprietary process developed by GeoBiotics, Inc., allows refractory gold ores to be easily and economically treated. The process involves the use of biooxidation in a heap configuration. GEOCOAT™ is suitable to a wide variety of ores but is particularly applicable to ores that respond to conventional concentration techniques. The refractory concentrate is coated onto a closely sized support medium, generally low-grade refractory ore or mine waste, and stacked as in a traditional heap leach. The heap is inoculated with a suitable bacterial culture and continuously contacted with solution containing acid, iron and nutrients. Due to the thin coating of concentrate, a large surface area is exposed to bacterial attack resulting in higher biooxidation kinetics than is found in whole ore heap biooxidation. Depending on mineralogy, sufficient oxidation for enhanced economic gold recovery is achieved in 30 to 90 days. After biooxidation, the concentrate is stripped from the support medium, neutralized and treated by conventional cyanidation processes.

AGC annually produces over 885,000 ounces of gold at the Obuasi operations in Ghana, West Africa from oxide and refractory sulfide ores. Processing facilities include conventional CIL and heap leaching, stirred tank biooxidation, and roasting. Ore is produced from multiple underground mines, one large open pit operation, and several satellite open pits. The mine is a large, integrated operation where the addition of a lower cost refractory ore processing technology could increase gold production and reclassify substantial amounts of low-grade sulfide materials from waste to ore.

In 1996, GeoBiotics and AGC began an extensive laboratory test program on samples from the Obuasi operations. The positive results from this program led to AGC and GeoBiotics entering into an agreement in June, 1998 with respect to the use of GeoBiotics' patented GEOCOAT™ technology at AGC's Obuasi operations. AGC and GeoBiotics agreed to conduct a field demonstration project of the GEOCOAT™ technologies. This paper summarizes the results of the field demonstration.

GEOCOAT™ TECHNOLOGY

The GEOCOAT™ process incorporates elements of two successful and commercially proven technologies: heap leaching and biooxidation. Gold-bearing sulfide minerals are concentrated by flotation and thickened. The resulting slurry is thinly coated onto crushed, screened support rock, stacked on a lined pad, and allowed to biooxidize. Coating is accomplished by spraying the concentrate slurry onto the support rock as it discharges from the end of a stacking conveyor onto the biooxidation heap. The hydrophobic nature of the concentrate assists in the formation of a coating on the support rock. No binding agent is required. The concentrate naturally adheres to the support rock and does not wash out of the heap during solution application or even during heavy rainstorms.

The support rock is relatively uniformly sized, in the range of one to two centimeters in diameter, and the concentrate coating is relatively thin, less than one millimeter in thickness. The weight ratio of support rock to concentrate is in the range of 5:1 to 10:1. The heap is inoculated with naturally occurring sulfide-oxidizing bacteria, such as *Thiobacillus ferrooxidans*. Nutrients are added to the heap via recirculating solutions. As biooxidation progresses, the sulfides in the concentrate are oxidized and the solubilized iron, arsenic and sulfate are carried from the heap by the recirculating solution. A portion of the solution stream is bled from the circuit and for disposal.

The relatively uniform size of the support rock leads to large interstitial spaces within the heap and low resistance to air and liquid flows. Sufficient air for biooxidation and heat removal is supplied to the heap by low-pressure blowers through a system of perforated pipes laid in the base of the heap.

After biooxidation, the coated rock is unloaded from the pad, and the oxidized concentrate is easily removed by trommeling or wet screening. The concentrate is neutralized and the gold is then

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recovered by conventional CIL. The support can be recycled or, in the case of low grade refractory ore, it too can be cyanide leached to recover gold values. Figure 1 presents is a schematic representation of the process.

