

THE APPLICATION OF GEOBIOTICS, LLC'S GEOCOAT® TECHNOLOGY TO THE BACTERIAL OXIDATION OF A REFRACTORY ARSENOPYRITE GOLD CONCENTRATE

Tamsin L Williams¹, Michael J. Gunn¹, Ashraf Jaffer¹, Paul I. Harvey¹, Pamela R. Tittes¹

¹GeoBiotics, LLC, 12345 W. Alameda Pkwy., Suite 310, Lakewood, Colorado, USA

ABSTRACT

GeoBiotics, LLC expects to supply its patented GEOCOAT® technology to bio-oxidize a refractory arsenopyrite/gold sulphide ore at a mine in the Northern Territory in Australia. The GEOCOAT® process entails the bacterial oxidation of sulphide concentrates by heap leaching on an engineered re-usable pad, the result being that associated gold is liberated from the refractory concentrate for recovery by cyanidation in a standard CIL circuit.

Results from an extensive metallurgical testwork program demonstrate rapid oxidation kinetics of the concentrate together with excellent gold extraction and modest acid consumption. This paper will discuss the results from the testwork program and the challenges that have been overcome in order to progress to plant design initiatives being developed for a full scale operation that is anticipated to commence in 2009.

INTRODUCTION

The ore deposit is located in the Northern Territory in Australia. The company owning the refractory gold sulphide ore also operates a processing plant approximately 110 km northwest of its refractory gold sulphide ore deposit. A strategic decision has been made to mine the ore and haul this to the current operational site for processing. The ore will then be crushed, milled and a concentrate made by flotation. The concentrate will then be biooxidised using the GEOCOAT® technology with the gold then recovered by conventional cyanidation. The GEOCOAT® operation for treating the refractory concentrate will be a separate project but will be integrated into the existing operating facility.

Within the deposit three main zones of mineralisation have been identified. Gold occurs as both free gold and as refractory gold in pyrite and arsenopyrite. As the gold occurs with both arsenopyrite and pyrite, conventional smelting of the ore is undesirable as this attracts heavy penalties due to the presence of arsenic. It is the refractory component of the ore that has been tested using the GeoBiotics, LLC GEOCOAT® process.

THE GEOCOAT® PROCESS

The GEOCOAT® technology developed by GeoBiotics, LLC facilitates the recovery of gold and base metals from sulfide refractory concentrates by bacterial oxidation of the concentrates in engineered heaps. The GEOCOAT® technology incorporates a process control management system (HotHeap™) designed to optimize biooxidation conditions (temperature, pH, Eh, solution chemistry) through the control of irrigation and aeration rates within the heap design. Additionally, the pregnant leach solution (PLS) bleed rates are carefully controlled. The contact between the bacteria and sulphide concentrate and the leach solution is also optimized in the GEOCOAT® technology design. Creation of optimal biooxidation conditions allows for microbial cultures to establish and proliferate, and, thereby, to maximize oxidation of sulphide minerals. Advantages of the GEOCOAT® technology over other oxidation technologies include: significantly lower capital costs, rapid process deployment, readily available equipment and construction materials, considerably lower power usage, excellent gold and base metal recoveries, safe and relatively easy operation, low workforce sophistication requirements, forgiving technology, allowance for feed grade variability, absence of gaseous emissions and readily treatable and containable waste products.

In the GEOCOAT® process sulphide flotation concentrate slurry is coated on to crushed, sized support rock so that a thin layer coats the surface of the support rock. The coated support rock is then stacked on to heap leach pads. The support rock may be any competent rock crushed and screened to -15mm and +5mm. Prior to coating the support, the concentrate is contacted with acidic ferric solution and microbial culture which helps neutralize any acid consumers present, and ensures even distribution of microbes throughout the heap. The slurry is then thickened and the concentrate coated on to the support rock. Generally the ratio of support rock to concentrate is between 8 or 9 to 1.

Air is supplied to the heap by a low-pressure blower and then distributed through a series of perforated pipes laid down within a 1m thick layer of drainage rock in the base of the heap. The air provides oxygen for the mixed microbial metabolism; carbon dioxide which the bacteria fix as a source of carbon; and, oxygen to the oxidation reactions. An irrigation system laid over the top and sides of the heap comprises a number of headers from which wobbler lines are run. The solution delivers nutrients and acid to the microbes as well as carrying leached metals from the heap. Once the desired levels of metals in solution are reached a bleed is taken from the circulating solution stream and treated either with neutralizing agents or, in the case of base metal concentrate, processed for the contained values.

Careful control of irrigation and aeration rates maintains temperatures within the heap for optimal microbial activity. GEOCOAT® uses best industry practice in the operation of bio-leaching and heap leaching facilities, and added to this is the HotHeap® control and operating philosophy supported by advanced process modeling. HotHeap® is a

biological heap leach operating philosophy coupled with an instrumentation and control system that maximizes heat conservation and thus bioleaching kinetics.

