



FLINDERS MINES LIMITED

Geochemical Characterisation of Mine Waste and Tailings Implications for Mine Waste Management

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FLINDERS MINES LIMITED GEOCHEMICAL CHARACTERISATION OF MINE WASTE AND TAILINGS IMPLICATIONS FOR MINE WASTE MANAGEMENT

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PROJECT 201012-00322 - GEOCHEMICAL CHARACTERISATION OF MINE WASTE - DELTA, EAGLE AND CHAMPION PITS

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1. INTRODUCTION

Flinders Mines Limited (FMS) proposes to develop an iron ore mining project on the Blacksmith tenement in the Hamersley Range, in the West Pilbara Region of Western Australia (the PIOP). The project includes the development and mining of six deposits. It is proposed that these deposits would be mined separately, with some associated infrastructure within the tenement. Annual ore production would be 15 million tonne per annum (Mtpa).

FMS engaged Graeme Campbell & Associates Pty Ltd (GCA) to geochemically characterise the proposed waste rock from three of the deposits: Delta, Eagle and Champion and the potential for release of harmful contaminants to downstream biodiversity assets. WorleyParsons understands that the geochemical characteristics of the material in the remaining pits are similar to those of the three pits assessed. This report takes the information from the GCA report (cited in Appendix A) and integrates it with additional information supplied by FMS on the oxidisable sulfur content from the deposits.

The geochemical properties of the material destined for the proposed Tailings Storage Facility (TSF) was also assessed by GCA with the full report and results shown in Appendix B.

The locations of the proposed pits and their associated waste rock dumps are shown on Figure 1.









Figure 1: Proposed pits, haul roads and waste dumps.







Figure 2: Schematic cross section of Pilbara style CID mineralisation (from FMS document in Appendix B).

For contextual purpose, Figure 2 presents a schematic cross section of a typical Pilbara style Channel Iron Deposit (CID). This shows a series of generally unconsolidated sediment layers overlying the CID. Pit shells in the five deposits to be developed by FMS are not expected to penetrate into unmineralised basement ('Footwall' in Figure 2).





2. ABBREVIATIONS AND DEFINITIONS

To assist in understanding some of the technical terms used in this and the GCA report (Appendices A & B), the abbreviations are expanded and the terms defined below.

Acid Base Accounting (ABA)

ABA is a series of chemical analyses and calculated values that provide a preliminary evaluation of the amounts, and relative balance, of the acid generation potential and acid-neutralisation potential of a sample. The calculated values are used to make preliminary projections about whether a sample will produce acid drainage. ABA includes the most common static tests used in the prediction of Acid Rock Drainage (ARD). The potential acid production is commonly determined by analysis for sulfur species. ARD prediction and ABA data interpretation requires an understanding of the analytical procedures, the future physical and geochemical conditions and the identity, location and reactivity of the contributing minerals. Kinetic tests, mineral identification and detailed material characterisation are required to provide this information.

Acid Neutralisation Capacity (ANC)

ANC is a general term for a sample's or a material's capability to neutralise acidity. ANC can be measured using different laboratory acid neutralisation procedures. The objective of ANC analysis is usually to determine the ARD potential. The objective is to predict the capacity of minesite waste materials to maintain a pH 6.0 or above. Assessment of the best static-test ANC requires a knowledge of future physical and geochemical conditions, the rate of acid generation and the identity, exposure and reactivity of the minerals with ANC and an understanding of the various analytical procedures.

Acid Rock Drainage (ARD)

ARD is acidic water discharge (i.e. pH <5.0), usually rich in iron, sulfate and other metals/metalloids. ARD usually forms under natural conditions when geological materials containing oxidisable forms of sulfur (i.e. pyrite) are exposed to atmospheric conditions or oxidising environments. ARD is produced when the neutralising potential is no longer capable of maintaining neutral pH conditions. In the context of mining, ARD may also be referred to as Acid Mine Drainage (AMD).

Base of oxidation (BoX)

The Box is the zone below which oxidation of (in this case) sulfur as sulfide species will not occur.





Maximum Potential Acidity (MPA)

MPA refers to the maximum amount of sulfuric acid (H_2SO_4) that is produced from complete oxidation of sulfide minerals (namely pyrite and pyrrotite) present in the rock material. The MPA is given as kgH_2SO_4/tonne and determined by multiplying the sulfide-S value (%) by 30.59¹ (or 623.7 moles/H⁺). This value is based on the stoichiometry of this chemical reaction which accounts for the maximum amount of acid that could be produced by material(s) containing 1% S.

Non-acid Forming (NAF)

NAF rock is material which is highly unlikely to produce acid when exposed to atmospheric oxygen and water and where the Acid Potential Ratio (APR) (defined as ANC/MPA) is ≥ 2 .

Potentially Acid Forming (PAF)

PAF is defined as the potential for acid generation from a particular sample. The calculation of PAF is an integral part of ABA. Knowledge of sample chemistry (especially pH), sulfur mineralogy and sulfide mineral chemistry is required for an accurate assessment. Total sulfur may be substituted for sulfide sulfur if there is no sulfate or organic sulfur. Accurate data interpretation requires an understanding of the analytical procedures, the physical and geochemical conditions the material will be subjected to and the identity, location and reactivity of the contributing minerals. Sulfides differ in their PAF and a correction may be required to the PAF calculation where non-pyrite sulfide minerals occur in significant amounts. A mineralogical assessment will be required to determine the sulfide mineralogy. The concentration of common sulfide metals like copper, molybdenum, lead and zinc can be used to estimate the concentration of non-iron sulfides.

¹ Dividing the S% by 30.59 converts this value to sulfuric acid (H_2SO_4)





3. METHODOLOGY

3.1 Waste rock assessment

This section provides an overview of geochemical testing undertaken on samples from three of the deposits associated with the proposed FMS development on its Blacksmith tenement.

Two geochemical tests were conducted by GCA on waste rock samples from the three deposits assessed; Delta, Eagle and Champion:

- Static testing; and
- Kinetic testing (Delta pit samples only).

Sample Locations

Samples were collected across the three main deposits of Delta, Eagle and Champion. They were selected on the basis of lithology and sulfur content with the aim of providing a good representation of the whole project area. A larger number of samples were collected from Delta as this currently represents the area to be mined first. A number of the high sulfur samples were also selected from basement rock.

Sample Collection

Samples were collected from 2m downhole intervals derived from Reverse Circulation (RC) drilling. Sample piles had been sitting on the surface for up to 3 years; however, most holes were less than 2 years old. The minimum amount of sample collected was 2-3kg with up to 5kg collected where possible. In each case the top few centimetres of material (defined as the "skin") was removed and a grab sample from the "core" of the pile was taken. For a small number of high sulfur samples the outer skin was also collected.

In total, 60 samples were collected for static test work (and 3 "skin" samples) and 18 (6 composites) for kinetic test work.

