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COMPANY: Beatons Creek Gold Pty Ltd  
ATTENTION: Chris Goti  
FROM: Graeme Campbell  
SUBJECT: Beatons Creek Gold Project: Weathering Dynamics and Solubility Behaviour of **Fresh-Zone-Conglomerate-waste** Samples (Kinetic-Testing Programme) for the **Fresh-Rock Project** – Provision of 'Source-Term' Information for Geochemical Modelling & Implications for Mine-Waste Management

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Chris,

The key findings of the kinetic-testing programme conducted on the Fresh-Zone-Conglomerate-waste (**FZ-Conglomerate-waste**) samples are presented and discussed in this report.

Testwork results are presented in **Tables 1-6**, and shown on **Figures 1-7**.

This study on the geochemical nature of the Fresh-Waste-Zone builds on the GCA (2020) investigation on the geochemistry of the Oxide-Waste-Zone for the Beatons Creek Gold Project.

Singly, the key deliverable from the kinetic-testing programme is provision of leachate-chemistry information for 'contact-water' quality modelling as undertaken by SRK Consulting for the Project.

In addition to leachate-assays generated by short (100 mm high) laboratory weathering-columns, as per the methodology described in the AMIRA (2002) document, the dataset presented herein usefully includes assays for "breakthrough-leachates" generated by slow, incremental leaching of the same short columns following extended, multi-month weathering. This "breakthrough-leachate" approach in kinetic-testing of mine-wastes

and process-tailings has been used in both GCA's client-project work, and in-house research on weathering dynamics, since the late-2000s.

Related approaches to the kinetic-testing of hyper-reactive, strongly-acid-forming pyritic mine-wastes (black-shales) derived from historic iron-ore mines in the Pilbara were reported by Pearce *et al.* (2017), and Salmon *et al.* (2018), employing technically elaborate apparatus, including long (1 m) columns, with computer-controlled, automated, continuous monitoring of electronic sensors for various physicochemical parameters. The alternative approach adopted herein is simply to vary the operating procedures for the short AMIRA (2002) columns, and thus maximise the information provided on weathering dynamics and solubility behaviour of the tested FZ-Conglomerate-waste samples. This approach was supplemented by the parallel determination of Oxygen-Consumption Rates (OCRs) and Carbon-Dioxide-Release Rates (CDRRs).

## 1.0 KINETIC-TESTWORK PROGRAMME

### 1.1 Background Information

The kinetic-testwork programme for the Project was initiated by Golder Associates (West Perth) during 2019 with the testing conducted by GLS Intertek (Maddington) until early-2020. After this time, the weathering-columns, with moist, weathered-solids intact, were forwarded to the GCA Testing Laboratory (Bridgetown).

#### 1.1.1 Samples

The following FZ-Conglomerate-waste samples, as 'coarse-crushings' (-10 mm nominal) derived from DD-core, have been subjected to kinetic-testing:

- X00726, Grants Hill Pit, BCDD18-002, 62.00-63.00 m, **0.85%S**
- X01906, Grants Hill Pit, BCDD18-008, 40.64-41.15 m, **3.62%S**
- X04351, Edwards Domain, BCDD18-024, 32.00-33.00 m, **1.64%S**

The above samples were selected by Golder in September 2019, and span the typical range in %S of *ca.* 1-3 % (at the 'metre-scale') for the FZ-Conglomerate-waste across all mining domains for the Project.

Since several kilograms of each of the above FZ-Conglomerate-waste samples were prepared, and since only a few kilograms were employed in the initial kinetic-testing programme coordinated by Golder, excess 'coarse-crushings' were usefully available for follow-up testing by GCA, as described below.

#### 1.1.2 Acid-Formation Potential, Lithochemistry, and Mineralogy

The static-testing programme (i.e. 'whole-rock' assays and tests) indicates that the FZ-Conglomerate-waste samples:

- classify as **Potentially-Acid Forming (PAF)**, reflective of 'accessory-pyrite' (corresponding to 0.85-3.62%S) within a 'gutless-groundmass' (i.e. devoid of carbonates) in terms of circum-neutral (pH 6-8) buffering (**Table 1**)
- are moderately enriched both in the chalcophyle suite As, Sb, and Se, and in Bi (**Table 2**)

- comprise chiefly quartz and muscovites / illites with sub-ordinate pyrite and Fe-chlorites, and traces of Ti-oxides (**Table 3**).<sup>1</sup>

Importantly, for the multi-%S samples X04351 and X01906, the pyrite is generally 'coarse-grained' (500-1,000  $\mu\text{m}$ ).

The element enrichments within the FZ-Conglomerate-waste samples are similar to that observed for the oxide-waste-zone samples tested in the GCA (2020) study, and likewise fall within the range typically recorded for mine-waste samples derived from hard-rock mines located on the Pilbara and Yilgarn blocks (Campbell, unpublished results since the late-1980s).

In brief, the FZ-Conglomerate-waste samples are essentially identical geochemically, save for varying pyrite abundance.

### 1.1.3 Intrinsic Pyrite Reactivity

The intrinsic pyrite reactivity in the FZ-Conglomerate-waste samples was determined via the direct measurement of the OCR at 30 °C (**OCR<sub>30oC</sub>**) for:

- 'air-dry-solids' (i.e. 'rock-fines' at residual-moisture/suction)
- moist-solids at gravimetric-water contents (GWCs) around 4-5 % (w/w) approximating a moisture status somewhat below 'field-capacity' (= Upper-Drainable Limit, UDL).<sup>2</sup>

In terms of site operations, the above range in moisture status relates to seasonal variations attendant with 'Dry-Spells' of extended (multi-month) duration interrupted infrequently by episodic 'Wet-Spells' that are short-lived (days).

The resulting OCR<sub>30oC</sub> values are presented in **Table 4**, together with the corresponding calculated Acid-Generation Rates at 30 °C (AGR<sub>30oC</sub>), based on the reaction stoichiometry for the complete oxidation of pyrite to H<sub>2</sub>SO<sub>4</sub> and "Fe(OH)<sub>3</sub>".

#### **Pyrite Reactivity in Moist 'Rock-Fines'**

Singly, the most important outcome of the OCR<sub>30oC</sub> determinations is that the 'accessory-pyrite' in the FZ-Conglomerate-waste samples exhibits a **moderate intrinsic reactivity**.

This assessment reflects experience by the author with OCR determinations over the past 10+ years for numerous samples of mine-wastes and process-tailings derived from WA gold-mines also characterised by an 'accessory-pyrite' abundance. Such moderate intrinsic reactivity, indicated by direct measurement of O<sub>2</sub>-consumption rate, is consistent with the 'coarse-grading' of the pyrite in the multi-%S samples X01906 and X04351 as determined in the mineralogical study (**Table 3**).

Though the OCR<sub>30oC</sub> values presented in **Table 4** correspond to moist 'rock-fines' aged for just days prior to testing, similar OCR<sub>30oC</sub> values were also recorded (see below) for the weathered-solids at different times during the kinetic-testing programme, corresponding to strongly-acidic (pH 2-3) conditions resulting from weathering.

<sup>1</sup> The predominance of quartz reflects the abundance of quartzose clasts in the FZ-Conglomerate unit.

<sup>2</sup> The OCR determinations were performed using the -4.75 mm fraction obtained via dry-sieving of the original 'coarse-crushings' from DD-core.

In terms of 'length-scales' associated with O<sub>2</sub>-diffusion control and pyrite oxidation, calculations based on the AGR<sub>30oC</sub> values of 360-560 mg H<sub>2</sub>SO<sub>4</sub>/kg/week indicate that, under steady-state conditions, the reach of the O<sub>2</sub>-diffusion-front would be around 1.5-2.0 m (i.e. starting with an atmospheric O<sub>2</sub> concentration of 20.9 % (v/v), O<sub>2</sub> would be fully consumed at a depth of *ca.* 1.5-2.0 m into a profile of moist 'rock-fines' of the FZ-Conglomerate-waste). This indicative 'O<sub>2</sub>-diffusion length' of 1.5-2.0 m is thus much longer than the 0.08 m heights of the beds of mine-waste-solids in the short (100 mm) laboratory columns employed in the kinetic-testing herein.

Importantly, the intrinsic pyrite reactivity for the FZ-Conglomerate-waste samples is such that forced airflow is **not** required during laboratory kinetic-testing programmes.<sup>3</sup>

### Pyrite Reactivity in Dry 'Rock-Fines'

Predictably, the OCR<sub>30oC</sub> values for the 'rock-fines' at 'residual-moistures/suctions' were almost 100-fold lower than those for the moist-solids (**Table 4**), and reflects the limiting availability of water for pyrite oxidation (Alarcón León *et al.* 2004; Campbell 2008).