TESTWORK

The biooxidation testwork program for the project comprised three phases of testwork. All of the biooxidation testwork has been conducted at the SGS Lakefield Research Laboratories in Johannesburg (SGS) in the Republic of South Africa. Testing conducted on the refractory arsenopyrite gold concentrate ('M') included batch amenability tests, GEOCOAT® column testwork in a 6m column, kinetic column tests in 2m columns, biooxidation liquor neutralization tests and laboratory scale settling tests on the concentrate and flotation tails, the biooxidised concentrate residue and the biooxidation liquor neutralizations product.

The three phases of testwork conducted by GeoBiotics, LLC were:

1. Initial 6m column using the 'M' concentrate with a local quarry rock ('A') as support, and the associated batch amenability tests (BAT) and kinetic column tests. BAT tests are conducted in 5L heated, agitated aerated reactors containing 3L of OK media and 750g ferric acid pre-leached concentrate, adapted inoculum was added at 10% v/v, pH was maintained at pH 1.4 to 1.6 though daily additions of acid or lime as required, aeration was supplied to each reactor in order to maintain a dissolved oxygen content of 3.5ppm to 4.5ppm and agitation of the reactor was maintained at 460 rpm using a pitch blade turbine.
2. Diagnostic testing conducted to define the problems created from the use of the 'A' support rock.
3. Three 6m columns conducted using a batch of purchased commercial concentrate (CC) to generate results that demonstrated the performance differences for the use of the 'A' support rock, inert support rock and another local inert support rock assigned as 'B' support rock. Ideally support rock is used merely as a substrate onto which the thickened concentrate is coated; it should have very little acid consumption, low levels of soluble metals and be highly competent. The 'A' support rock was sourced from a quarry in a nearby town. This rock was being used as railway ballast. The inert support rock is an acid washed purchased quartz and the 'B' support rock was sourced near the client's current operating plant facility.

Phase 1

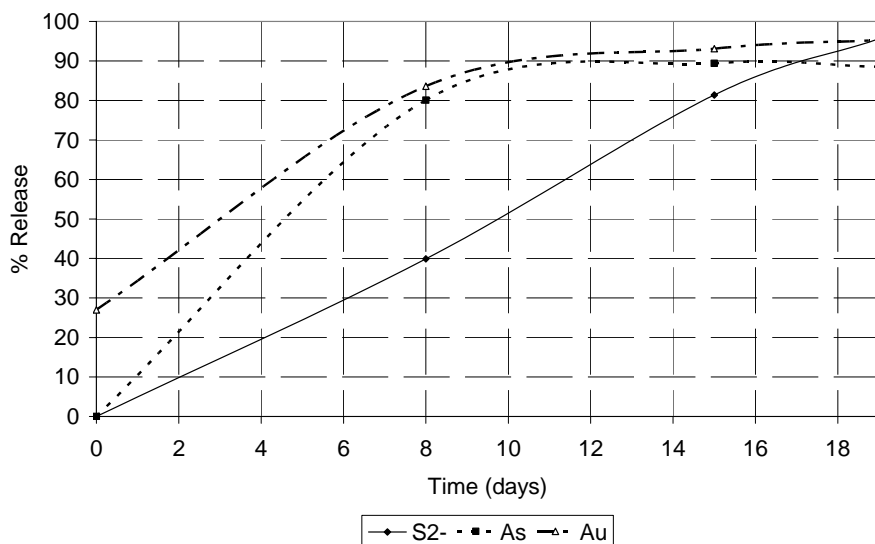
The first phase of testing completed at SGS was a series of testwork programs including coating conditions, BATs, 2m kinetic columns, and finally 6m columns to fully define the acid balance and bio-oxidation performance of GEOCOAT® on the 'M' concentrate. Samples of concentrate were received from the mine as well as support rock ('A') which was sourced from a nearby town's railway ballast quarry. The adaptation and buildup of the bacterial cultures for inoculation of the column tests identified mesophiles as being the bacterial regime of choice for the site.

Prior to the commencement of the GEOCOAT® bioleach columns a series of coating scoping tests were carried out to determine the optimum coating slurry % solids, the optimum coating ratio of support rock to concentrate and the optimum crush size of the support rock. Results indicated that a support rock crush size of -15mm and +5 mm and a slurry density of 65% was optimum. The optimum coating ratio was established to be 9:1.

A baseline gold extraction of 27% was established by conducting direct cyanidation on the 'M' concentrate 'as received'. The sulphide concentrate was prepared by pre-leaching, with a ~20 g/l ferric acid solution (pH 1.6) for 4 hours at a liquid to solids ratio of 4:1 simulating the use of the PLS solution bleed in a commercial GEOCOAT® operation. This removes any soluble toxic base metals and flotation reagents from the surface of the concentrate which could be detrimental to the microbial cultures, and to partly dissolve acid consumers. Table 1 shows the assays results for the 'M' concentrate before and after ferric acid washing.