A total of 33 of the static samples were from above BoX and 27 were from basement units below BoX.

For a full explanation of sample locations and collection see Attachment 1 in the GCA report shown in Appendix A.

In addition, FMS has identified on pit cross-sections (Appendix C), where total sulfur concentrations are greater than 0.3% (analysis of samples obtained by RC drilling) for resource estimation. It is generally accepted that total sulfur concentrations >0.3% can result in acid generation, i.e. from PAF material. For example, Table 1 identifies the guidelines from Price *et al.*, (1997) indicating the potential for ARD with regards to materials containing sulfides < & > 0.3% sulfide-S.





Table 1: Suggested guidelines for establishing ARD potential from geological materials < & > 0.3% sulfide-S

Sulfide (S%)	Paste pH	NPR	Potential for ARD	Reason
<0.3%	>5.5		None	No further ARD testing required provided there are no other concerns for metal leaching. Exceptions: host rock with no basic minerals, sulfide minerals that are weakly acid soluble
>0.3%	<5.5	<1	Likely	Likely to be ARD generating.
		1-2	Possibly	Possibly ARD generating if NP is insufficiently reactive or is depleted at a rate faster than that of sulfides.
		2-4	Low	Not potentially ARD generating unless significant preferential exposure of sulfides occurs along fractures or extremely reactive sulfides are present together with insufficiently reactive NP
		>4	None	No further ARD testing required unless materials are to be used as a source of alkalinity.

After Price et al., (1997)

3.1.1 Static testing

Static geochemical tests provide information on bulk geochemical characteristics of materials. They do not provide information on rates of chemical processes or the rates of which weathering products are released.

Static testing is a procedure for characterising the physical, chemical, or biological status of a sample at one point in time. It includes measurements of the mineral and chemical composition and the analyses required in ABA procedure.

In the GCA assessment, the following tests were undertaken:

- Acid forming characteristics and salinity;
- Multi-element composition;
- Minor-element solubility; and
- Clay characteristics.





3.1.2 Kinetic testing

Kinetic testing is a procedure used to measure the magnitude and/or effects of dynamic processes, including rates of reaction, material alteration and drainage chemistry and loadings from waste material that results from weathering.

Unlike static tests, kinetic tests measure the performance of a sample over a prolonged period of time. Material composition and/or environmental conditions are often simplified or controlled to permit measurement of the physical, chemical, or biological characteristics, processes or relationships which are of interest.

Kinetic tests have many different forms and locations, including lysimeters, field test pads, leaching columns and humidity cells. In ARD studies, the most common form of kinetic tests are laboratory procedures designed to determine the quality of water and rates of reaction resulting from the interaction of water and the mine material.

Kinetic testing in the GCA assessment involved:

- Waste regolith (the weathered surface material); and
- Waste bedrock (unweathered or fresh basement rock).

For a detailed description of the methodology refer to the GCA report in Appendix A.

Kinetic testing was restricted to the Delta pit as it is intended to be mined first.

3.1.3 Sulfur content: Basement materials

A series of cross-sections (provided by FMS) through all five aforementioned deposits shows the total sulfur concentrations >0.3% in drillholes constructed for the purpose of resource definition. The cross-sections are presented in Appendix B and discussed in the results section.

3.2 Tailings material

The tailings material assessment carried out by GCA used similar methods as for the waste rock analyses (Sections 3.1.1, 3.1.2 and the GCA report in Appendix B (Attachment II)).





4. RESULTS

4.1 Waste rock assessment

4.1.1 Static test results

Detailed results are provided in Appendix A with an overview provided in this Section.

The results are presented for each of the three deposits for which samples were obtained with a summary at the end of the Section.

In the following subsections, 'waste regolith' (oxidised) describes the material above the BoX and 'waste bedrock' (not oxidised) to that material below the BoX.

Delta Deposit

All samples above the BoX contained negligible sulfides and can be described as NAF. The samples were neutral to alkaline (pH 7 to 8) with low concentration of soluble salts.

The waste bedrock samples were classified as both PAF and NAF which indicated the tight spatial variability of pyrite abundance in the basement shale units.

All samples were analysed for their multi-element composition (e.g. arsenic (As), antimony (Sb), selenium (Se), molybdenum (Mo) and boron (B). All analyses correspond to detection limits relevant to environmental baseline assessments. The values cited in the GCA report indicate that the pyrite from the Delta deposit are relatively clean or void of these minor elements.

To assess the stability of the major/minor elements in the samples, a range of waste regolith samples was tested. The concentration of minor elements in the water extractions was either below or close to the respective detection limits consistent with results for mine wastes which are Fe-rich, weakly mineralised and devoid of sulfide and carbonate minerals.

Kaolinite, which has some capacity to buffer mineral acidity, was found to be the sole clay mineral detected in the waste regolith samples i.e. with sodic cation exchange characteristics.

Eagle Deposit

Testing in the Eagle deposit was restricted to static testing.

All waste regolith samples contained negligible sulfides and were classified as NAF and were neutral to alkaline (pH 7 to 8).

The waste bedrock samples were variously classified as PAF or NAF as for the Delta deposit.





The multi-element composition of the Eagle deposit samples was similar to that of Delta deposit.

The waste regolith samples produced water extracts that were circum-neutral (pH 7) and with concentrations close to or below detection limits. The waste bedrock samples produced water extracts that were acidic and enriched in iron (Fe), aluminium (Al) and manganese (Mn).

As with the Delta deposit, kaolinite was the sole clay mineral and the samples were variously sodic.

Champion Deposit

Testing in the Champion deposit was restricted to static testing.

All waste regolith samples contained negligible sulfides and were classified as NAF and with a circum-neutral pH (pH 6 to 8) and low concentrations of soluble salts.

The waste bedrock samples were variously classified as PAF or NAF as for the Delta and Eagle deposits. Sample results indicated only a modest capacity for buffering (neutralising any acidity) by reactive carbonates.

The multi-element composition of the Champion deposit samples was similar to that of the Delta and Eagle deposits.

The waste bedrock samples produced water extracts that were acidic and enriched in iron (Fe), aluminium (Al), manganese (Mn), copper (Cu), nickel (Ni), zinc (Zn) and cobalt (Co).

As with the Delta and Eagle deposits kaolinite was the sole clay mineral and the samples were variously sodic.

4.1.2 Kinetic test results

Kinetic testing was undertaken on a total of 18 Delta deposit samples. No kinetic testing was undertaken on Eagle and Champion deposit samples. Given the high degree of geochemical homogeneity between the deposits, the results can be extrapolated with a high level of confidence.

Delta Deposit

The analyses can be separated into waste regolith and waste bedrock groups and are presented in that format below.

Waste regolith

A range of waste regolith samples were subjected to kinetic testing (weathering columns) to assess minor-element stability in rock types destined to be placed on the outermost





sections of the waste landform at closure, i.e. likely to be subjected to the greatest exposure to weathering in the long term.