## 2.0 STAGE-1 TESTING: MODIFIED AMIRA (2002) PROTOCOL

### 2.1 General

The Stage-1 testing programme initiated and coordinated by Golder corresponds to the "Kinetic Leach Column" procedure, as described in the AMIRA (2002) document, save for the absence of flood-lamps (100 W) for dewatering of the mine-waste-solids during weathering. Instead, the weathering-columns were left to dewater at the ambient-temperature of the laboratory of *ca.* 20 °C.

Commencing in September 2019, weathering was conducted for 20 weeks, and included a pre-rinse cycle at "week-0" to deplete pre-existing solutes in the 'coarse-crushings' (-10 mm nominal) tested.

Following receipt of the weathering-columns with weathered-solids intact at GCA in early-2020, it was evident that "soil-pans" had developed in the lower sections of the columns. The "soil-pans" were visibly wet ('glistening'), and cemented, though readily broken-up using a steel screwdriver. Such "soil-pans" reflect illuviation of clay-sized, silt-sized, and sand-sized particles during flushing under ponded conditions using deionised-water.

Accordingly, though difficult to quantify fully, the pyrite reactivity, and solute-generation rates, estimated from the Stage-1 kinetic-testing programme are likely biased "on-the-low-side", especially as the testing progressed through time, due to a near-saturated state of the "soil-pan" where finer-grained pyrite is likely to reside (from illuviation).

### 2.2 Key Outcomes

The leachate-assay results for the Stage-1 kinetic-testing, are presented in **Table 5**, and the time-trends for leachate-pH values, and Sulphate-Elution Rates (SERs), are shown on **Figure 1** and **Figure 2**, respectively.

<sup>3</sup> In the investigations reported by Pearce *et al.* (2017) and Salmon *et al.* (2018) for the hyper-reactive black shales from historic iron-ore mining in the Pilbara, forced aeration was mandatory to ensure O<sub>2</sub>-supply was non-limiting for pyrite oxidation, due to both the extreme AGRs of 10,000+ mg H<sub>2</sub>SO<sub>4</sub>/kg/week, and the use of columns 1 m in length.

### 2.2.1 Leachate-pH

The steady decrease in leachate-pH with progressive weathering (**Figure 1**) reflects the limited capacity for circum-neutral buffering by the FZ-Conglomerate-waste groundmass which is evident from the groundmass mineralogy (**Table 3**). Calculations indicate that, for samples X04351 (1.64%S) and X01906 (3.62%S), leachate-pH values had decreased to 4 after the generation of *ca.* 0.4 kg H<sub>2</sub>SO<sub>4</sub>/tonne which is appreciably less than the Bulk-ANC values of 5-7 kg H<sub>2</sub>SO<sub>4</sub>/tonne for these samples, as determined by the AMIRA (2002) methodology (**Table 1**).<sup>4</sup> Estimated consumption of acid before the leachate-pH values fell to 4 is, however, close to the Bulk-ANC values up to 1 kg H<sub>2</sub>SO<sub>4</sub>/tonne, corresponding to GCA's modified AMIRA (2002) method which constrains acid consumption by aluminosilicates.

In the case of sample X00726 (0.85%S), the leachate-pH had decreased to 4.8 by week-20 (**Table 5**) associated with an estimated acid consumption of *ca.* 0.2 kg H<sub>2</sub>SO<sub>4</sub>/tonne by this stage of weathering.

### 2.2.2 Sulphate-Elution Rate (SER)

The SER<sub>200C</sub> values recorded during the 20-week testing period were typically within the range 10-30 mg SO<sub>4</sub>/kg/week (**Figure 2**), though a temporal increase occurred at week-9 when flushing was inadvertently performed out of sequence, and for sample X1906 (3.62%S) by week-20 when the SER<sub>200C</sub> value jumped to 160 mg SO<sub>4</sub>/kg/week when the leachate-pH dropped below 3 (**Figure 1**).

Based on the cumulative loading of SO<sub>4</sub> eluted from the columns, calculations indicate that the following acid-generation loadings had been generated by week-20:

- X00726 (0.85%S)                      0.2 kg H<sub>2</sub>SO<sub>4</sub>/tonne
- X04351 (1.64%S)                      0.5 kg H<sub>2</sub>SO<sub>4</sub>/tonne
- X01906 (3.62%S)                      1.2 kg H<sub>2</sub>SO<sub>4</sub>/tonne

Though SO<sub>4</sub> derived from pyrite oxidation will be retained in insoluble phases within the weathering-columns, the above acid-generation loadings correspond to around 1 % of the total acid-loading that would be generated from the complete oxidation of all pyrite in the columns.

### 2.2.3 Minor-Element Solubility

Predictably, the solubility of minor-elements generally increased with progressive weathering reflective with the trend of decreasing leachate-pH (**Table 5**).

Rates of minor-element release, as for SO<sub>4</sub> release, are suspected to be biased "on-the-low-side", due to "soil-pan" development.

<sup>4</sup> ANC = Acid-Neutralisation Capacity.

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### 3.0 STAGE-2 TESTING: "BREAKTHROUGH-LEACHATE" COLLECTION FOLLOWING EXTENDED WEATHERING

#### 3.1 General

##### 3.1.1 Resurrection of Weathering-Columns from Stage-1 Testing

Following receipt by GCA of the weathering-columns with the moist weathered-solids intact, the weathering-columns were stored in a CT-room at *ca.* 20 °C for around 2-3 months. During this time the weathering-columns were contained within plastic-bags that were not airtight, so that the weathered-solids in each column gradually dried-out to air-dryness.

In early-December 2020, the air-dry weathered-solids in the weathering-columns were lightly moistened with deionised-water, and then removed from the columns to reconstitute the mixture of "soil-fines" and "grits/gravels" originally packed into the columns.<sup>5</sup> The "soil-pans" were broken-up and the whole mass of weathered-solids homogenised via 'hand-mixing'. The weathering-columns were then repacked (with new Whatman-No.-2 filter-papers at the base of the columns), and moistened to a GWC value around 4-5 % (w/w).

The resulting '*resurrected-columns*' were then stored in an incubator at 30 °C, and were covered with a large clockglass to restrict evaporative water loss. The columns remained in the incubator for around 1-2 weeks, and through weighing every few days, small amounts (typically 20 gms) of deionised-water were misted onto the weathered-solids to compensate for evaporation. The intention of this pre-treatment was to allow dissolution of the sulphate-salts in the weathered-solids generated from "historic" weathering which includes the 2-3 month period prior to attainment of an air-dry state. It also allowed rehydration of desiccated biofilms to re-establish biogeochemical activity.

##### 3.1.2 Slow, Incremental Leaching to Collect "Breakthrough-Leachate"

Following the above 're-equilibration' treatment, deionised-water was added to the surface of each column in 25 mL aliquots every 2 days via a plastic-syringe. In applying the deionised-water, the tip of the syringe was laterally moved randomly above the weathered-solids surface with intermittent dripping. This slow addition of deionised-water allowed infiltration and redistribution to take place slowly, and thus "engage" a wide range in pore-sizes (including micro-pores) in the wetting-up process preceding drainage. In terms of Darcy flow, the rate of addition of deionised-water corresponded to an average recharge rate of *ca.* 0.5-1.0 mm/day.<sup>6</sup>

During the slow leaching treatment, the columns were stored in a CT-room at 20 °C, and the tops of the columns were covered with large clockglasses to restrict evaporation.

It took up to 3 weeks before "breakthrough-leachates" could be collected for all columns. Samples X00726 (0.85%S) and X04351 (1.64%S) required *ca.* 250 mL of deionised-water before "breakthrough-leachates" emerged, whereas sample X01906 (3.62%S)

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<sup>5</sup> The air-dry weathered-solids for sample X01906 (3.62%S), in particular, had a conspicuous "sugary" appearance reflective of accrued sulphate-salts from weathering.

<sup>6</sup> During the flushing step as per the AMIRA (2002) kinetic-testing procedure, the flow rates are generally 'of-the-order' 100 mm/day (i.e. much faster than the slow flow rates employed herein which favour elution of solutes from micro-pores, etc.).

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needed *ca.* 300 mL of deionised-water.<sup>7</sup> The differing "water-demands" for the samples relates to differing particle-size and pore-size distributions within the beds of weathered-solids, and the ensuing influence of the seepage-face lower boundary condition of the columns for the onset of drainage under gravity.

In terms of "storm-depth equivalents", the 250 mL of deionised-water required for samples X00726 and X04351 to generate "breakthrough-leachates" corresponds to *ca.* 10 mm, and the 300 mL of deionised-water for sample X01906 corresponds to *ca.* 13 mm.

For each column, 30 mL of "breakthrough-leachate" was collected for assaying, and corresponds to *ca.* 1.3 mm as a "storm-depth equivalent".