Table 1: Pre-Biooxidation Chemical Analyses of the 'M' Concentrate Sample			
Analysis	Unit	Before Ferric Acid Pre-leach	After Ferric Acid Pre-Leach
Au	g/t	41.5	40.5
Fe(T)	%	22.3	20.4
S(T)	%	21.3	23.1
S ²⁻	%	19.9	19.7
S ⁰	%	<0.5	<0.5
SO ₄ ²⁻	%	<0.4	5.3
CO ₃ ²⁻	%	6.1	1.1
Si	%	11.2	10.1
As	%	4.1	3.9

Batch amenability tests were run using a mesophilic culture operating at 40°C ± 1°C. The mesophilic culture adapted rapidly to the ferric acid leached concentrate with a negligible lag period for commencement of bacterial



growth and subsequent sulphide oxidation. Amenable testing ran for a period of nineteen (19) days with solid samples removed from the test on days 8, 15 and 19. The levels of sulphide oxidation, arsenic release and gold liberation at each of these points has been included as Figure 1.

Figure 1: A curve illustrating the gold liberation, sulphide oxidation and arsenic release at various points during the batch amenability mesophile test.

The maximum sulphide oxidation achieved during the batch biooxidation amenability tests of the ferric acid leached concentrate was 95.6% (after 19 days). The corresponding gold dissolution was 95.3% of the gold. It was found that the ferric acid leached concentrate was net acid generating (138.7kg/t) during the batch tests. A summary of these results is displayed in Table 2.

Test	Duration (days)	Acid consumption (kg/t conc.)	% Liberation			Fe:As ratio
			Sulphide	Arsenic	Gold	
Mesophile BAT	19	-(138.7)	95.6	88.5	95.3	6.5

The Fe:As molar ratios of the biooxidation product solutions were above 3:1, the generally recommended minimum acceptance for successful TCLP testing. This ratio implies that a stable arsenic precipitate would be formed during the neutralisation process for disposal to a tailings dam.

The GEOCOAT® biooxidation heap leach process is simulated in the laboratory by conducting biooxidation column testwork in a 2m high by 150mm diameter column for kinetic definition, and 6m high by 150 mm diameter columns for design data. All of the columns are equipped with heaters capable of maintaining the desired temperature, internal temperature measurement sensors, sample ports for intermediate solid and solution sampling (6 meter columns only), and a bottom air addition point.

A peristaltic pump delivers the leach solution to the top of the column at a controlled rate. Solution application is via a rotating arm feeder system and the effluent is collected at the base of the column in a separate container. The airflow is controlled at the required rate with rotameters.

The 2m kinetic columns were operated at 25°C, 35°C and 40°C each for a period of 92 days, simulating the temperature regimes that the commercial heap will need to move through. The columns were irrigated at a rate ranging from 10 – 30 l/m²/h and aerated at a rate of 0.2L/min. The on solution was adjusted to a pH of 1.2 through the addition of concentrated sulphuric acid. A summary of the final results from the 2m kinetic column tests is included as Table 3.

Sample	Temperature (°C)	Duration (days)	Sulphide sulphur oxidation (%)	Gold liberation (%)	Acid Consumption (kg/t column)
--------	------------------	-----------------	--------------------------------	---------------------	--------------------------------

					charge)
Ferric/acid leached concentrate	25	92	25.7	65.5	31.5
	35	92	78.5	87.0	21.3
	40	92	83.9	89.7	20.8

The 2m kinetic columns indicated that at 40°C, a maximum of approximately 84% sulphide oxidation and 89% gold recovery after 92 days was achievable. All three kinetic columns had a net acid consumption compared to the batch amenability test which had a net acid generation. This result was disappointing. The support rock was the logical problem but had been tested for acid consumption and found to be acceptable.

A 6m GEOCOAT® biooxidation column was conducted in much the same way as the 2m columns except the aeration rate was 0.4L/min. and the operating temperature of the column was set at 38°C-40°C. Operation of the 6m column took place over a period of 93 days and solids and solution samples were removed from the column on days 29, 60, 81 and finally on day 93. Three sample ports are located at 2m, 4m and 6m below the top of the 6m column and samples removed from these ports are referred to as top, middle and bottom respectively. Table 4 displays a summary of some of the results.