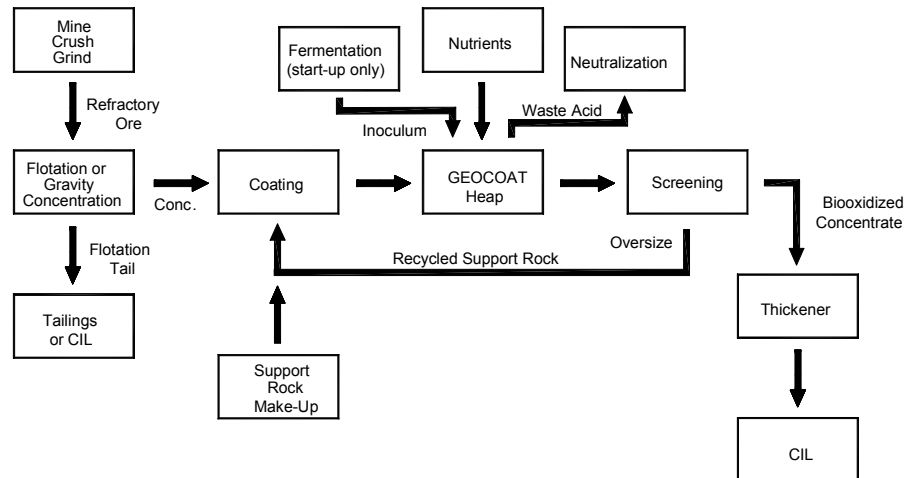


Figure 1
GEOCOAT™ Process Flow Diagram

ASHANTI OBUASI OPERATIONS

Gold mining has been conducted at Obuasi since before the turn of the century, and large scale operations started around 1930. Optimization and mine planning at the site is an ongoing exercise as AGC responds to changing economic and physical conditions. Currently, AGC operates four mills and a cyanide heap leach facility at Obuasi: as summarized in Table 1.

The Oxide Treatment Plant processes oxide ores and consists of crushing, milling, and CIL facilities.

The Sulfide Treatment Plant processes sulfide refractory ore and consists of crushing, milling, flotation and stirred tank biooxidation of the flotation concentrate. Flotation tailings and biooxidized concentrate are leached in CIL facilities. The stirred tank biooxidation facility is the largest of its kind in the world and has been operating successfully since startup in 1994. The sulfides consist of arsenopyrite, pyrite, and some pyrrhotite.

The Pompora Treatment Plant processes refractory sulfide and carbonaceous ore and consists of crushing, milling, flotation, and roasting of the flotation concentrate. Throughput in the Edwards roasters is limited and approximately one fourth of the concentrate is trucked to STP for stirred tank biooxidation. Flotation tails and roaster calcines are leached in CIL facilities.



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The Tailings Treatment Plant processes material that is hydraulically reclaimed from old PTP tailings and consists of CIL facilities.

The Heap Leach facility (now idled) processed oxide ores that were below the cutoff grade for OTP. Gold was recovered from the pregnant leach solution at OTP.

Clearly, there are a variety of options for processing ores at Obuasi. A new, lower cost heap biooxidation technology could prove to be an economic means to supplement the existing oxidation processes.

Of particular interest is the ability of GEOCOAT™ heap biooxidation technology to use a refractory sulfide resource of a grade below the cutoff for the current STP and PTP oxidation facilities as the support rock. After biooxidation, this lower grade sulfide ore could be processed in the OTP or HL facilities.

FIELD DEMONSTRATION

AGC and GeoBiotics jointly built a heap to demonstrate the GEOCOAT™ technology at scale. The field demonstration heap was constructed in 6 weeks from empty space to an active demonstration plant. It was located adjacent to the STP plant. Stacking of the heap took place over a 5-day period. The heap contained 125 tonnes of concentrate and 1,082 tonnes of support rock, producing a final support rock to concentrate weight ratio of 8.7:1. The support rock was sourced from OTP mill rejects. The support rock was – 25 and + 6 mm in size. The concentrate slurry was sprayed onto the support rock as the rock was discharged from the end of a modified stacking conveyor. Coating operations were not suspended when it rained. The concentrate coating process was efficient and effective, and exhibited no significant problems. Thermocouples were placed in the heap during stacking.

The concentrate was refractory due to both sulfides and a carbonaceous preg-robbing component. Baseline cyanidation gold recovery before biooxidation was 53.8%.