Prior to commencing the kinetic testing the bulk geochemistry and mineralogy of the samples were characterised and are consistent with the static testing outlined above.

Weathering of the waste regolith samples yielded negligible amounts of solutes during alternating cycles of desiccation (drying cycle) and inundation (wetting cycle), e.g. the leachate Electrical Conductivity (EC) was less than 100μ S/cm. The concentration of minor-elements was either below or close to the respective detection limits of the analytical instrumentation.

Waste bedrock

Three composite waste bedrock samples were subjected to kinetic testing.

All composites were mildly acidic (pH 4 to 6) with moderate contents of soluble salts, mainly sulfate. Over the course of the six weekly weathering cycles performed, the leachate pH values were typically in the range 5 to 8. Sulfide oxidation rates indicate that the pyrite in the samples is not atypically reactive.

Manganese was the sole metal that exhibited appreciable solubility and reflects dissolution of the mineral siderite ($FeCO_3$ where the Fe ion is commonly replaced by Mn) during weathering. Any iron released was effectively oxidised and precipitated.

4.1.3 In-situ sulfur concentrations

The cross-sections in Appendix C show the proposed pit shells, location of the cross-section relative to the deposit, RC drillhole locations and total sulfur concentrations >0.3% (as identified from analyses of drillhole cuttings). Table 2 provides data on the number of drillholes which intersected bedrock and intersected total sulfur values >0.3%.





Table 2: Resource assessment drillholes with total sulfur values >0.3%

Pit	Line	No. of drillholes	No. of drillholes >0.3% sulfur	Comment
Ajax		11	0	
Badger		11	0	
Blackjack		10	0	
Champion	L8	24	0	
	LII	7	0	
	L19	16	5	All intersections below pit shell
	SE L4	15	4	All intersections below pit shell
Delta	L6	33	5	All intersections below pit shell
	L12	27	1	All intersections below pit shell
	L24	23	1	All intersections below pit shell
Eagle	L1	24	1	All intersections below pit shell
	1250	10	1	All intersections below pit shell
	19525	18	1	All intersections below pit shell
Totals		229	19	8% of all holes presented with total sulfur >0.3%

In summary, of 229 resource evaluation RC drillholes for which sulfur concentrations >0.3% were plotted on cross-sections over the proposed Blacksmith tenement pits, only 19 (8%) 'tested positive'. All intersections were below the proposed pit shells.

4.2 Tailings material

Results of the tailings solids sample submitted are presented in Attachments III and IV of the GCA report presented in Appendix B.

Results indicate that the tailings solid sample analyses contained negligible sulfides (sulfide as S 0.01%) and minute / trace carbonates (CO_3 -C 0.07%) and is classified as NAF.

The tailings solids sample was variously enriched in As, Sb, Se and silver (Ag); however, the degree of enrichment was not marked. The sample was dominated by the minerals haematite with subordinate kaolinite, goethite and quartz.





5. DISCUSSION AND CONCLUSIONS

5.1 Waste rock

The management implications presented in the GCA report reflect a working model of mine waste geochemistry for the Delta, Eagle and Champion deposits specifically but can be extrapolated with confidence to the other deposits given the high degree of geochemical homogeneity exhibited from one deposit to another. This statement is supported by similar results from other deposits in the Pilbara region which share related geology and style of mineralisation (channel iron deposits - CID).

5.1.1 Waste regolith

Geochemically, the various waste regolith units (rocks within the zone of oxidation / weathering) are predicted to be benign, i.e. extremes of pH and salinity should not place constraints on how the materials are managed. The ex-pit waste rock streams should be about neutral pH and of low salinity.

Minor element enrichments should pose no concerns to water quality or uptake by vegetation. The high concentrations of hydrated iron oxides should ensure that minor elements are retained by sorption reactions (i.e. absorption and adsorption).

The majority of waste rock produced during mining is durable and well suited to applications where exposure occurs (rock armouring, construction, bunding etc.). Together with topsoil, these rock types should be identified for use in construction the outermost sections of the waste landforms. Friable materials should be blended with the blocky material and topsoil to allow a rooting medium for vegetation growth.

In summary, waste landform design and rehabilitation should not be constrained by the physicochemical properties of the mine waste streams.

5.1.2 Waste bedrock

Under the current mining plan, the interbedded shales and Banded Iron Formation (BIF) from the unweathered (unoxidised) basement zone of the pits may or may not be disturbed.

If the bedrock is mined, it is expected that a proportion will contain PAF materials which may release circum-neutral sulfates and Mn when inundated by episodic rainfall events above 10-20mm. Waste stream management would need to take into account PAF rock types and isolate such material from the seasonal wetting-front on the waste dumps. NAF material where of suitable strength can be used as the 'skin' of the waste dumps with the PAF material within the core so as to minimise exposure of PAF waste rock to long term wetting and desiccation.





5.1.3 In-situ sulfur concentrations

The in-situ sulfur concentrations obtained from resource definition drilling indicate that all intersections of total sulfur >0.3% occur below the proposed pit shells.

5.2 Tailings

From the test work results obtained in the GCA study (Appendix B), it is concluded that the process tailings to be produced should be geochemically benign because of the strongly weathered and leached condition of the ores *in situ*. As they are subjected to slow, 'residual weathering' under the episodic, pulsed rainfall regime of the Pilbara it is expected that nothing harmful to the environment will be released.

REFERENCE

Price, W.A., Errington, J. and Koyanagi, V. 1997. *Guidelines for the Prediction of Acid Rock Drainage and Metal Leaching for Mines in British Columbia: Part I - General Procedures and Information Requirements*, Proc. 4th International Conference on Acid Rock Drainage, Vancouver, BC, p1-14.





APPENDIX A

GRAEME CAMPBELL & ASSOCIATES PTY LTD Specialists in Mine-Waste Geochemistry, & Soil-Moisture-Retention Testing

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1112 COMPANY: Flinders Mines Limited ATTENTION: Mick Anstey FROM: Graeme Campbell SUBJECT: Flinders Pilbara Iron-Ore Project (FPIOP): Geochemical Characterisation of Mine-Waste Samples from Delta, Eagle, and Champion Pits - Implications for Mine-Waste Management DATE: 15th November 2011 NO. PAGES (including this page): 182

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The occurrences of S, and associated univariate-statistics, for the waste-zones of the Delta, Eagle and Champion Pits, are presented in Attachment I.

Details of the testwork methods employed are presented in Attachment II.

Classification criteria in terms of Acid-Formation Potential (AFP) are summarised in Attachment III.

Copies of the laboratory reports are presented in Attachment IV.

1.0 OREBODY-WIDE APPRAISAL OF SULPHUR-OCCURRENCES

The Exploration-Database (for Delta, Eagle and Champion combined) from which the univariate-statistics of S-occurrences are derived, correspond to Total-S assays at 2-m intervals (Attachment I). <u>The Exploration-Database therefore allows definition of S-occurrences at a "fine-spatial-resolution" within the pit-waste/ore-zones</u>. This "metre-scale-resolution" of S-occurrences is small compared with the likely "mining-resolution" of *c*. 5 m, as controlled by the large equipment to be employed during open-pit mining.