Column	Sample	Duration (Days)	Oxidation (%)			Gold liberation (%)	Acid Consumption (kg/t Column Charge)
			Sulphide	Iron	Arsenic		
Ferric acid leached concentrate	Top	29	44.4	35.7	69.4	83.3	5.4
	Middle	29	48.3	36.2	70.6	85.4	
	Bottom	29	29.8	31.6	57.3	77.4	
	Top	60	77.4	40.4	80.0	89.9	8.6
	Middle	60	73.2	39.8	77.4	85.7	
	Bottom	60	75.0	12.4	55.1	82.6	
	Top	81	81.6	25.8	78.6	89.9	12.4
	Middle	81	85.3	3.5	65.6	85.6	
	Bottom	81	83.5	0.0	44.3	83.1	
	Top	93	72.5	36.5	70.0	86.9	13.8
	Middle	93	73.3	23.9	54.7	86.9	
	Bottom	93	62.8	13.5	38.9	80.1	

The 6m column tests indicated 85% oxidation is possible and an average of 85% gold liberation and recovery could be achieved after 81 days in the middle of the column. Extending the tests duration to 93 days did not significantly improve gold liberation and strangely indicated a lower overall sulphide oxidation of 73%. Iron and arsenic dissolutions fluctuated during the test. In contrast to the BAT tests again, the 6m column tests indicated a net acid consumption (13.8kg/t) after 93 days. An additional 6m acid consumption column was run on the local 'A' support rock alone; this ran for a period of 96 days and indicated an acid demand of 39.7 kg H₂SO₄/t support rock.

The apparent discrepancy in results pointed to the local 'A' support rock. Additional testing was carried out using a waste rock support, 'B' support rock, that was rigorously tested for acid consumption, and an inert quartzite support rock.

Phase 2

The second phase of testwork involved diagnostic tests to define the problems created from the use of the 'A' support rock. Due to the lack of any available 'M' concentrate material, the tests for the second phase were conducted on a purchased batch of commercial concentrate (CC) with similar metallurgical and geological properties to the 'M' concentrate.

The aim of the second phase of testing, conducted in January 2007, was to determine the effect of any precipitation on the sulphide oxidation kinetics during column leaching. The program consisted of conducting 'ferric generator' columns on both the 'A' support rock and Inert Support (IS) rock to determine the extent of iron precipitation in each, and stirred reactor tests [BAT] using 'A' and IS support rocks with commercial stock concentrate to measure the dissolution of iron from the concentrate and trace elements from the support rock. Finally cyanidation tests were conducted on the residues from the BAT tests to determine gold liberation.

Ferric generator column tests were conducted using the 'A' and inert support rock in two separate columns. The support rock was crushed to -15mm and +5mm in size and the columns were operated at a temperature of 40 °C. Ferrous solution was circulated through the column and the mesophilic bacteria present within the columns converts the ferrous to ferric. The rate at which ferrous is converted to ferric can be used to indicate whether the support rock has any inhibitory effect on the bacterial culture. The Eh is a good indicator of the ratio of ferric to ferrous. Figure 2 illustrates a curve of the Eh measurements from the two ferric generator columns, one containing the inert support and the other the 'A' support. The reference electrode used to measure the Eh was a Ag/AgCl electrode.

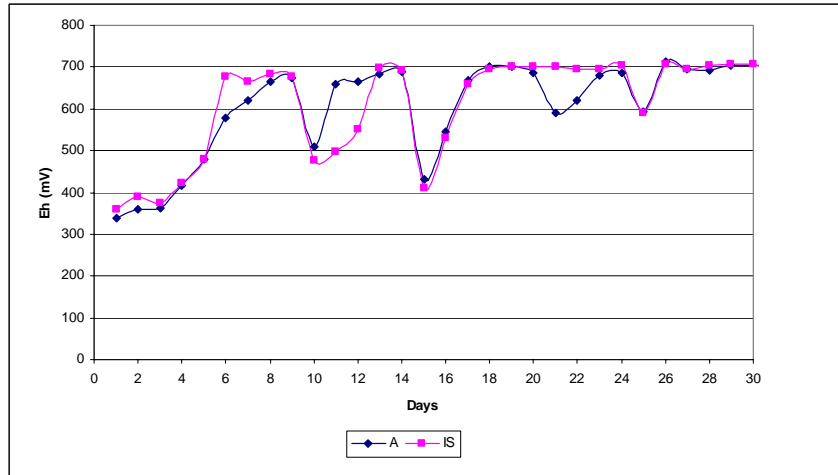


Figure 2: The curves generated from measuring the Eh in the two ferric generator columns.

Examination of the curves show that both columns reached high levels and both were able to recover to the same high levels shortly after ferrous sulphate was added, on day 14. This result suggests that the 'A' support rock chemistry is neither inhibitory nor toxic to the bacteria, and will thus not affect oxidation rates.

The amount of iron that precipitated out of the irrigation solution for each of the columns was also monitored and is included as Figure 3. This curve shows that iron is precipitated out of solution in the form of jarosite and however the amount of iron precipitated from the 'A' column is approximately twice that of the inert support rock column.