The heap was 17.7 by 19.8 m its base and 3.8 m in height and was operated by a crew of four casual laborers supplied by AGC. They were trained on the job by GeoBiotics for a period of 3 weeks after which time they operated the heap with minimal supervision. The heap was inoculated with a mixed bacterial culture from GeoBiotics' research laboratory containing *Thiobacillus ferrooxidans*, *Thiobacillus thiooxidans*, and *Leptospirillum ferrooxidans*. The bacteria were fermented on site and added to the heap after acidulation was complete. The heap required 8 days to acidify due to the carbonate content of the support rock.

During heap dismantling no migration of concentrate was observed through the heap or into the underlying base rock. Tropical rainstorms did not wash any concentrate out of the heap. Temperatures were monitored and were easily controlled at a peak of 46°C through manipulation of solution application and aeration rates.

Solid samples were removed from the heap at six locations (on a 2 by 3 grid) at 1-meter intervals after 30, 45, 60 and 88 days of biooxidation and after a final rinse. (See Figure 2.) Sample holes were cased and capped. Samples were assayed by SGS Laboratories Ltd. (Ghana), an independent metallurgical testing laboratory, for gold, iron, arsenic, total sulfur, sulfate sulfur and elemental sulfur. Sulfide sulfur was determined by difference. Gold recovery was also determined by SGS, using a standard AGC bottle roll leach procedure developed to predict the gold recovery in CIL facilities for biooxidized concentrates.

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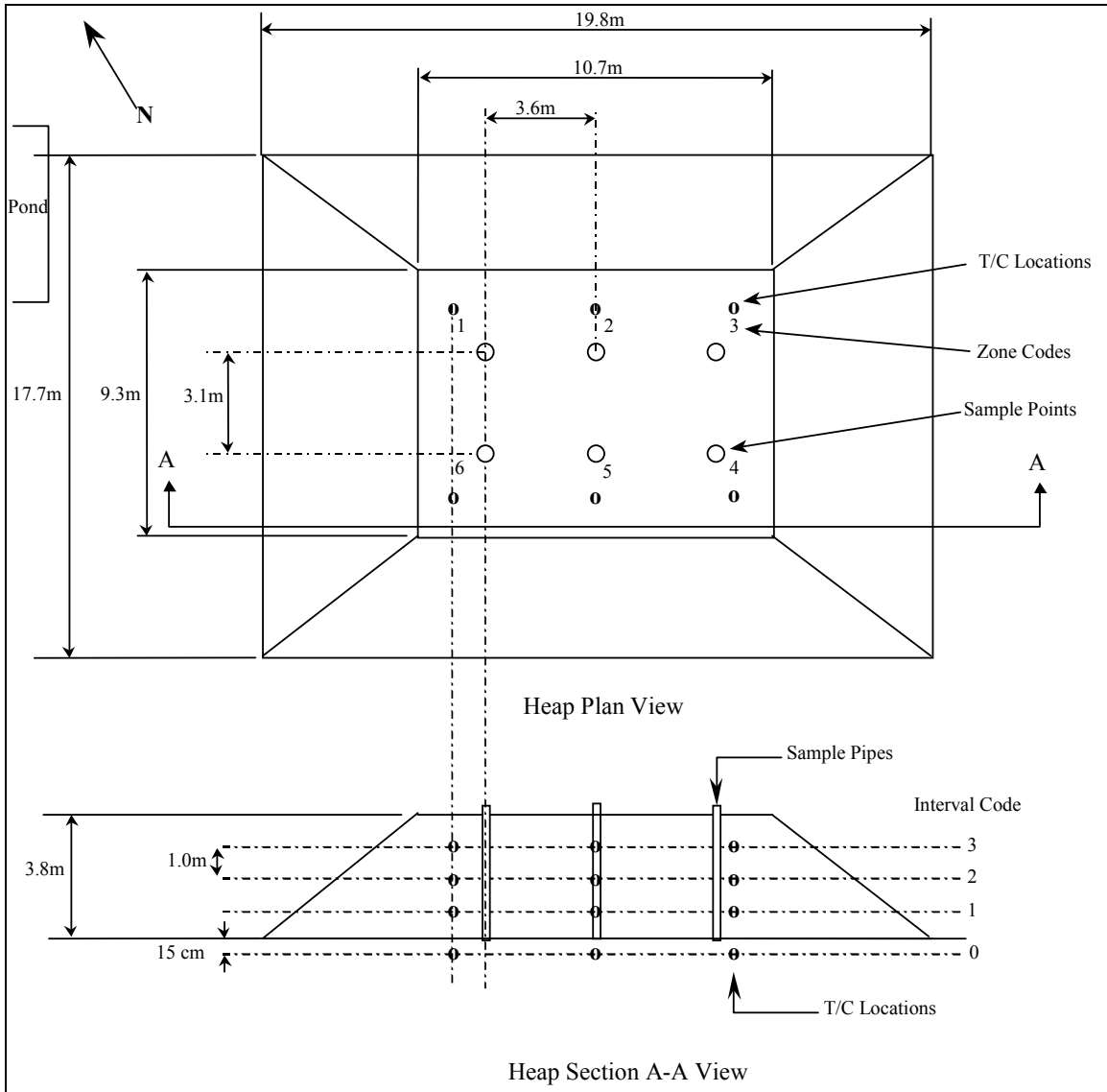