### 3.1.3 Context of "Breakthrough-Leachates" for Dumped FZ-Conglomerate-waste

To first-order, the "breakthrough-leachates" relate to about 0.1 m bed of moist 'rock-fines' (-10 mm nominal) in a dumped profile of FZ-Conglomerate-waste previously weathered at 20 °C for a few months prior to an episodic recharge increment of around 10 mm at a slow flow rate of about 1 mm/day which yielded around 1 mm of internal seepage under gravity (saturated) flow conditions.

Since the FZ-Conglomerate-waste *in situ* is dominated by clasts with minor amounts of matrix, a 0.1 m bed of 'rock-fines' may be broadly viewed as relating to a nominal 1 m layer of the dumped FZ-Conglomerate-waste with varying distribution of the matrix ('rock-fines').

## 3.2 Key Outcomes

### 3.2.1 Relative Leachate Strengths

As expected, the chemistry of the "breakthrough-leachates" generated in the Stage-2 testing was **much stronger** than that for the leachates generated during the Stage-1 testing as per the AMIRA (2002) methodology (**Table 5**).

For SO<sub>4</sub>, Fe, Al, Ni, Co, Cu, Zn, and Cr, the contrasting chemistries of the "breakthrough-leachates" and the week-20 leachates for the AMIRA (2002) testing regime is highlighted by **Figure 3** to **Figure 7**.

Despite FZ-Conglomerate-waste samples of moderate pyrite reactivity tested in the current work, and the hyper-reactive Black-Shale-waste samples tested by Pearce and Pearce (2016), a similar *relative degree* of difference in leachate strengths is evident in both investigations when compared with the corresponding leachates generated by the AMIRA (2002) kinetic-testing protocol.<sup>8</sup>

### 3.2.2 Main Suite of Solutes

The "breakthrough-leachate" assays indicate that the main solutes in porewaters of a 'wetted-up' profile of FZ-Conglomerate-waste will comprise, as expected, SO<sub>4</sub>, Fe, Al, and 'free-acidity'.

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<sup>7</sup> On the final day for the more "water-demanding" sample X01906, *ca.* 75 mL of deionised-water was added on that day.

<sup>8</sup> This similarity reflects a similar ratio of the "storm-depth equivalent" of applied deionised-water, and column length, which is around 1:10 (L:L) in both investigations.

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Sub-ordinate solutes include Ni, Co, Cu, Zn, Cr, and Mn likely reflective of 'acid-attack' of the Fe-chlorites chiefly.

#### 4.0 CONCLUSIONS AND MANAGEMENT IMPLICATIONS

The kinetic-testing programmes highlight the PAF character of the FZ-Conglomerate-waste stream to be produced during the Fresh-Rock Project.

During construction of the in-pit Grants Hill waste-rock dump (WRD), and the out-of-pit Central WRD, a 'tight' PAF-profile will be produced via end-tipping from low tip-heads and dozing-over to blend clasts and 'rock-fines' (matrix), thus preventing preferred-flow pathways resulting from rock-particle segregation during dumping. In this way, infiltration and 'wetting-front' penetration into the PAF-profile from major 'wet-spells' will be effectively constrained for geochemical control during the 'build-phases' of the WRDs.

When the WRDs are decommissioned and rehabilitated, a store/release-cover system will be required for infiltration-control over the longer term.

#### 5.0 CLOSING

Information on leachate chemistries generated by the kinetic-testing programmes for the FZ-Conglomerate-waste samples serves as 'source-term' data for the geochemical modelling undertaken by SRK Consulting.

I trust the above is useful to you.

Regards,

**Dr GD Campbell**  
**Director**

encl. Tables 1-6  
 Figures 1-7

#### REFERENCES

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## **TABLES**

**Table 1: Results for Acid-Base-Analysis (ABA) and Net-Acid-Generation (NAG) Testing**

SAMPLE_ID	MINING_DOMAIN	DRILLHOLE_ID	DOWNHOLE-INTERVAL (m)	LITHOLOGY	pH-(1:5)	EC-(1:5) [mS/cm]	TOTAL-S (%)	SO4-S [HCl] (%)	TOTAL-C (%)	CARB.-ANC (calc'd)	BULK-ANC (#)	BULK-ANC (##)	NAG-pH4.5	NAG-pH7.0	NAG-pH	AFP CATEGORY
					GLS	GLS	GLS	GLS	GLS	GLS	GCA	GLS	GLS	GLS		
					kg H2SO4/tonne			kg H2SO4/tonne			GLS					
X00726	Grants Hill	BCDD18-002	62.00-63.00	FZ-Conglomerate	7.2	0.104	0.85	0.02	0.03	2	10	1	13	20	2.7	PAF
X04351	Edwards	BCDD18-024	32.00-33.00	FZ-Conglomerate	5.7	0.300	1.64	0.05	0.02	2	7	1	40	31	2.4	PAF
X01906	Grants Hill	BCDD18-008	40.64-41.15	FZ-Conglomerate	4.9	0.529	3.62	0.17	0.04	3	5	<1 (<1)	68	80	2.1	PAF

Notes:

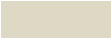
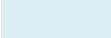
FZ = Fresh-Zone; EC = Electrical-Conductivity; ANC = Acid-Neutralisation Capacity; NAG = Net-Acid Generation; AFP = Acid-Formation Potential; PAF = Potentially-Acid Forming.  
 pH-(1:5) and EC-(1:5) values correspond to pH and EC measured on sample slurries prepared with crushings (-2 mm nominal), deionised-water, and a solid:solution ratio of **ca. 1:5 (w/w)**.  
 All results expressed on a dry-weight basis, except for pH-(1:5), EC-(1:5), and NAG-pH.  
 Values in parentheses represent duplicates.  
 Calculated Carbonate-ANC values assume that all Total-C is associated with Ca/Mg-carbonates (i.e. 'non-ferroan-carbonates').

# signifies use of pulverised (pulp) sample (-75 µm nominal) as per method in the AMIRA (2002) document, and an initial applied HCl loading of 100 kg H2SO4/tonne by GLS (i.e. large excess of HCl applied).  
 ## signifies modified AMIRA (2002) method by GCA using the -2 mm fraction (i.e. rock chips) in testing, and an initial applied HCl loading constrained by the CO3-C value (estimated).

**Table 2: Multi-Element-Analysis Results**

SAMPLE_ID	MINING_DOMAIN	DRILLHOLE_ID	DOWNHOLE_INTERVAL (m)	LITHOLOGY	AFP	S	C	Ca	Mg	K	Na	Fe	Al	Ti	As	Sb	Se	Mo
						%									mg/kg			
X00726	Grants Hill	BCDD18-002	62.00-63.00	FZ-Conglomerate	PAF	0.85	0.03	0.01	0.71	2.17	0.11	2.53	5.75	0.09	98.1	4.57	0.5	6.6
X04351	Edwards	BCDD18-024	32.00-33.00	FZ-Conglomerate	PAF	1.64	0.02	0.01	0.43	1.83	0.07	2.65	4.48	0.07	80.9	4.55	1.0	1.8
X01906	Grants Hill	BCDD18-008	40.64-41.15	FZ-Conglomerate	PAF	3.62	0.04	0.01	0.40	2.45	0.16	4.44	5.96	0.08	160.5	14.53	1.4	5.0
<b>Average-Crustal Abundance (Bowen 1979)</b>															1.5	0.2	0.05	1.5

SAMPLE_ID	MINING_DOMAIN	DRILLHOLE_ID	DOWNHOLE_INTERVAL (m)	LITHOLOGY	AFP	Cu	Zn	Cd	Pb	Ni	Cr	Co	Mn	Ag	Bi	P	Sr	Ba	Sn	V	Tl	Th	U
						mg/kg																	
X00726	Grants Hill	BCDD18-002	62.00-63.00	FZ-Conglomerate	PAF	46.7	54	0.09	28.9	102.9	176	26.6	148	0.11	1.03	104	26.08	207.2	2.8	58	1.02	14.73	9.31
X04351	Edwards	BCDD18-024	32.00-33.00	FZ-Conglomerate	PAF	46.7	40	0.09	32.9	92.8	148	33.1	106	0.16	2.03	<50	12.25	186.5	1.6	45	0.90	11.67	6.07
X01906	Grants Hill	BCDD18-008	40.64-41.15	FZ-Conglomerate	PAF	84.8	44	0.09	39.0	160.9	211	61.7	90	0.38	3.52	72	24.54	273.2	2.2	77	1.28	9.15	9.30
<b>Average Crustal Abundance (Bowen 1979)</b>						50	75	0.11	14	80	100	20	950	0.07	0.05	1,000	370	500	2.2	160	0.6	12	2.4

 signifies element content 10-100 times average-crustal abundance  
 signifies element content 100+ times average-crustal abundance

Reference: Bowen HJM, 1979, "Environmental Chemistry of the Elements", Academic Press, New York

Note: Assays correspond to 4-acid digestion with ICP-OES/MS analytical 'finish'.