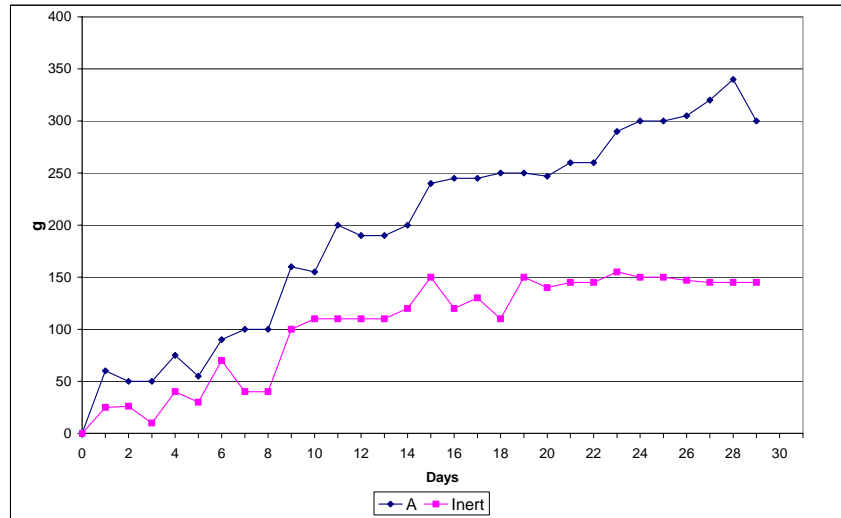


Figure 3: The curves generated from iron precipitation within the ferric generator columns during measuring Eh measurement in the two ferric generator columns.

The results indicate that the amount of iron precipitated may have a negative effect on the oxidation rates due to solution contact with the sulphide mineral surface being reduced by jarosite precipitates.

A set of five BAT tests were run each containing the adapted culture with combinations of commercial stock concentrate-'A' support rock ('A'/CC) and commercial stock concentrate-inert support rock (IS/CC). Two coating

ratios were tested, these were 1:1 and 9:1 for each combination of concentrate and support rock, respectively. Successive solution analyses were taken every five days and measured for Fe and trace elements such as Al, Na, Si and Ca. Figure 4 (1:1 tests) and Figure 5 (9:1 tests) show the curves generated from measuring total iron concentration during the BAT tests.

During the course of the 1:1 BAT the total iron concentration steadily increased but decreased during the course of 9:1 BAT tests. The decreasing trend is due to the higher concentration of 'A' support rock used. Over the operation period for both BAT test measurements of Si decreased steadily over the first 15 days with a small increase of levels reporting to solution from days 15 to 20. In addition, measurements of Al, Ca and Fe indicated that these elements dissolved over the first five days followed by a significant decrease in the measured concentrations from day 5 to day 15. These trends are consistent with the formation of an iron precipitate. Re-dissolution of these elements from the precipitate occurs during the final five days of the BAT tests.