Figure 2
Sample Locations

The average CIL bottle roll gold recoveries for samples taken from the heap as a function of time are shown in Table 2.



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Early in the demonstration heap operation, the biooxidation exhibited some variability. Several areas of the heap were performing better than others as determined by heap temperatures and interim sample analysis. The areas showing initially lower kinetics were those areas stacked first. Minor operational aspects of stacking of the heap improved during the course of stacking over five days. Those heap sections that were stacked last were more uniform and initially biooxidized more rapidly.

By the termination of the demonstration, sampling indicated that all areas of the heap were fairly uniform in extent of biooxidation, elemental sulfur content, and gold recovery. There were no significant differences as a function of height interval or drill hole location (zone) in the gold extraction results shown in Table 3. A small improvement in gold recovery was noted after rinsing (AR).

Initial biooxidation of sulfides resulted in the production of elemental sulfur in the concentrate. Elemental sulfur is known to result in higher cyanide consumption during subsequent gold leaching. The sulfur content in the demonstration heap reached a peak of 0.78% after 60 days of biooxidation and decreased to 0.11% after 88 days of biooxidation and rinsing. This heap exhibited an elemental sulfur build up and decay similar to that observed by days with solutions of decreasing iron and acid content. A final fresh water rinse produced an effluent of 1,200 ppm iron.

Removal of the biooxidized concentrate coating was conducted with a GeoBiotics' designed trommel constructed by AGC's maintenance staff. The concentrate was easily removed from the support rock. The concentrate was sampled for assaying and CIL testing.

Table 4 presents a summary of the metallurgical results obtained.

Complete test work to optimize the CIL conditions was not conducted, however preliminary optimization studies show that the cyanide consumption can be reduced to 7.6 kg/t. Further optimization is possible.



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Power consumption during heap operation was limited to two 2.25 kW blowers and a single 0.75 kW solution application pump. Blower operation was varied to control temperatures in the heap. Average aeration rate was 50% of the blower capacity.

The demonstration heap did experience some problems, primarily due to the scale of the operation. Handling the slurry was difficult as it was delivered by tanker at a low density which required thickening on site in a retrofitted tank prior to coating. The support rock was contaminated with carbonates, iron grinding ball fragments, laterite, and oversized material due to lack of a proper dedicated screening plant, and a leak formed in the effluent pond. In a commercial facility, provisions would be made to prevent these problems.

Biological processes tend to improve over time as the bacteria adapt and operations personnel become familiar with the process. It is reasonable to expect that a similar improvement in operations would be seen for the GEOCOAT™ process.

DISCUSSION

Preliminary engineering studies by Kvaerner Metals and Jacobs Engineering indicate that the GEOCOAT™ heap biooxidation technology exhibits both low capital requirements, and low operating costs. This pilot demonstration supports these assertions.