**Table 3: Mineralogical Results**

FZ-Conglomerate		FZ-Conglomerate		FZ-Conglomerate	
Grants Hill (0.85%S; 0.03%Total-C) BCDD18-002, 62.00-63.00 m		Edwards (1.64%S; 0.02%Total-C) BCDD18-024, 32.00-33.00 m		Grants Hill (3.62%S; 0.04%Total-C) BCDD18-008, 40.64-41.15 m	
PAF (X00726)		PAF (X04351)		PAF (X01906)	
quartz	> 50 %	quartz	> 50 %	quartz	> 50 %
muscovite / illite	20-50 %	muscovite / illite	20-50 %	muscovite / illite	20-50 %
<b>pyrite</b>	1-10 %	<b>pyrite</b>	1-10 %	<b>pyrite</b>	1-10 %
Fe-chlorite		Fe-chlorite		Fe-chlorite	
Ti-oxides	< 1 %	Ti-oxides	< 1 %	Ti-oxides	< 1 %
galena (0.0030%Pb) chalcopyrite (0.0047%Cu) Bi / Sb (1.03ppmBi / 4.57ppmSb)	isolated grains only			galena (0.0039%Pb)	isolated grains only

Notes:

dominant = greater than 50 %; major = 20-50 %; minor = 10-20 %; accessory = 1-10 %; trace is less than 1 %

For Sample\_IDs X01906 and X04351, pyrite occurs predominantly as **coarse-grained** (500-1,000 µm) forms associated with mica and quartz.

For Sample\_ID X00726, pyrite occurs mostly as disseminated fine-grained (< 10 µm) forms hosted by muscovite / illite fines.

**Table 4: Pyrite Reactivity as a Functon of Seasonal Moisture Status Applicable to Operations**

Note: All rate data corresponds to 30 oC

SAMPLE_ID	MINING_DOMAIN	DRILLHOLE_ID	DOWNHOLE-INTERVAL (m)	LITHOLOGY	TOTAL-S (%)	Status During 'Dry-Spells' of Multi-month Duration		Status During Short-Lived 'Wet-Spells' (days)	
						Residual-Moistures/ Suctions ('Dusty')		Moist / Wet (less than 'Field-Capacity' typically)	
						OCR (kg O2/kg/s)	AGR (mg H2SO4/kg/week)	OCR (kg O2/kg/s)	AGR (mg H2SO4/kg/week)
						GLS	GCA	calc'd	GCA
X00726	Grants Hill	BCDD18-002	62.00-63.00	FZ-Conglomerate	0.85	1.2E-12	1	4.7E-10	470
X04351	Edwards	BCDD18-024	32.00-33.00	FZ-Conglomerate	1.64	4.3E-12	4	3.6E-10	360
X01906	Grants Hill	BCDD18-008	40.64-41.15	FZ-Conglomerate	3.62	5.9E-12	6	5.6E-10	560

Notes:

OCR = Oxygen-Consumption Rate; AGR = Acid-Generation Rate

The OCR determinations employed the -4.75 mm fractions obtained from the 'coarse-crushings' via dry-sieving.

Units of OCR expressed as **kg O2/kg/s** are approximately 1,000-fold lower than related units of kg O2/m3/s.

OCRs are directly measured via determining variations in heads-space-O2 concentrations in Oxygen-Consumption Cells (OCCs).

For the OCRs determined for the moist 'rock-fines', the air-dry 'rock-fines' were first moistened by spraying with deionised-water, and 'working-over' by 'hand-mixing' before being 'aged' for 2-3 days in plastic-bags in a CT-room at 20 oC. The Gravimetric-Water Contents were *ca.* 4-5 % (w/w).

AGRs are calculated from corresponding OCRs assuming stoichiometry of the complete oxidation of pyrite to H2SO4 and "Fe(OH)3".

The unit of **mg H2SO4/kg/week** for AGR relates to the unit invariably used in laboratory-column weathering testing based on rates of SO4 eluted during flushing, etc.

**Table 5: Leachate-Analysis Results for Weathering-Columns**

PARAMETER / ELEMENT	Stage-1 Testing Coordinated by Golder							Stage-2 Testing
	PRE-RINSE 'Week-0'	WEEKS						"breakthrough-leachate" after multi-month weathering (GCA)
		[Modified AMIRA (2002) without heating from flood-lamps at GLS]						
		4	8	9	12	16	20	
<b><i>pH, Salinity &amp; Alkalinity</i></b>								
pH	5.5	4.8	4.5	4.4	4.1	3.8	3.7	2.6
EC (µS/cm)	398	555	571	412	556	626	680	7,930
acidity (mg/L CaCO <sub>3</sub> )	2.6	9.9	14.9	19.6	40.3	56.6	98.0	8,074.2
<b><i>Major-Ion Chemistry</i></b>								
Mg (mg/L)	34.52	53.13	55.75		54.50	52.99	54.88	583
Ca (mg/L)	2.19	2.74	2.92		2.78	2.94	3.01	59
K (mg/L)	14.8	19.7	21.4		17.4	16.5	14.7	11
Na (mg/L)	11.0	10.5	5.8		2.1	1.3	0.9	5
Cl (mg/L)	3	<2	<2		<2	<2	<2	-
F (mg/L)	-	<0.1	0.1		<0.1	<0.1	<0.1	-
SO <sub>4</sub> (mg/L)	190	266	279	185	271	295	318	9,125
Al (mg/L)	0.06	0.45	1.04		1.88	2.73	4.58	826
Fe (mg/L)	0.32	0.33	0.76		1.79	2.03	3.62	693
Fe(II) (mg/L)	0.39	0.36	0.80		1.78	1.95	3.10	294
Fe(III) (mg/L)	<0.01	<0.01	<0.01		<0.01	0.08	0.52	399
Mn (mg/L)	0.57	1.44	1.68		1.80	1.92	2.03	24
Si (mg/L)	3.07	8.30	10.87		3.25	4.99	6.15	68
<b><i>Minor-Element Chemistry</i></b>								
As (µg/L)	8.2	4.1	6.1		6.8	6.6	13.1	5,847
Sb (µg/L)	2.02	1.59	1.38		1.00	0.51	0.62	5
B (µg/L)	30	<10	30		<10	<10	<10	350
Mo (µg/L)	0.11	0.05	<0.05		<0.05	1.10	<0.05	2
Se (µg/L)	14.6	11.0	11.9		9.4	9.9	11.2	68
P (µg/L)	<100	<100	<100		<100	<100	<100	300
Ni (µg/L)	2,090	2,900	4,190		6,030	7,420	9,330	145,921
Co (µg/L)	893.9	1,023.2	1,784.5		2,176.5	2,737.5	3,458.9	56,737
Cu (µg/L)	20	90	380		950	1,350	2,220	34,843
Zn (µg/L)	230	360	690		1,090	1,400	1,770	30,495
Cr (µg/L)	<10	<10	<10		<10	<10	20	45,426
Cd (µg/L)	<0.5	0.6	1.1		1.5	2.4	3.0	58
Pb (µg/L)	2	17	27		32	33	30	107
Hg (µg/L)	<0.1	<0.1	<0.1		<0.1	<0.1	0.2	0
Sn (µg/L)	<0.1	<0.1	<0.1		0.5	1.0	<0.1	3
Ag (µg/L)	<0.01	<0.01	<0.01		0.09	0.12	0.05	0
Ba (µg/L)	9.72	10.91	8.84		9.17	7.27	5.45	9
Sr (µg/L)	25.52	29.95	35.97		33.93	39.15	40.59	236
Bi (µg/L)	<0.005	<0.005	<0.005		<0.005	0.008	<0.005	1
Ti (µg/L)	<10	<10	<10		<10	<10	<10	-
Tl (µg/L)	0.27	0.39	0.55		0.65	0.79	0.74	0
Th (µg/L)	<0.005	<0.005	<0.005		0.027	0.065	0.119	547
U (µg/L)	3.462	16.242	39.898		93.635	126.285	212.017	5,024
V (µg/L)	<10	<10	<10		<10	<10	<10	117
Bc (µg/L)	3.2	8.9	20.6		29.1	38.9	56.5	-
<b>Leachate Wt (kg)</b>	<b>0.78</b>	<b>0.66</b>	<b>0.64</b>	<b>0.63</b>	<b>0.45</b>	<b>0.54</b>	<b>0.57</b>	<b>0.028</b>

**Note:**

EC = Electrical-Conductivity.