With the exception of the Shale units from within the Basement-Zone (i.e. broadly below the Base-of-Oxidation [BoX]), sulphide-mineral abundance in the various lithotypes is negligible (viz. Total-S values typically less than 0.1 %). This is a generic feature of lithotypes above the BoX at iron-ore mines in the Pilbara.¹

In terms of assessing the potential for the formation of Acid-Rock Drainage (ARD), a "S-threshold/cutoff" of 0.3 % (as S) is employed herein. Although Sulphide-S values less than 0.3 % may result in acidification, this is restricted to specific assemblages of sulphide- and groundmass-minerals. In particular, it applies to lithotypes for which both the sulphide-minerals include hyper-reactive varieties (e.g. framboidal-pyrite), and

¹ Campbell (unpublished results since the late -1980s).

the groundmass comprises simply quartz, soil-clays, and sesquioxides (i.e. devoid of reactive-carbonates, and primary-rock-silicates).² However, this "type-mineralogy" is not characteristic of the mine-waste streams to be produced from above the BoX during the FPIOP.

The Shale units from the Basement-Zone generally contain trace-to-accessory amounts of pyrite, and so are geochemically distinct from the above-BoX lithotypes. The latter are all classified as <u>Non-Acid Forming (NAF)</u>, whereas the former are classified as either NAF, or <u>Potentially-Acid Forming (PAF)</u>, depending on pyrite abundance, as discussed further below.

2.0 GEOCHEMISTRY OF SAMPLES FROM DELTA PIT

In the following, the descriptor "waste-regolith" is used broadly for lithotypes from above the BoX, and "waste-bedrock" is used for lithotypes from below the BoX (i.e. from the Basement-Zone).

2.1 Static-Testing Programme

The testwork results are presented in Tables 1-5, and shown on Figure 1.

2.1.1 Acid-Forming Characteristics and Salinity

All <u>waste-regolith</u> samples contained "negligible-sulphides", and were classified as NAF (Table 1), as expected from statistical appraisal of S-occurrences (Attachment I).

The samples were neutral-to-alkaline (viz. pH 7-8) with low contents of soluble-salts. Such pH and salinity regimes are typical of S-deficient-mine-waste streams produced at iron-ore-mines in the Pilbara.³

The <u>waste-bedrock</u> samples were variously classified as PAF and NAF (Table 1). The Sulphide-S values ranged up to 2.5 %, and the Acid-Neutralisation-Capacity (ANC) values were 17-45 kg H_2SO_4 /tonne. The pH-buffering curves (Figure 1) indicate only a modest capacity for circum-neutral buffering by reactive-carbonates.

Over a 6-m-run, individual-2-m-intervals were either PAF or NAF, and *highlights the* "*tight-spatial-variation*" of pyrite abundance in the Shale units (from Whaleback-Shale and Dales-Gorge members of the Brockman Formation) within the Basement-Zone. Although only three 6-m-runs from the Basement-Zone were assessed herein, the indications are that, due to the paucity of reactive-carbonates, NAF-intervals provide limited geochemical benefit when "mixed" with adjoining PAF-intervals during mining.

² <u>References:</u>

Price W, 2005, "Criteria Used in Material Characterization and the Prediction of Drainage Chemistry: "Screaming Criteria"", Presentation B.1 in "Proceedings of the 12th Annual British Columbia – MEND ML/ARD Workshop on "Challenges in the Prediction of Drainage Chemistry", November 30 to December 1, 2005, Vancouver, British Columbia.

Price WA, Morin K and Hutt N, 1997, "Guidelines for the Prediction of Acid Rock Drainage and Metal Leaching for Mines in British Columbia: Part II. Recommended Procedures for Static and Kinetic Testing", pp. 15-30 in "Proceedings of the Fourth International Conference on Acid Rock Drainage", Volume I, Vancouver.

Campbell GD, unpublished results since the late-1980s.

³ Campbell (unpublished results).

2.1.2 Multi-Element Composition

All samples were analysed for As, Sb, Se, Mo and B (Table 2). These minor-elements occur as oxyanions (e.g. arsenates, antimonates, etc.) in natural systems, and their pH-solubility relationships are such that concentrations can potentially be within the mg/L+ range at circum-neutral-pH. Selected waste-regolith samples were subjected to multi-element analyses (Table 3).⁴ All analyses correspond to detection-limits relevant to environmental, "base-line" assessments.

The samples subjected to multi-element analyses had contents of major- and minorelements below, or close to, those recorded for soils, regoliths, and bedrocks derived from unmineralised terrain (Table 3).

The ranges in contents of the above "oxyanion-minor-element-suite" were (Table 2):

- 6.7-61 mg/kg for As;
- 0.46-3.7 mg/kg for Sb;
- 0.06-2.6 mg/kg for Se;
- 0.6-5.4 mg/kg for Mo; and,
- less than 50 mg/kg, to 100 mg/kg, for B.

The above Total-As, Total-Sb, Total-Se, Total-Mo, and Total-B contents above fall within the range generally recorded for mine-waste samples derived from other iron-ore mines on the Pilbara block, especially for lithotypes devoid of sulphide-minerals (e.g. located above the BoX).⁵ That the waste-bedrock samples also had modest contents of these minor-elements means that, environmentally, the contained pyrite was relatively "clean", and reflects the nature of mineralisation within the Delta Deposit.

2.1.3 Minor-Element Solubility

To assess the stability of major/minor-elements, a range of <u>waste-regolith</u> samples was subjected to Water-Extraction Tests (Table 4).⁶ In this testwork, crushed samples (nominal -2 mm) were extracted for *c*. 1 day via the bottle-roll technique, employing slurries prepared from deionised-water, at a solid:solution ratio of *c*. 1:2 (w/w). The resulting water-extracts were centrifuged, filtered (0.45-µm-membrane), and preserved, as appropriate, for specific analyses (see Attachment II).⁷

<u>Note</u>: To assist interpretation of the Water-Extraction-Test results, a broad comparison may be made between the testwork conditions, and elution of solutes from the surficial-zone of the waste-dumps by rainfall. The solid:solution ratio employed in the testing was c. 1:2 (w/w). If the Dry-Bulk-Density (DBD) of the mixture of the fine-earth (viz. -2 mm) fraction, and clasts, is

⁴ Multi-element analyses were undertaken on the composite-waste-bedrock samples subjected to kinetic-testing (Section 2.2.2).

⁵ Campbell (unpublished results).

⁶ Additional waste-regolith samples were subjected to kinetic-testing (Section 2.2.1). Water-Extraction Tests were not undertaken on "individual-waste-bedrock" samples, since composite-waste-bedrock samples were subjected to kinetic-testing (Section 2.2.2).