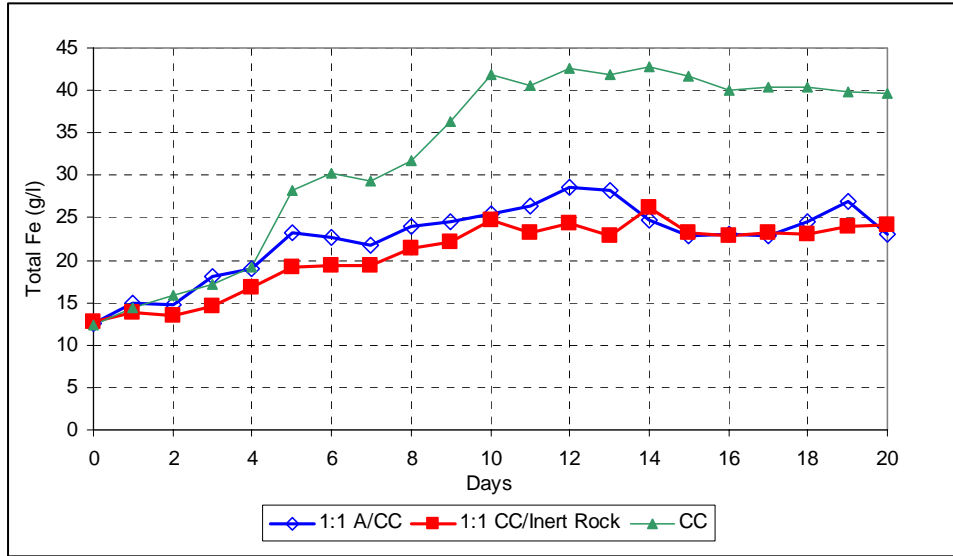


Figure 4: Total Fe trend during the 1:1 BAT tests

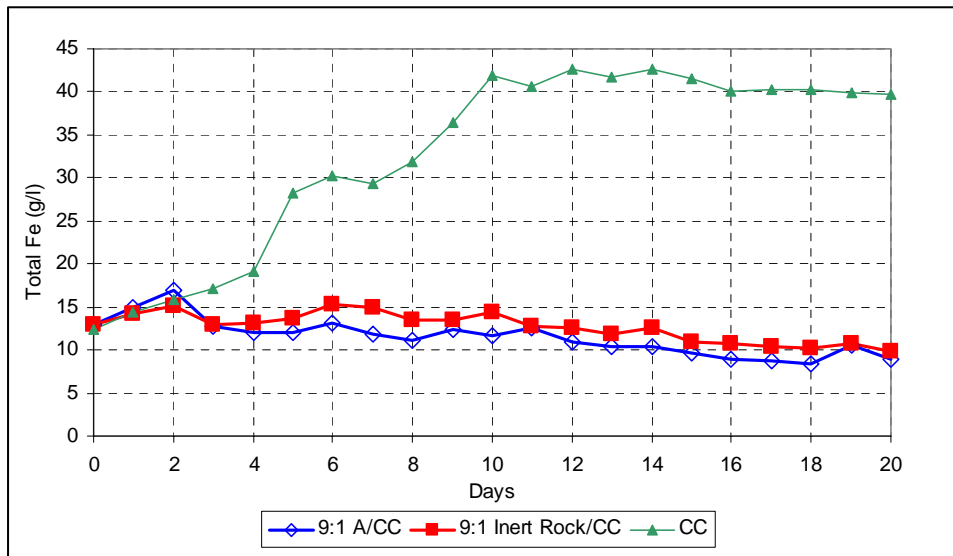


Figure 5: Total Fe trend during the 9:1 BAT tests

Upon completion of the BAT tests the resultant solids residue was submitted for gold recovery via cyanidation the results of which are displayed in Table 5.

BAT Test	FC	'A'/CC 1:1	Inert /CC 1:1	'A'/CC 9:1	Inert /CC 9:1
Au recovery (%)	96.1	94.1	94.8	88.4	92.6

Gold recoveries from the 1:1 'A' and 1:1 Inert BAT tests are very similar. When ratios of support rock to concentrate similar to those seen in a commercial operation are tested then the gold recovery from the tests using the 9:1 'A' support rock compares poorly with the Inert Support rock as gold recoveries in the former are approximately 4% lower. This result provides further evidence of sulphide oxidation being inhibited by the formation of the iron precipitate when using the 'A' support rock. The nature of this precipitate is still uncertain, although mineralogical analysis indicated jarosite formation. The data from all of the tests suggests that the formation of the iron precipitate when using 'A' support rock limits the sulphide oxidation.

Phase 3

The aim of the third phase of testing was to compare the performance of the two supplied support rocks ('A' and 'B') with the inert support rock in a simulated GEOCOAT® heap leach environment. These tests were conducted at the SGS Lakefield Research facility in Johannesburg by SGS Lakefield Africa in the period between April – November 2007.

Three 6m GEOCOAT® columns were operated for a 90 day cycle using 'A' support rock, inert support rock and the 'B' support rock. The most important outcomes from this phase of testwork were the comparisons between the three columns with respect to acid consumption, achievable sulphide oxidation and subsequent gold recovery.

Commercial stock concentrate was used again for this test program. Table 6 shows assay results from the commercial stock concentrate both before and after ferric acid pre-leaching and compares these to the assay results for various elements in the pre-leaching of 'M' concentrate from the first phase of testing (Table 1). The results displayed in the table show similar levels of Fe, As and sulphide in the two concentrate subsequent to ferric acid leaching.

Analysis	Unit	Before Ferric Acid Pre-leach (Commercial stock)	After Ferric Acid Pre-Leach (Commercial stock)	After Ferric Acid Pre-Leach ('M')
Au	g/t	128.0	106.6	40.5
Fe(T)	%	15.5	19.0	20.4
S(T)	%	15.3	17.9	23.1
S ²⁻	%	14.7	15.0	19.7
S ⁰	%	<0.5	<0.5	<0.5
SO ₄ ²⁻	%	-	2.6	-
CO ₃ ²⁻	%	4.1	2.1	1.1
Si	%	14.0	17.7	10.1
As	%	5.1	4.0	3.9

Once the ferric leached residue had been thickened the commercial stock concentrate was coated onto Inert support rock, the original 'A' support rock and 'B' support rock. The separate coated support rocks were loaded into three separate 6m columns. All columns operated in the mesophile temperature range at approximately 40°C.

Table 7 shows a selection of assays on the three support rocks and indicates that both the Inert and 'B' support rocks have very similar levels of Fe, Ca and Mg and that these are all significantly lower than the levels of these elements found in the 'A' support rock. Mineralogy was conducted on a cross section of samples from the 'A' support rock. Results from the mineralogical investigation revealed that the samples were very similar and were comprised mainly of quartz, K-feldspar and plagioclase with calcite. The conclusion from the mineralogical investigation was that the presence of significant amounts of calcite, up to 10% based on microscopic examination, in the support rocks was problematic. The calcite continually reacts with the acid and results in unstable pH within the column/heap leading to the precipitation of jarosite. The final conclusion being that the 'A' support rock was not a suitable candidate for the GEOCOAT® process.