**2.16 kg** (dry-solids equivalent) of -10 mm nominal fraction. Flushing undertaken using 800 mL of deionised-water, and 'weekly-wettings' between flushings (typically every 4 weeks) undertaken with 200 mL of deionised-water. A misunderstanding between Golder and GLS meant that flushings occurred at week-9 when only 'wetting' should have occurred. This also meant that the flushing at week-12 corresponded to a 3-week period of weathering (cf. 4 weeks).

**Table 5 (Cont'd): Leachate-Analysis Results for Weathering-Columns**

**X01906 (3.62%S)**

PARAMETER / ELEMENT	Stage-1 Testing Coordinated by Golder							Stage-2 Testing "breakthrough-leachate" after multi-month weathering (GCA)
	PRE- RINSE 'Week-0'	WEEKS						
		[Modified AMIRA (2002) without heating from flood-lamps at GLS]						
		4	8	9	12	16	20	
<b><u>pH, Salinity &amp; Alkalinity</u></b>								
pH	4.8	4.1	3.7	3.6	3.3	2.8	2.4	2.4
EC (µS/cm)	429	702	755	613	709	1,470	3,260	14,210
acidity (mg/L CaCO3)	14.9	31.9	73.4	76.9	141.3	576.8	2,692.2	26,667.3
<b><u>Major-Ion Chemistry</u></b>								
Mg (mg/L)	32.41	56.53	50.93		36.90	52.37	46.53	808.35
Ca (mg/L)	8.49	13.65	12.31		7.59	13.67	12.98	48.60
K (mg/L)	15.0	22.6	21.5		10.3	8.4	0.4	1.0
Na (mg/L)	14.0	14.6	7.5		2.1	2.0	1.5	1.0
Cl (mg/L)	4	3	<2		<2	3	12	-
F (mg/L)	-	<0.1	<0.1		<0.1	<0.1	<0.1	-
SO4 (mg/L)	218	340	352	266	318	722	2,420	26,510
Al (mg/L)	0.44	1.84	3.76		8.01	30.98	107.91	2,049.30
Fe (mg/L)	1.14	3.11	8.69		19.45	56.49	543.94	5,949.30
Fe(II) (mg/L)	1.28	2.90	8.90		19.00	30.70	84.25	1,272.50
Fe(III) (mg/L)	<0.01	0.21	<0.01		0.45	25.79	459.69	4,676.80
Mn (mg/L)	0.58	2.70	2.87		2.60	3.98	3.12	27.762
Si (mg/L)	3.02	12.53	15.80		4.64	9.76	15.37	56.60
<b><u>Minor-Element Chemistry</u></b>								
As (µg/L)	4.9	7.8	23.6		47.9	165.7	6,617.1	198,357.55
Sb (µg/L)	4.16	2.66	2.48		1.06	2.94	9.69	44.50
B (µg/L)	30	20	20		<10	<10	<10	300
Mo (µg/L)	0.07	<0.05	<0.05		<0.05	0.08	4.45	95.90
Se (µg/L)	7.5	6.7	6.2		5.6	12.8	15.6	154.0
P (µg/L)	<100	<100	<100		<100	<100	<100	3,350
Ni (µg/L)	3,620	6,410	8,320		9,760	20,250	28,430	201,181.5
Co (µg/L)	1,615.2	2,359.1	3,585.0		3,408.1	6,625.9	8,810.3	73,753.70
Cu (µg/L)	1,220	2,390	4,210		6,500	15,380	17,430	83,412.0
Zn (µg/L)	600	1,190	1,920		2,600	5,630	7,210	66,370
Cr (µg/L)	<10	<10	30		410	2,510	23,070	127,493.5
Cd (µg/L)	6.2	8.0	12.4		15.0	33.8	45.5	326.980
Pb (µg/L)	17	56	51		18	12	4	<0.2
Hg (µg/L)	<0.1	<0.1	<0.1		<0.1	<0.1	0.2	0.10
Sn (µg/L)	<0.1	<0.1	<0.1		<0.1	0.5	0.3	8.50
Ag (µg/L)	<0.01	0.02	0.02		0.06	0.15	0.17	1.00
Ba (µg/L)	22.39	7.87	6.05		2.45	1.70	0.57	40.35
Sr (µg/L)	51.21	73.83	86.80		52.93	86.98	55.20	17.50
Bi (µg/L)	<0.005	<0.005	<0.005		<0.005	0.011	0.218	5.425
Ti (µg/L)	<10	<10	<10		<10	<10	<10	-
Tl (µg/L)	0.47	0.77	1.15		0.98	1.16	0.27	1.050
Th (µg/L)	<0.005	0.013	0.148		1.154	12.036	136.018	1,877.52
U (µg/L)	162.167	352.085	687.549		1,005.05	2,221.62	2,701.83	11,461.67
V (µg/L)	<10	<10	<10		<10	<10	<10	1,679.10
Be (µg/L)	21.4	43.6	97.1		102.9	221.0	248.6	-
<b>Leachate Wt (kg)</b>	<b>0.78</b>	<b>0.66</b>	<b>0.63</b>	<b>0.64</b>	<b>0.43</b>	<b>0.50</b>	<b>0.56</b>	<b>0.030</b>

Note:

2.15 kg (dry-solids equivalent) of -10 mm nominal fraction.



**Table 5 (Cont'd): Leachate-Analysis Results for Weathering-Columns**

**X00726 (0.85%S)**

PARAMETER / ELEMENT	PRE-RINSE 'Week-0'	Stage-1 Testing Coordinated by Golder						Stage-2 Testing "breakthrough-leachate" after multi-month weathering (GCA)
		WEEKS						
		[Modified AMIRA (2002) without heating from flood-lamps at GLS]						
		4	8	9	12	16	20	
<b><i>pH, Salinity &amp; Alkalinity</i></b>								
pH	7.5	6.7	6.1	6.2	5.5	5.3	4.8	3.7
EC (µS/cm)	144	322	287	143	253	314	433	3,260
HCO3 (mg/L CaCO3)	11	6	<5	4				
acidity (mg/L CaCO3)	0.8	3.5	2.1	2.4	3.4	4.4	8.7	246.5
<b><i>Major-Ion Chemistry</i></b>								
Ca (mg/L)	0.67	2.74	5.99		6.95	12.73	23.69	347.75
Mg (mg/L)	0.47	3.02	3.80		4.56	8.56	16.33	250.05
K (mg/L)	4.0	8.5	12.4		14.2	19.1	26.4	90.0
Na (mg/L)	23.7	48.4	37.5		20.7	15.4	13.6	37.5
Cl (mg/L)	6	<2	<2		<2	<2	<2	-
F (mg/L)	-	0.1	<0.1		<0.1	<0.1	<0.1	-
SO4 (mg/L)	45	130	115	53	87	125	188	2,230
Al (mg/L)	0.04	<0.01	<0.01		<0.01	0.02	0.16	22.15
Fe (mg/L)	<0.01	<0.01	<0.01		0.02	0.03	0.04	0.45
Fe(II) (mg/L)	<0.01	0.06	0.04		<0.01	0.03	0.11	1.70
Fe(III) (mg/L)	<0.01	<0.01	<0.01		0.02	<0.01	<0.01	<0.01
Mn (mg/L)	<0.01	0.08	0.12		0.18	0.40	0.82	15.558
Si (mg/L)	2.67	3.82	5.77		3.07	3.02	4.74	37.35
<b><i>Minor-Element Chemistry</i></b>								
As (µg/L)	210.3	295.0	221.7		74.4	31.0	13.8	304.70
Sb (µg/L)	44.02	55.46	50.52		22.34	16.89	12.52	7.45
B (µg/L)	30	<10	30		<10	<10	20	300
Mo (µg/L)	8.08	3.03	1.94		0.76	0.27	0.15	0.10
Se (µg/L)	11.4	12.6	10.7		14.6	24.9	30.5	224.0
P (µg/L)	<100	<100	<100		<100	<100	<100	<10
Ni (µg/L)	<10	70	150		300	790	18,100	52,732.5
Co (µg/L)	<0.1	9.8	28.9		57.0	172.4	440.9	15,725.45
Cu (µg/L)	<10	<10	<10		<10	<10	20	2,237.5
Zn (µg/L)	<10	<10	<10		<10	10	40	1,890
Cr (µg/L)	<10	<10	<10		<10	<10	<10	32.0
Cd (µg/L)	<0.5	0.6	<0.5		<0.5	<0.5	<0.5	14.285
Pb (µg/L)	<2	<2	3		13	37	132	1,077.5
Hg (µg/L)	<0.1	<0.1	<0.1		<0.1	<0.1	0.1	0.05
Sn (µg/L)	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1	0.75
Ag (µg/L)	<0.01	<0.01	<0.01		0.36	<0.01	0.01	<0.05
Ba (µg/L)	0.33	4.44	6.97		9.80	24.01	43.00	28.10
Sr (µg/L)	4.75	29.95	58.79		66.43	135.65	238.19	2,725.95
Bi (µg/L)	<0.005	<0.005	<0.005		<0.005	<0.005	<0.005	0.015
Ti (µg/L)	<10	<10	<10		<10	<10	<10	-
Tl (µg/L)	0.04	0.10	0.14		0.16	0.29	0.41	2.445
Th (µg/L)	<0.005	<0.005	<0.005		0.062	<0.005	<0.005	0.685
U (µg/L)	0.322	0.069	0.064		0.271	0.357	4.812	3,109.580
V (µg/L)	<10	<10	<10		<10	<10	<10	0.30
Be (µg/L)	<0.1	<0.1	<0.1		<0.1	0.3	1.4	-
<b>Leachate Wt (kg)</b>	<b>0.78</b>	<b>0.65</b>	<b>0.65</b>	<b>0.62</b>	<b>0.44</b>	<b>0.45</b>	<b>0.48</b>	<b>0.030</b>

Note:

2.14 kg (dry-solids equivalent) of -10 mm nominal fraction.