⁷ It should be noted that, despite centrifuging, it often proved difficult to vacuum-filter the water-extracts through a 0.45μm-membrane, due to "ultrafines" likely approaching near-colloidal dimensions. A combination of low ionic-strengths, and particle-particle abrasion during continuous agitation, likely accounts for the generation of ultrafines during the water-extraction testwork.

 $c. 2.0 \text{ t/m}^3$, then for an annual rainfall of c. 300-400 mm, the "equivalent" solid:solution ratio experienced by the top 0.1 m may be taken as c. 1:2 (w/w). Therefore, the testwork results broadly correspond to the efficient leaching of the top decimetre of a mine-waste-profile by a year's worth of rainfall, and where all drainage-waters are collected in a dam without any mixing with runoff-waters derived from up-catchment areas. Although approximate, this comparison assists in placing the testwork results into broad perspective in terms of water-quality contexts for downstream environs. Nonetheless, sight must not be lost of the testwork conditions employed (viz. samples as powders in suspensions that were continuously agitated). The Water-Extraction Tests herein serves simply to identify any weakly-bound forms of solutes which are susceptible to release to solution upon contact with meteoric-waters.

The concentration of minor-elements in the water-extracts were either below, or close to, the respective detection-limits (viz. typically within the range 0.1-10 μ g/L) [Table 4]. These results are consistent with the hydrogeochemical expectation of a sparingly-low solubility of minor-elements (at circum-neutral-pH) for mine-wastes which are Ferich, weakly-mineralised, and devoid of sulphide- and carbonate-minerals.

The Se concentrations in the water-extracts ranged up to 0.5 μ g/L, corresponding to test-slurries with a solid:solution ratio of *c*. 1:2 (w/w). In related water-extraction testwork on ferruginous-overburden samples from the Yandi Iron-Ore Mine, Gardiner (2003) reported Se concentrations in water-extracts of *c*. 21-43 μ g/L (see Tables 3.11-3.13 in Gardiner [2003]), corresponding to test-slurries with a solid:solution ratio of *c*. 1:20 (w/w).⁸ When expressed in terms of μ g of Se extracted per kg of dry-solids, the mine-waste samples tested in the present study had Water-Extractable-Se contents ranging up to *c*. 1 μ g Se/kg, whereas Gardiner (2003) reported Water-Extractable-Se contents within the range *c*. 400-900 μ g Se/kg. There is therefore more than a 100-fold difference in the Water-Extractable-Se contents between this study, and that of Gardiner (2003). Based on the latter results, it was concluded that elevated Se solubility could be a water-quality issue for pit-lakes at mine-closure. However, there are numerous inconsistencies in the Se (and other) results reported by Gardiner (2003). Given the potential implications of such apparent Se-solubility behaviour to the iron-ore-mining industry generally, it is justified to critique these Se-analysis anomalies.

Anomalous-Results from Gardiner (2003): Sample LAET-908 had a Total-Se content less than 0.01 mg/kg (Table 3.7), yet its Water-Extractable-Se content (calculated from the Water-Extract-Se concentration of 31.5 μ g/L in Table 3.12) is 0.63 mg/kg. Related discrepancies occur for the Zn results. Water-Extract-Fe concentrations ranged up to 13.2 mg/L (Table 3.13) which are untenable for "true" Soluble-Fe forms at circum-neutral-pH, and the oxic-redox conditions of the test-slurries employed in the water-extraction testwork. Finally, several water-extracts had apparent alkalinities greater than 1,000 mg/L (as CaCO₃), and Ca concentrations within the range *c*. 200-800 mg/L, yet the corresponding EC values were only *c*. 80-150 μ S/cm (Tables 3.11-3.13). These anomalous results can be explained by the occurrence of ultra-fine (i.e. sub- μ m-sized) forms of carbonate-minerals (e.g. calcites), clays and Fe/Al-sesquioxides which passed through the 0.45 μ m-membrane, and then released bound forms of minor-elements (e.g. Se and Zn) to solution when the filtrates were preserved for analysis by acidifying with HNO₃. In a similar fashion, for the analysis of the unacidified water-extracts, consumption of HCl in acidimetric titration to determine alkalinities chiefly reflected dissolution of suspended ultra-fine forms of carbonate-minerals, etc. (c.f. "true" HCO₃ in solution).

The net outcome of the above critique is that the stability of Se (and other minor-elements) in Sdeficient varieties of mine-wastes at iron-ore-mines in the Pilbara is likely considerably greater, and therefore solubility at circum-neutral-pH considerably lower, than reported by Gardiner

⁸ Gardiner SJ, 2003, "Impacts of Mining and Mine Closure on Water Quality and the Nature of the Shallow Aquifer, Yandi Iron Ore Mine", MSc Thesis, Department of Applied Geology, Curtin University of Technology, Drs R Watkins and C Evans as Supervisors.

(2003).⁹ Selenium (and other minor-elements) certainly correspond to forms of high stability for the mine-waste samples tested herein.

In brief, minor-element solubility at circum-neutral-pH (viz. "metalliferous-drainage") should not be an issue for management of the "gutless" waste-regolith streams produced during from the Delta Pit. This conclusion is further supported by the kinetic-testing discussed below.

2.1.4 Clay-Mineralogy and Clay-Surface-Chemistry

Kaolinite was the sole phyllosilicate (viz. clay-mineral) detected in the waste-regolith samples subjected to mineralogical assessment (Table 5).

The Effective-Cation-Exchange-Capacity (eCEC) values were 2.3-3.2 cmol (p+)/kg, and the Exchangeable-Sodium-Percentage (ESP) values were *c*. 24-34 %. The samples were therefore variously sodic.

2.2 Kinetic-Testing Programme

The testwork results are presented in Tables 6-13.

2.2.1 Waste-regoliths

A range of waste-regolith samples were subjected to kinetic-testing (viz. Weathering-Columns) in order to extend the findings the Water-Extraction Tests above, and thereby allow <u>further assessment of minor-element stability in lithotypes destined to be placed in the outermost sections of the waste-landforms at closure.</u>

Details of the kinetic-testing are presented in Attachment II. In broad terms, the leachates produced from the weathering-columns approximate flushing of the top few decimetres of mine-wastes (comprising a mixture of fine-earth [-2mm], and clast fractions) by a storm-depth of c. 40-50 mm. The "store" of solutes produced during the drying-phase broadly corresponds to that associated with evaporative-drying to residual moistures/suctions over the course of a few days.

The samples tested represent the six (6) generic types of waste-regoliths to be produced from the Delta Pit, viz.

DID1, DID2, DID3, DID4, CID, and BID

Prior to commencing the kinetic-testing, the "bulk-geochemistry" and mineralogy of these samples were characterised (Tables 6-8), and are consistent with the results of the static-testing discussed above.