Analysis	Unit	Inert Support Rock	'A' Support Rock	'B' Support Rock
Fe(T)	%	3.9	8.3	4.9
S(T)	%	0.3	0.15	0.2
CO ₃ ²⁻	%	-	0.01	<0.01
Al	%	5.1	7.8	8.3
Si	%	36.5	24.1	31.6
Na	%	0.1	3.5	-
Ca	%	0.5	4.6	0.3
Mg	%	1.3	3.8	1.1
As	ppm	98	95	216

The purpose of the Inert support rock test was to provide “reference” data trends as the best case performance scenario for the GEOCOAT® column test. The inert support rock used is known to exhibit very low acid consumptions and is stable in the system. Figure 6 shows the daily rate of Fe and As reporting to solution over the period of the 90 day tests for each of the three columns. The highest rates of leaching can be seen in the inert column but the rates of leaching in the ‘B’ columns are also very good. The poorest leaching rates are observed within the column containing the ‘A’ support rock.

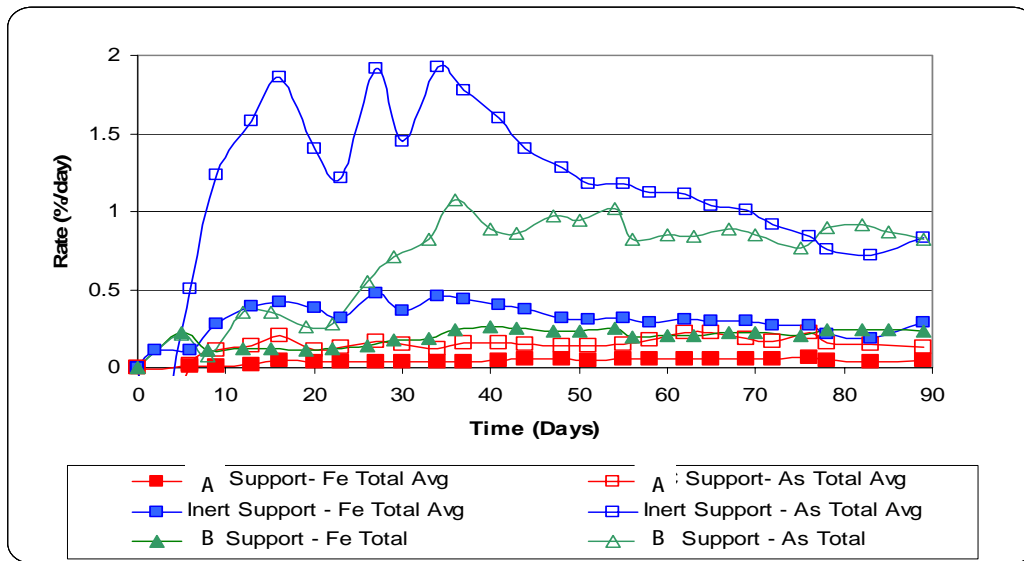


Figure 6: Leaching rates over 90 days in the three 6m columns containing the ‘A’, ‘B’ and Inert support rock.

The leach rates of a particular concentrate coated onto a particular support rock is entirely dependent on the conditions in the column such as temperature, pH, irrigation rates and the subsequent bacterial activity. Since all of these parameters were the same for all of the tests the only variable between the columns was the support rock.

The arsenic and iron leach rates can be used to infer the rate of bio-oxidation of the arsenopyrite and pyrite respectively in the concentrate coated onto the various support rocks. Arsenic leach rates are generally higher than iron leach rates because under ideal conditions, the arsenopyrite leaches faster than pyrite. The As and Fe leach rates in conjunction with the sulphide oxidation profile of each of the columns provides a more accurate assessment of the columns’ performance.

Solid samples were removed from the top, middle and bottom of each of the 6m columns on days 21, 33, 61 and finally on day 90. The sulphide oxidation is calculated from a mass balance using gold as a reference point from each of the sample measurements. Figure 7 represents the average throughout the length of the column at the given time during the test. The results show that the column containing the Inert support rock had faster sulphide oxidation kinetics at the beginning of the test. As the leach progressed, the rate of sulphide oxidation in the column containing the ‘B’ support rock increased to provide the highest sulphide oxidation level. The sulphide oxidation levels within the

column containing the 'A' support rock are consistently lower than either of the other two columns throughout the duration of the test period.