**Table 6: Pyrite Reactivity Variation During Stage-2 Testwork**

Note: All rate data corresponds to **30 oC**.

SAMPLE ID	MINING DOMAIN	DRILLHOLE ID	DOWNHOLE-INTERVAL (m)	LITHOLOGY	TOTAL-S (%)	REACTION TIME (days)	OCR (kg O2/kg/s)	AGR (mg H2SO4/kg/week)	CDRR (kg CO2/kg/s)
					GLS		GCA	GCA	GCA
X00726	Grants Hill	BCDD18-002	62.00-63.00	FZ-Conglomerate	0.85	4	5.6E-11	56	1.5E-12
						31	1.2E-10	120	6.9E-12
						52	8.6E-11	86	8.1E-12
X04351	Edwards	BCDD18-024	32.00-33.00	FZ-Conglomerate	1.64	4	3.8E-10	380	1.9E-12
						31	3.2E-10	320	1.9E-12
						52	2.9E-10	290	5.1E-12
X01906	Grants Hill	BCDD18-008	40.64-41.15	FZ-Conglomerate	3.62	4	3.5E-10	350	1.2E-12
						31	3.3E-10	330	1.2E-12
						52	2.9E-10	290	5.1E-12

Notes:

OCR = Oxygen-Consumption Rate; AGR = Acid-Generation Rate; CDRR = Carbon-Dioxide-Release Rate

The weathered-solids in the columns correspond to 'coarse-crushings' (-10 mm nominal) as per the Stage-1 testwork coordinated by Golder.

Units of OCR expressed as **kg O2/kg/s** are approximately 1,000-fold lower than related units of kg O2/m3/s.

OCRs are directly measured via determining variations in heads-space-O2 concentrations in Oxygen-Consumption Cells (OCCs).

The CDRRs are determined in a related way via determining heads-space-CO2 concentrations.

The Gravimetric-Water Contents (GWCs) of the weathered-solids are *ca.* 4-5 % (w/w). Through regular weighing, deionised-water is misted onto the columns to compensate for evaporative water losses during 'ageing' of the columns in incubator @ 30 oC.

AGRs are calculated from corresponding OCRs assuming stoichiometry of the complete oxidation of pyrite to H2SO4 and "Fe(OH)3".

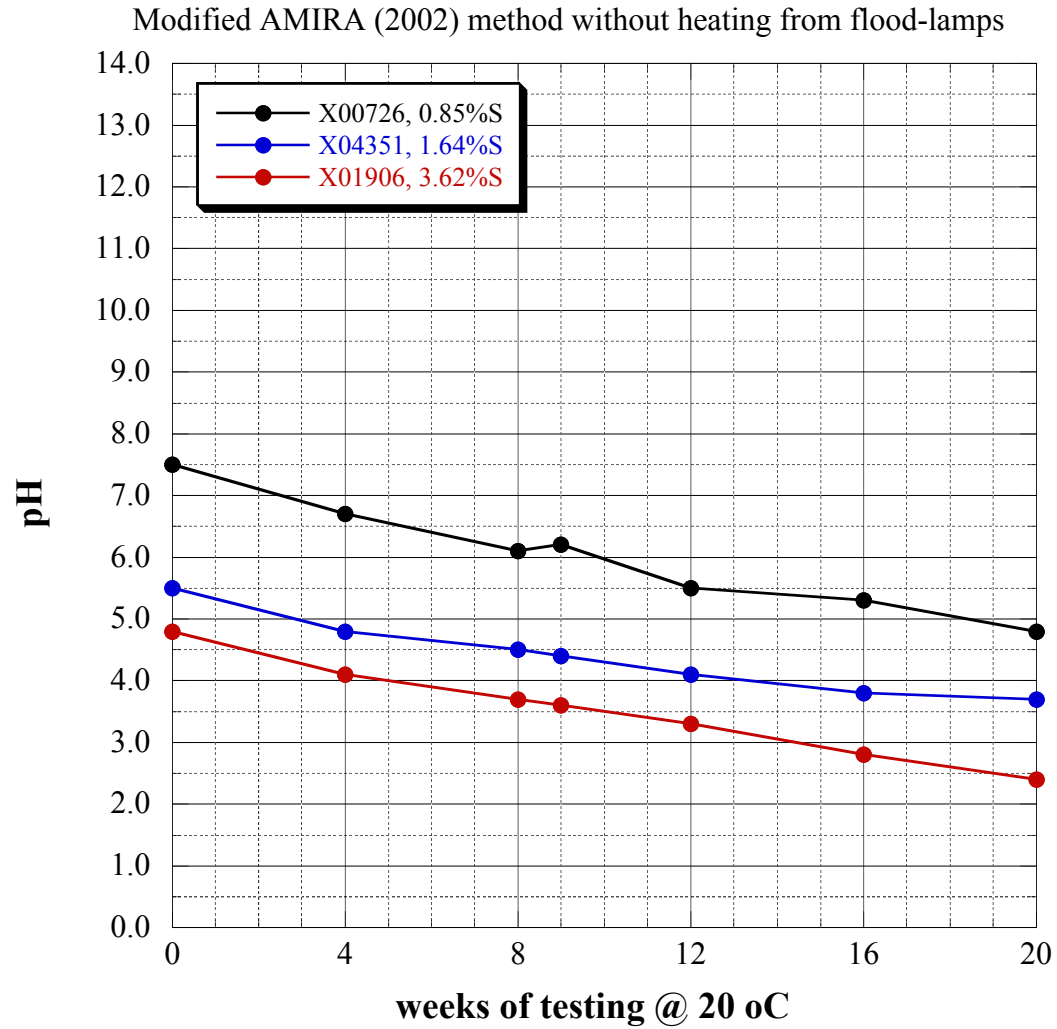
The unit of **mg H2SO4/kg/week** for AGR relates to the unit invariably used in laboratory-column weathering testing based on rates of SO4 eluted during flushing, etc.