The leachate-analysis results for up to six (6) weekly-weathering-cycles, including a pre-rinse-cycle, are presented in Table 9. All leachate were subjected to "full-chemical-analysis" comprising the determination of major-parameters, and major/minor-elements via multi-element analyses. The leachates were often turbid, due to "ultra-fines" which often passed through the 0.45-µm-membrane during vacuum-filtration. Accordingly, the Filtrable-Minor-Element concentrations are variously biased "on-the-high-side", due

⁹ This misleading information reported by Gardner (2003) has been flagged in a number of recent GCA-reports for proposed iron-ore Projects in the Pilbara.

to contributions from ultra-fine-particulate forms (e.g. Fe/Al-sesquioxides of "near-nano" dimensions, etc.).¹⁰

Weathering of the waste-regolith samples yielded negligible amounts of solutes during alternating cycles of desiccation and inundation (e.g. the Leachate-EC values were always less than 100 μ S/cm, and could decrease to less than the detection-limit of 10 μ S/cm).¹¹ The concentration of minor-elements in the leachates were either below, or close to, the respective detection-limits (viz. typically within the range 0.1-10 μ g/L). Similar results were obtained in the Water-Extraction Tests.

Summarising, the very nature of the "gutless" waste-regoliths means that, weatheringwise, they simply have "nothing-to-give" hydrogeochemically. This reflects their generic "negligible-S-tenor", and heavily-leached state from weathering *in situ* typical of geomedia above the BoX on the Pilbara block. Accordingly, minor-elements occur as stable forms of low solubility at "ambient-pH" (i.e. circum-neutral-pH).

2.2.2 Waste-bedrocks

Three (3) composite-waste-bedrock samples were subjected to kinetic-testing, viz.

• Shl, Shl-(WS), and, Shl-(DGS).

The composites were equal-weight-composites prepared using the crushed-splits (viz. - 2 mm) of the respective "individual-samples".

All composites were mildly-acidic (pH c. 4-6) with moderate contents of soluble-salts (chiefly sulphates) [Table 10]. The Sulphide-S values were 1.3-2.0 %, corresponding to accessory amounts of pyrite (Table 12). There was also accessory amounts of siderites with a lattice-Mn-mole fraction up to c. 5 %. Although variously enriched in As, Sb and Se, the degree of enrichment in these minor-elements was not marked (Table 11).

Over the six (6) weekly-weathering-cycles performed, the Leachate-pH values were typically within the range 5-8 (Table 13).

Calculations indicate that, over Cycle-4 to Cycle-6, steady Sulphide-Oxidation Rates (SORs) of *c*. 50-90 mg SO₄/kg/week were attained. Given the Sulphide-S values of 1.3-2.0 %, and the Leachate-pH values of *c*. 5-8, such SORs indicate that the pyrite in the samples is not atypically reactive.

Manganese was the sole metal which exhibited appreciable solubility (viz. Leachate-Mn concentrations ranging up to *c*. 40-50 mg/L). Such Mn solubility reflects dissolution of the siderites during weathering. Any Fe(II) released from siderite dissolution was effectively oxidised to Fe(III), followed by hydrolysis/precipitation for form Fe(III)-oxyhydroxides, since the Leachate-Fe concentrations were typically less than the detection-limit of 0.01 mg/L.

Summarising, the weathering-cycles completed for the PAF-composite-waste-bedrock samples correspond to the <u>initial "lag-phase" stage of weathering</u> (viz. the period during which sulphide-oxidation occurs, but acidifications is suppressed, due to circum-neutral-buffering by groundmass-minerals). In addition to potable-to-brackish (SO₄-

¹⁰ Related "ultra-fines" were also recorded in the water-extracts discussed above.

¹¹ EC = Electrical-Conductivity.

dominated) salinities, lag-phase weathering is associated with Mn concentrations within the mg/L+ range (associated with siderite dissolution).

3.0 GEOCHEMISTRY OF SAMPLES FROM EAGLE PIT

Testing of samples from the Eagle Pit was restricted to static-testing. The testwork results are presented in Tables 14-18.

3.1 Acid-Forming Characteristics and Salinity

All <u>waste-regolith</u> samples contained "negligible-sulphides", and were classified as NAF (Table 14), as expected from statistical appraisal of S-occurrences (Attachment I). The samples were neutral-to-alkaline (viz. pH 7-8) with low contents of soluble-salts.

The <u>waste-bedrock</u> samples were variously classified as PAF and NAF (Table 14). The Sulphide-S values ranged up to 2.5 %, and the ANC values ranged up to 26 kg H_2SO_4 /tonne.

Over a 6-m-run, individual-2-m-intervals were either PAF or NAF, and highlights the "tight-spatial-variation" of pyrite abundance in the Shale units (from Whaleback-Shale and Dales-Gorge members of the Brockman Formation) within the Basement-Zone.

The above findings closely match those for the mine-waste samples from the Delta Pit.

2.2 Multi-Element Composition

All samples were analysed for As, Sb, Se, Mo and B (Table 15), and selected wastebedrock samples were subjected to multi-element analyses (Table 16).

The ranges in contents of the above "oxyanion-minor-element-suite" were:

- 7.7-51 mg/kg for As;
- 0.74-4.0 mg/kg for Sb;
- 0.24-3.9 mg/kg for Se;
- 1.0-3.4 mg/kg for Mo; and,
- less than 50 mg/kg for B.

The above Total-As, Total-Sb, Total-Se, Total-Mo, and Total-B contents were similar to those for the samples from the Delta Pit.

3.3 Minor-Element Solubility

The <u>waste-regolith</u> samples subjected to the Water-Extraction Tests produced waterextracts that were circum-neutral, and with concentrations of minor-elements either below, or close to, the respective detection-limits (viz. typically within the range 0.1-10 μ g/L) [Table 17].

The <u>waste-bedrock</u> samples produced water-extracts that were acidic, and enriched in Soluble-Fe, -Al, and -Mn forms.

3.4 Clay-Mineralogy and Clay-Surface-Chemistry

Kaolinite was the sole phyllosilicate (viz. clay-mineral) detected in the waste-regolith samples subjected to mineralogical assessment (Table 18).

The eCEC values were 1.6-3.5 cmol (p+)/kg, and the ESP values were *c*. 17-54 %. The samples were therefore variously sodic.

4.0 GEOCHEMISTRY OF SAMPLES FROM CHAMPION PIT

Testing of samples from the Champion Pit was restricted to static-testing. The testwork results are presented in Tables 19-23.

4.1 Acid-Forming Characteristics and Salinity

All <u>waste-regolith</u> samples contained "negligible-sulphides", and were classified as NAF (Table 19), as expected from statistical appraisal of S-occurrences (Attachment I). The samples were circum-neutral (viz. pH 6-8) with low contents of soluble-salts.