The capital cost for the GEOCOAT™ process is low due to the inherent simplicity of the process. Biooxidation at close to ambient pressures and temperatures greatly reduces the need for exotic materials of construction. The heap is constructed on a conventional pad lined with HDPE or PVC. A front-end loader and conventional stacking equipment are employed for stacking. The concentrate slurry requires a thickener, holding tank and a pump. During operation of the heap, low pressure blowers provide the necessary air and a pump continuously applies the solution through a series of conventional Wobblers™. All piping is either plastic or rubber. The dismantling of the heap can be carried out with a front-end loader and concentrate recovery is effected by trommeling. Rinsing of the heap *in situ* removes the requirement for a CCD wash circuit. Perhaps a single thickener may be required to achieve the desired CIL feed density.

The operating cost for the GEOCOAT™ process is also low due to the simplicity of the process. Nutrient consumptions of a heap process can be lower than a similar mill process due to the recycle of solutions. The post biooxidation cyanide consumptions achieved are similar to or lower than those found in other biooxidation processes, and there is far more flexibility to further reduce these consumptions by extending biooxidation time at a small incremental cost. An additional incentive to reduce cyanide consumption is the reduction of tailings cyanide destruction costs after leaching. Post biooxidation rinsing of the heap proved to be successful and led to the low lime consumption prior to cyanidation. During biooxidation, heap effluent solutions were recycled to the heap, with a bleed to maintain target ferric iron levels. This arrangement led to low water consumption rates. Often, the unit consumptions of reagents during testing are higher than the consumptions eventually encountered in commercial practice. The low rates seen in this demonstration support the concept that heap biooxidation is a robust processing alternative for refractory ores.

Stacking, operations, and heap dismantling were conducted with casual laborers and equipment operators who required minimal on-the-job training. The ease of operation permitted these low training levels for the workforce. Temperatures, air flow and solution flow rates were monitored. These minimal instrumentation requirements incurred no significant operating expenditures. Solutions were assayed once daily for pH, Eh, iron and arsenic. During heap operations, the only maintenance requirement was to patch a hole that developed in the lined pond. The batch nature of the heap construction and heap dismantling process inherently simplifies maintenance of the conveyors, stackers, trommel, and loaders that would be used in a commercial operation.



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No unexpected capital equipment was required and the contingency for the demonstration capital was not expended. Similarly, no unexpected operating costs were encountered during the field test. More extensive sampling and cyanidation assaying were conducted than originally envisioned, leading to higher outside metallurgical testing costs than initially projected.

POTENTIAL IMPACT AT OBUASI

New approaches to mineral processing of refractory sulfide ores can be simple and inexpensive. The GeoBiotics GEOCOAT™ heap biooxidation process is such an approach to oxidize concentrates (as the coating) or ores (as the support rock). It has low capital and operating costs, and can be implemented rapidly to replace or supplement the existing refractory ore processing technologies. Inherently, this simple process will be easier to construct and operate and consequently be less expensive than alternative processes for sulfide mineral oxidation.

A major feature of the GEOCOAT™ process is that it enables the biooxidation of low-grade materials. Many refractory deposits, including those at Obuasi, contain marginal (below cut-off grade) materials that can not be economically treated in the existing refractory process. The GEOCOAT™ process allows these low-grade materials to be utilized as support rock and thus undergo biooxidation.

Incorporating the GEOCOAT™ process would expand and separate oxidation facilities, thus adding more flexibility to current operations. For example, lower grade preg-robbing concentrates could be oxidized separately, avoiding preg-robbing gold losses in existing oxidation facilities.

As a result of the success of the demonstration, AGC is evaluating the inclusion of the GEOCOAT™ process at the Obuasi operations. The technology is versatile and can be integrated into the process flow sheet in a number of different ways. AGC has entered into a license agreement with GeoBiotics covering use of the process.

A second field demonstration of the technology is currently being constructed. The second test will use a slightly different concentrate and low-grade sulfide ore as the support rock in a similarly sized heap.

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