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## **FIGURES**

Figure 1

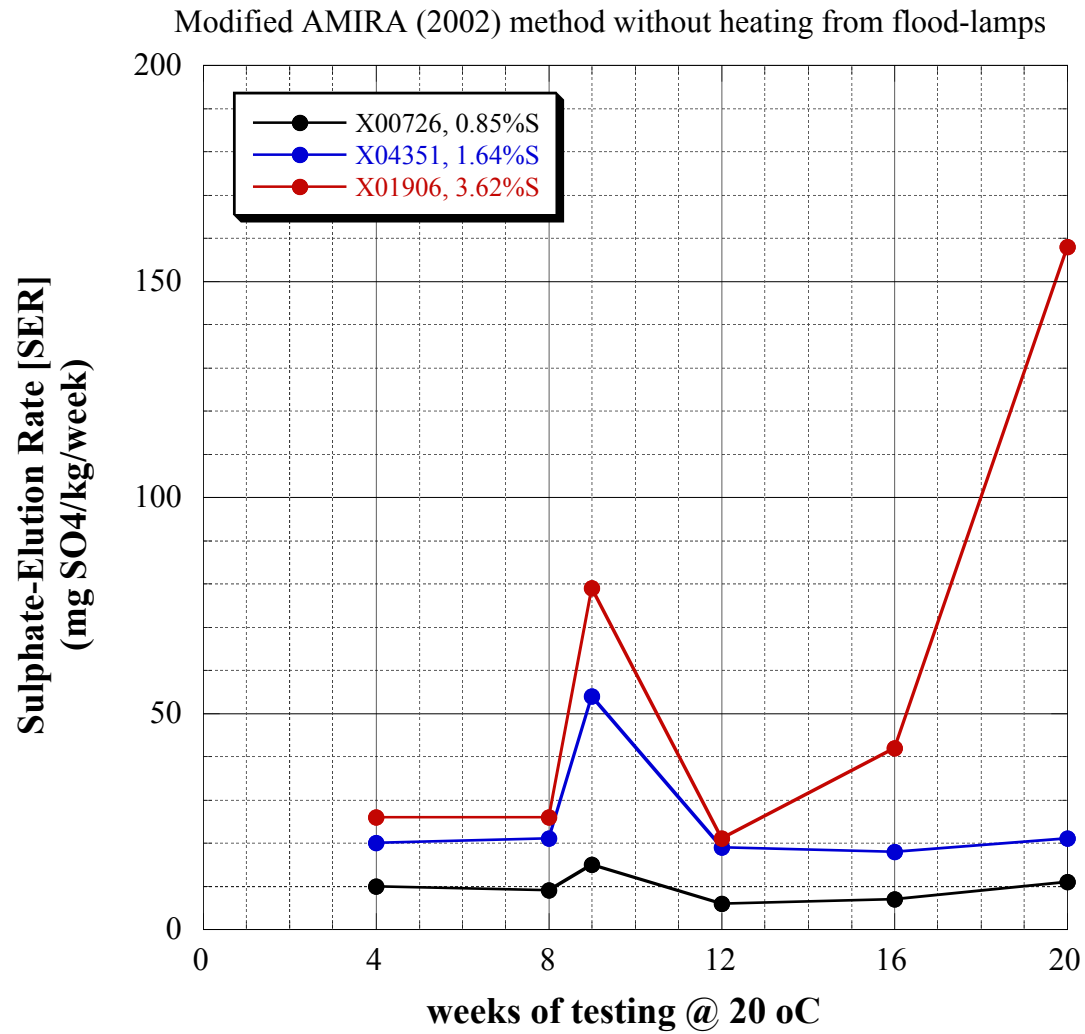
Variation in Leachate-pH Values for FZ-Conglomerate-waste Samples



typically 4-weekly weathering with "bulk" flushing (i.e. equivalent storm-depth of *ca.* 35 mm)  
with deionised-water at a rapid flushing / drainage rate of *ca.* 100 mm per day

Figure 2

Variation in Sulphate-Elution Rates for FZ-Conglomerate-waste Samples



typically 4-weekly weathering with "bulk" flushing (i.e. equivalent storm-depth of *ca.* 35 mm)  
with deionised-water at a rapid flushing / drainage rate of *ca.* 100 mm per day

Figure 3

Leachate-SO<sub>4</sub> Concentrations for FZ-Conglomerate-waste Samples  
X01906 (3.62%S) and X04351 (1.64%S)

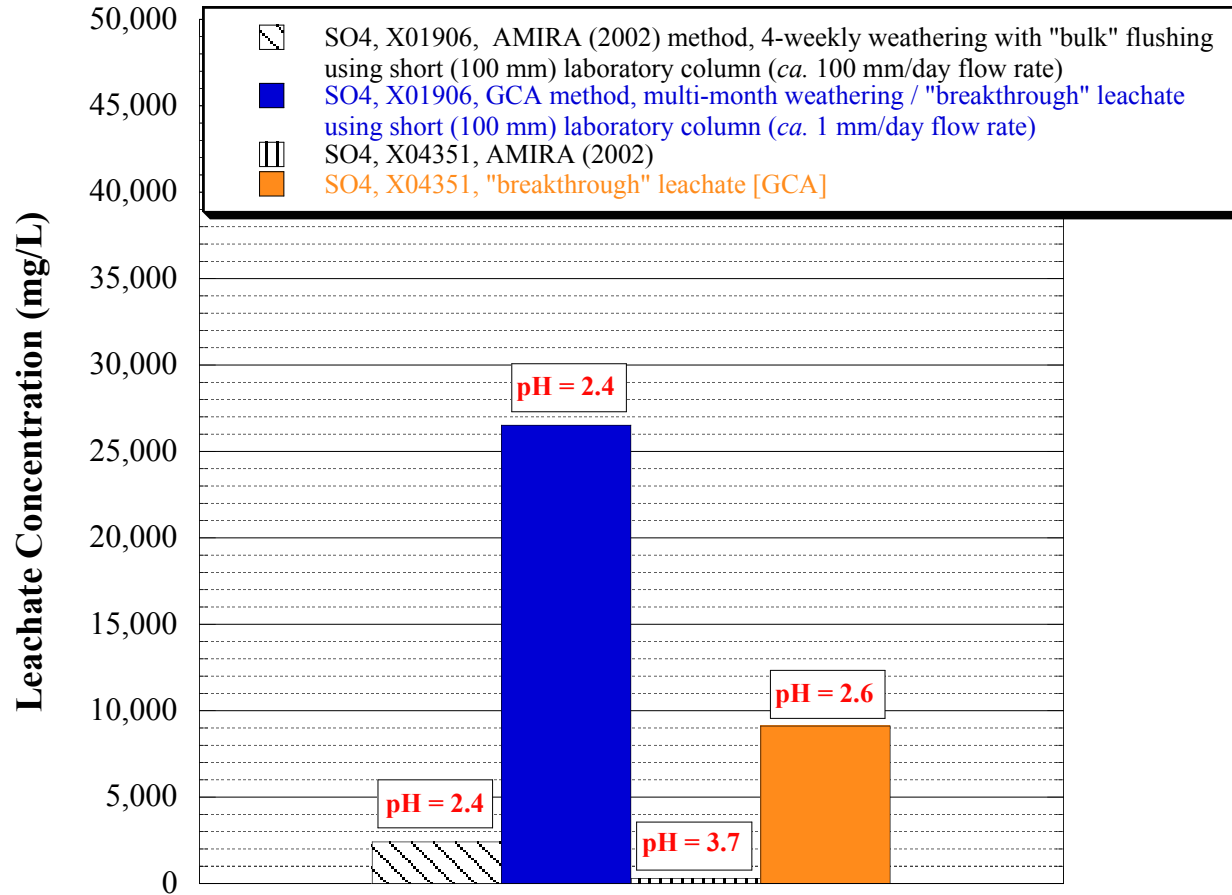


Figure 4

Leachate-Fe and -Al Concentrations for  
FZ-Conglomerate-waste Sample X01906 (3.62%S)