The <u>waste-bedrock</u> samples were variously classified as PAF and NAF (Table 19). The Sulphide-S values ranged up to 2.8 %, and the ANC values ranged up to 38 kg H_2SO_4 /tonne. Although only a small population of samples was tested, the indications are that the groundmass of the samples from the Champion Pit are less than those for the Delta and Eagle Pits. The pH-buffering curve (Figure 2) for sample GCA9726 (Shl) indicate only a modest capacity for circum-neutral buffering by reactive-carbonates.

There was no systematic variation in the acid-forming characteristics between the "skin" and "core" samples collected from drillhole HPRC0345 (Attachment I).

The above findings accord with those for the mine-waste samples from the Delta and Eagle Pits.

4.2 Multi-Element Composition

All samples were analysed for As, Sb, Se, Mo and B (Table 20), and selected wastebedrock samples were subjected to multi-element analyses (Table 21).

The ranges in contents of the above "oxyanion-minor-element-suite" were:

- 9.5-91 mg/kg for As;
- 0.94-5.6 mg/kg for Sb;
- 0.28-2.8 mg/kg for Se;
- 0.6-3.6 mg/kg for Mo; and,
- less than 50 mg/kg for B.

The above Total-As, Total-Sb, Total-Se, Total-Mo, and Total-B contents were similar to those for the samples from the Delta and Eagle Pits.

4.3 Minor-Element Solubility

The <u>waste-bedrock</u> samples subjected to the Water-Extraction Tests produced waterextracts that were acidic, and enriched in Soluble-Fe, -Al, -Mn, -Cu, -Ni, -Zn, and -Co forms (Table 22).

4.4 Clay-Mineralogy and Clay-Surface-Chemistry

Kaolinite was the sole phyllosilicate (viz. clay-mineral) detected in the waste-regolith samples subjected to mineralogical assessment (Table 23).

The eCEC values were 2.4-3.1 cmol (p+)/kg, and the ESP values were *c*. 14-57 %. The samples were therefore variously sodic.

5.0 IMPLICATIONS FOR MINE-WASTE MANAGEMENT

The management implications outlined below reflect a working-model of mine-waste geochemistry for the Delta, Eagle and Champion Pits developed from the testwork results obtained in this study, as well as experience with other deposits on the Pilbara block which share a related geology, and style of mineralisation (viz. "channel-type-iron-ore deposits").

5.1 Waste-regoliths

Geochemically, the various waste-regolith units (i.e. lithotypes above the BoX) from all Pits should be benign (i.e. extremes in pH and/or salinity should <u>not</u> place constraints on how such materials are managed). The 'ex-pit' streams of the waste-regolith units should be circum-neutral, and of low salinity. Such pH and salinity regimes should prevail over the longer-term during weathering on the waste-dumps, as governed by the frequency, and penetration-depth, of the seasonal wetting-front.¹²

Since the remnant "chalcophyle-signature" reflecting mineralisation is weak, minorelement enrichments should pose no concerns to water-quality, or uptake by plant-roots. The abundance of Fe-oxyhydroxides should ensure that minor-elements are retained by sorption reactions of the "high-affinity/poorly-reversible" type, as have occurred *in situ* over the eons.

Since the majority of the lithotypes produced during mining are competent, chunky and durable, they are well suited to applications where exposure occurs over the longer-term (e.g. rock-armouring, construction of pit-safety-bund, etc.). Where earthy, friable lithotypes are produced, their susceptibility to erosion should be dampened by the expected abundance of clasts, and the fact that their "fine-earth" fraction (viz. -2 mm) should not be enriched in smectites (i.e. "high-activity" clays that exhibit marked shrink-swell behaviour). Together with topsoils, such lithotypes should be earmarked for use in constructing the outermost-sections of the waste-landforms, so that water-retention capacities, in particular, are favourable to vegetation. However, since friable materials are susceptible to erosion, a balance needs to be struck between creating a

¹² Campbell GD, 2008, "Mine-Waste Geochemistry, Rainfall Seasonality, and Coincidence of the Wetting/Oxidation-Fronts: A Conceptual Arid-Zone Weathering Model", PowerPoint-presentation delivered at the May 2008 Workshop of the Goldfields Environmental Management Group, Kalgoorlie. Campbell GD, 2007, "Isolation of Reactive Mine-Wastes in the WA Goldfields: How Arid-Zone Weathering and Hydroecology Simplify Cover-Design Studies", Section 8 in "Planning for Mine-Closure Seminar", Australian Centre for Geomechanics, 14-15 June 2007, 40 pp.

profile which is <u>both</u> texturally suitable as a rooting-medium for plant growth, <u>and</u> physically stable. These challenges are generic to mine-waste management at hard-rock mines.

In brief, waste-landform design and rehabilitation should not be constrained by the physicochemical nature of the mine-waste streams. Planning for waste-landform decommissioning should integrate industry best-practice concepts for rehabilitation and mine-site closure (DITR 2006a,b), and the practical know-how from other Pilbara iron-ore mines.¹³

5.2 Waste-bedrocks

It is understood that, based on the current mining-plan, the interbedded Shales and BIFs from the Basement-Zone (i.e. waste-bedrocks below the BoX) of the Pits may, or may not, be disturbed.

If the waste-bedrocks are mined, then the indications are that most truckloads will comprise PAF-rock overall, and reflects the spatial distribution of "trace/accessory-pyrite" in a sideritic-groundmass. The 'ex-pit' streams of such PAF-rock should be potential "source-terms" of moderate strength for circum-neutral-sulphates, and Mn, when inundated by episodic rainfall of sizeable storm-depths (e.g. above 10-20 mm). Provision would therefore need to be made to isolate such lithotypes beneath the reach of the seasonal wetting-front on the waste-dumps.

6.0 CLOSURE

I trust the above is useful to you.

Regards,

Dr GD Campbell Director

¹³ Department of Industry, Tourism and Resources, 2006a, "Mine Closure and Completion", Leading Practice Sustainable Development Program for the Mining Industry, Canberra. Department of Industry, Tourism and Resources, 2006b, "Mine Rehabilitation", Leading Practice Sustainable Development Program for the Mining Industry, Canberra.