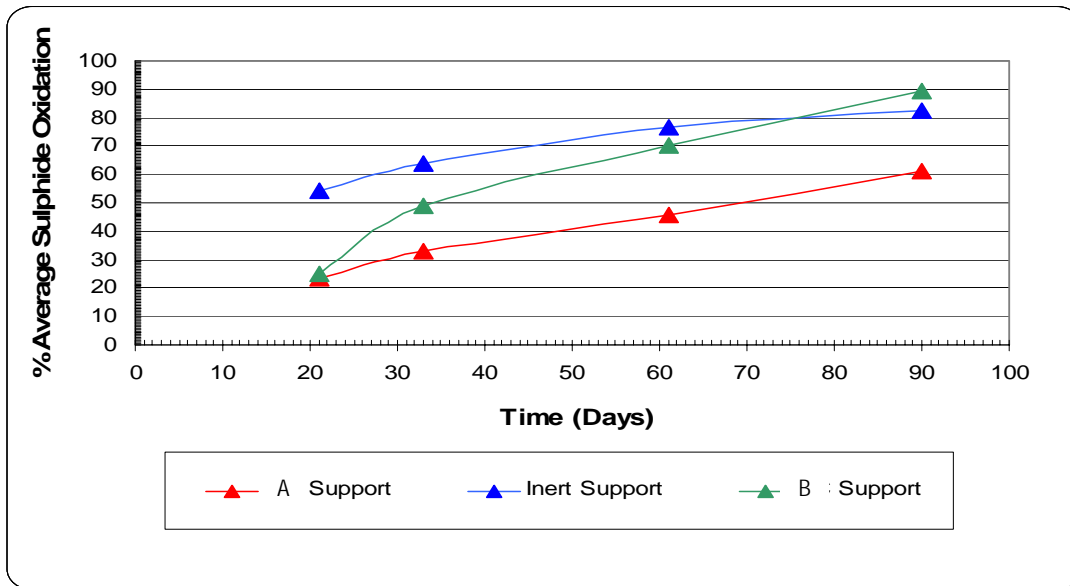


Figure 7: GEOCOAT® Column Average Sulphide Oxidation

After 90 days all three columns were dismantled, rinsed and unloaded. The residue was then removed from the support rock and submitted for assay and gold recovery by cyanidation. A sample of the commercial stock concentrate 'as received' was tested for baseline gold extraction by cyanidation in 48 hour agitated leaching tests, this extraction was measured to be 61% compared with the baseline of 28% for 'M' concentrate. A summary of the mass balances for the three GEOCOAT® columns is displayed in Table 8.

Column Tests	Oxidation (%) based on Con only			Gold liberation (%)	Acid Consumption (kg/t con)
	Sulphide	Iron	Arsenic		
Inert Support Rock	82	80	95	96	17
'A' Support Rock	61	34	35	90	427
'B' Support Rock	90	73	83	97	97

The overall results from the third phase of tests indicated that the 'A' support rock column did not perform well compared to the results obtained from the columns containing the inert support and 'B' support rocks. The acid consumption of the 'A' support rock was measured in excess of 400kg/t in comparison to the 'B' material which was approximately 100kg/t at the end of the 90 day leach cycle.

A sulphide oxidation level of approximately 90% was achieved from the 'B' support rock after 90 days compared to only 60% achieved from the 'A' support rock column and approximately 82% from the Inert Support rock column test.

Prior to coating all the support rocks were crushed and sized to -15mm and +5mm. The results from support screening tests after 6m column bio-oxidation indicate that for the 'B' support rock, although there is breakage of support rock during the process, very little of the support rock reports to the -5mm fines fraction. The 'A' support rock exhibited significant breakage during leaching and approximately 1% of the support rock reported to the -5mm fines fraction.

CONCLUSIONS FROM LABORATORY TESTING

The testwork program ultimately demonstrated the applicability of the GEOCOAT® process for the biooxidation of the concentrate and has provided the critical design parameters for the engineering of the plant and estimation of reagent requirements and operating costs.

The quality of support rock and its long term response to ferric acid exposure was shown to be a critical factor in the performance of the GEOCOAT® process. The methods of selection have been revised to include mineralogical and chemical analysis, and longer term acid leach tests.

BIBLIOGRAPHY

Broadhurst, J L. March 1993. The Nature and Stability of Arsenic Residues from the BIOX® Process. Biomine 1993 Conference Proceedings, Adelaide, pp 13.1-10.

Broadhurst, J L. April 1990. Recommended Standard Toxicity Characteristic Leaching Procedure for Arsenic-Containing Waste Samples. GENCOR Process Research, Report No PR 90/49F: pp 29.

Holder, N H M and T. Stanek. 25 September 2006. GEOCOAT® Test Program on 'M' Concentrate. SGS Lakefield Johannesburg. Report No Biomet 06/15.

Jaffer, A. December 2007. Close Out Report for GEOCOAT® Test Columns (Third Phase). GeoBiotics, LLC Denver. Report for 'Client'.

Richards, J. M. and G. J. Martin. 8 January 2006. Identification of Mineral Assemblages in a Support Rock used in a Geobiotics Process. SGS Lakefield Johannesburg. Mineralogical Report No:MIN1106/117.

Stanek, T, and M Mothobi. 19 November 2007. 'Client' Support Rock Testwork. SGS Lakefield Johannesburg. Report No Biomet 07/05.