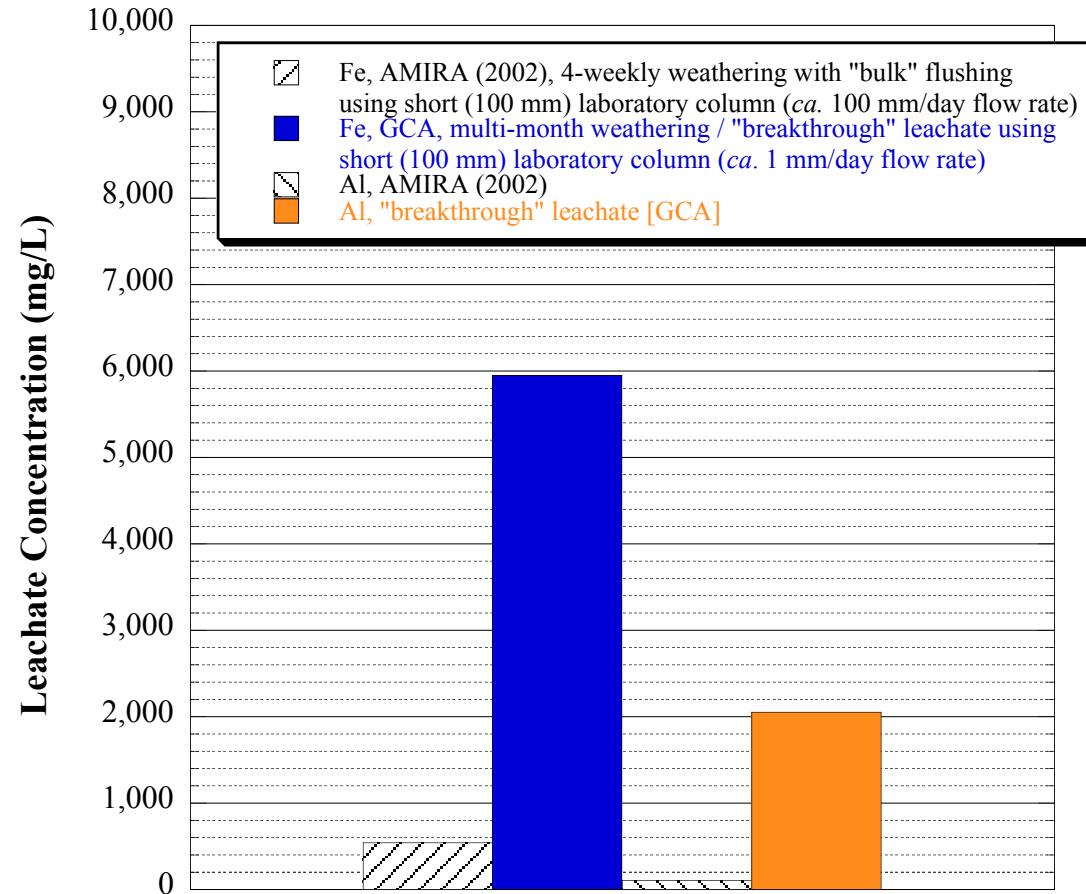


Figure 5

**Leachate-Fe and -Al Concentrations for  
FZ-Conglomerate-waste Sample X04351 (1.64%S)**

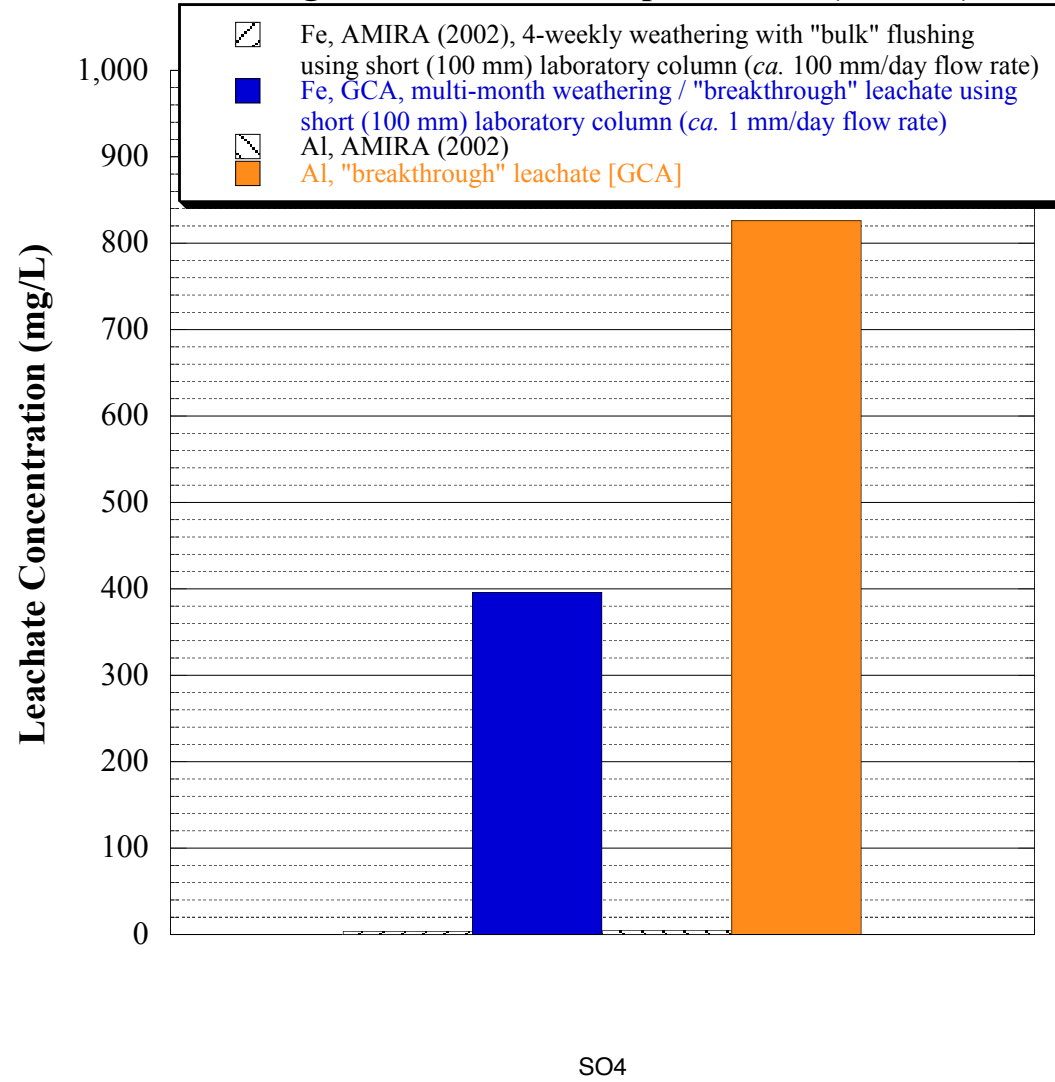




Figure 6

Leachate-Ni, -Co, -Cu, -Zn and -Cr Concentrations for  
FZ-Conglomerate-waste Sample X01906 (3.62 %S)

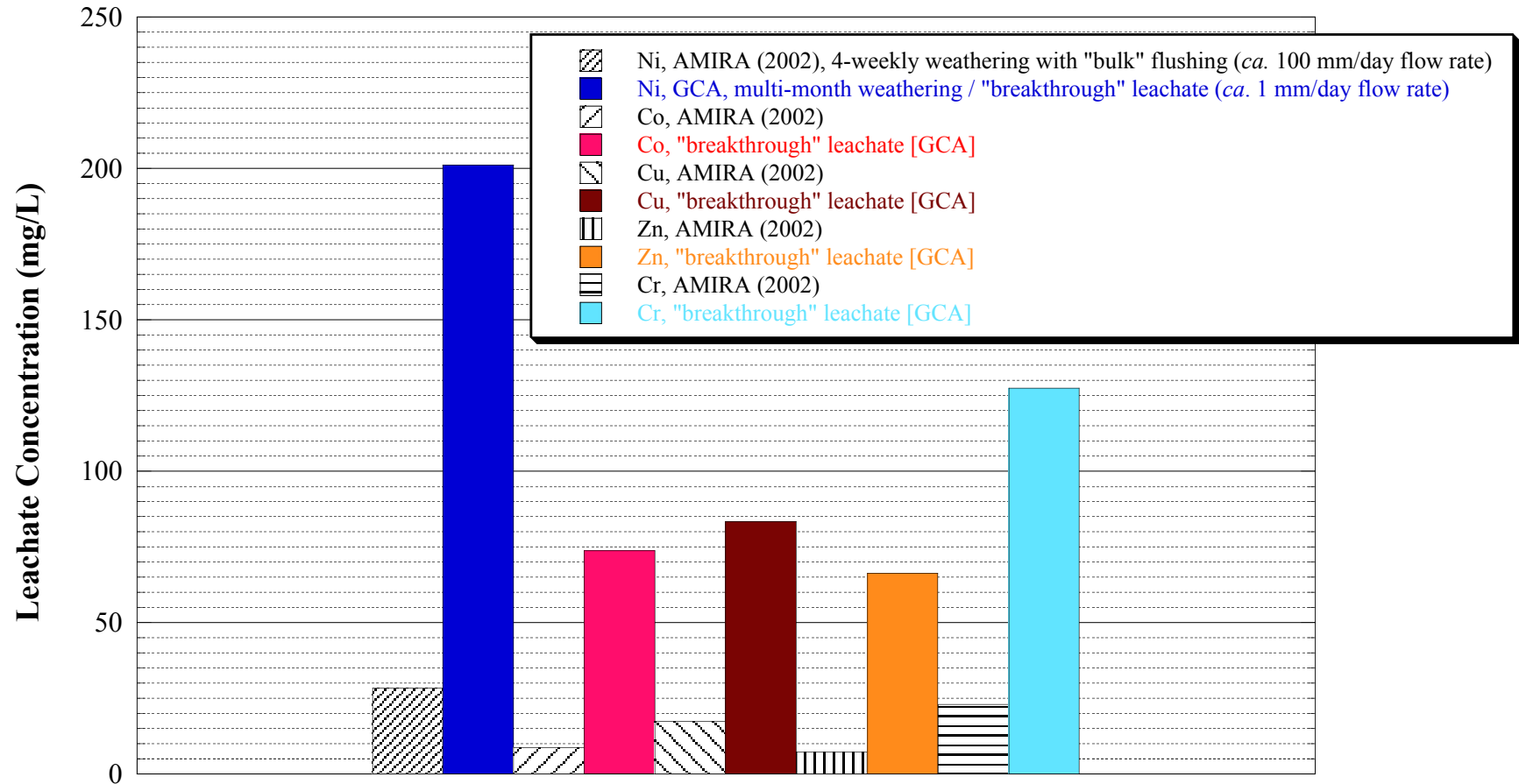


Figure 7

Leachate-Ni, -Co, -Cu, -Zn and -Cr-Concentrations for  
FZ-Conglomerate-waste Sample X04351 (1.62%S)