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Table 1: Acid-Base-Analysis and Net-Acid-Generation Results for Mine-Waste Samples (Delta)

GCA-	SITE-	DRILLHOLE &			EC-(1:2)	TOTAL-S	SO ₄ -S	SULPHIDE-	TOTAL-C	CO ₃ -C	ANC	NAPP	NAG		ANC/	AFP
SAMPLE	SAMPLE	DOWN-HOLE	LITHOTYPE	pH-(1:2)	[mS/cm]	(%)	(%)	S (%)	(%)	(%)	kg l	H ₂ SO ₄ /ton	ne	NAG-pH	MPA	CATEGORY
NO.	NO.	INTERVAL (m)													RATIO	
Samples from	n Above-BoX	(= "waste-regoliths"														
GCA9665	HPDS001	HPRC2170, 4-6	RC	8.0	0.16	0.02 [0.011]	< 0.01	0.02	0.17 (0.16)	0.11 (0.11)	16 (19)	nc	<0.5	8.3	nc	NAF
GCA9666	HPDS002	HPRC2170, 28-30	DID1	8.0	0.083	0.03 [0.012]	< 0.01	0.03	0.07	0.02	4	nc	<0.5	6.5	nc	NAF
GCA9667	HPDS003	HPRC2135, 24-26	DID1	7.9	0.038	0.04 [0.015]	< 0.01	0.04	0.08	0.02	3	nc	< 0.5	6.1	nc	NAF
GCA9668	HPDS004	HPRC2087, 22-24	DID1	7.7	0.054	0.04 [0.020]	< 0.01	0.04	0.06	< 0.01	4	nc	<0.5	6.2	nc	NAF
GCA9669	HPDS005	HPRC3152, 10-12	DID2	7.8	0.053	0.04 [0.020]	< 0.01	0.04	0.10	0.04	3	nc	< 0.5	5.9	nc	NAF
GCA9670	HPDS006	HPRC2105, 14-16	DID2	7.6	0.028	0.03 [0.016]	< 0.01	0.03	0.09	0.05	3	nc	< 0.5	6.0	nc	NAF
GCA9671	HPDS007	HPRC2218, 20-22	DID2	7.6	0.029	0.04 [0.021]	< 0.01	0.04	0.09	0.05	3	nc	<0.5	5.9	nc	NAF
GCA9672	HPDS008	HPRC3152, 22-24	DID3	7.5	0.096	0.05 [0.029]	< 0.01	0.05	0.10	0.02	3	nc	< 0.5	5.4	nc	NAF
GCA9673	HPDS009	HPRC2105, 32-34	DID3	7.2	0.030	0.03 [0.016]	< 0.01	0.03	0.11	0.03	4	nc	<0.5	5.4	nc	NAF
GCA9674	HPDS010	HPRC3013, 22-24	DID3	6.8	0.10	0.03 [0.014]	< 0.01	0.03	0.11	0.06	4	nc	<0.5	5.9	nc	NAF
GCA9675	HPDS011	HPRC2171, 52-54	DID4	7.1 (7.2)	0.032 (0.026)	0.03 [0.010]	< 0.01	0.03	0.18	0.10	4	nc	< 0.5	5.2	nc	NAF
GCA9676	HPDS012	HPRC3152, 40-42	DID4	7.2	0.043	0.02 [0.010]	< 0.01	0.02	0.11	0.05	3	nc	<0.5	5.0	nc	NAF
GCA9677	HPDS013	HPRC3013, 24-26	DID4	7.2	0.027	0.02 [0.013]	< 0.01	0.02	0.15	0.10	3	nc	<0.5	5.5	nc	NAF
GCA9678	HPDS014	HPRC2177, 84-86	CID	6.8	0.071	0.02 [0.005]	< 0.01	0.02	0.19	0.13	4	nc	<0.5	6.0	nc	NAF
GCA9679	HPDS015	HPRC3156, 50-52	BID	7.0	0.042	0.02 [0.008]	< 0.01	0.02	0.14	0.09	3	nc	< 0.5	6.0	nc	NAF
GCA9680	HPDS016	HPRC3013, 34-36	BID	6.8	0.066	0.02 [0.023]	< 0.01	0.02	0.45	0.19	6	nc	< 0.5	5.9	nc	NAF
GCA9681	HPDS017	HPRC2105, 42-44	BID	6.9	0.047	0.03 [0.030]	< 0.01	0.03	0.31	0.15	5	nc	<0.5	5.6	nc	NAF
Samples from	n Basement [= Below-BoX] (i.e. "wa	ste-bedrocks")													
GCA9682	HPDS018	HPRC2197, 50-52	Shl	4.4	1.2	1.2 [1.04]	0.23	1.0	2.3	1.5	25	5.6	2.3 (3.2)	3.7 (3.7)	<1	PAF
GCA9683	HPDS019	HPRC2197, 52-54	Shl	3.8	1.6	2.7 [2.36]	0.31	2.5	3.1	2.2	34	43	23	3.6	<1	PAF
GCA9684	HPDS020	HPRC2197, 54-56	Bif	6.1	0.59	0.39 [0.382]	0.02	0.37	3.7	3.5	45	-33	<0.5	7.5	>3	NAF
GCA9685	HPDS021	HPRC3027, 42-44	Shl-(WS)	4.6 (4.6)	1.4 (1.4)	2.1 [1.43]	0.21	1.9	3.6	2.8	22 (26)	37	9.5	4.2	<1	PAF
GCA9686	HPDS022	HPRC3027, 44-46	Shl-(WS)	5.3	1.8	2.7 [2.50]	0.23	2.5	4.1	3.4	33	44	17	4.0	<1	PAF
GCA9687	HPDS023	HPRC3027, 46-48	Bif	6.2	0.39	0.18 [0.197]	< 0.01	0.18	3.2	3.0	42	-36	<0.5	8.0	>3	NAF
GCA9688	HPDS024	HPRC2323, 80-82	Shl-(DGS)	5.6	1.2	1.9 [1.68]	0.14	1.8	1.7	0.97	17	39	28	2.7	<1	PAF
GCA9689	HPDS025	HPRC2323, 82-84	Bif	6.4	0.32	0.09 [0.126]	< 0.01	0.09	1.0	0.94	24	nc	< 0.5	8.0	nc	NAF
GCA9690	HPDS026	HPRC2323, 84-86	Shl-(DGS)	6.6	0.41	0.69 [0.531]	0.02	0.67	3.1	3.0	27	-6.4	< 0.5	7.7	1.3	PAF

Notes: EC = Electrical Conductivity; ANC = Acid-Neutralisation-Capacity; NAPP = Net-Acid-Producing-Potential; AFP = Acid-Formation-Potential; NAG = Net-Acid Generation; nc = not calculated; NAF = Non-Acid-Forming; PAF = Potentially-Acid Forming, pH-(1:2) and EC-(1:2) values correspond to pH and EC measured on sample slurries prepared with deionised-water, and a solid:solution ratio of c. 1:2 (w/w).

All results expressed on a dry-weight basis, except for pH-(1:2), EC-(1:2), and NAG-pH. Values in round-parentheses represent duplicates.

N.B. Total-S values in square-parentheses correspond to results from Exploration-Database.

						TOTAL-	TOTAL-		
GCA-	SITE-	DRILLHOLE &		SULPHIDE-S	TOTAL-As	Sb	Se	TOTAL-Mo	TOTAL-B
SAMPLE	SAMPLE	DOWN-HOLE	LITHOTYPE	(%)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
NO.	NO.	INTERVAL (m)							
Samples from A	bove-BoX (=	"waste-regoliths"							
GCA9665	HPDS001	HPRC2170, 4-6	RC	0.02	8.8	0.98	0.47	0.8	<50
GCA9666	HPDS002	HPRC2170, 28-30	DID1	0.03	8.6	0.99	0.28	0.9	<50
GCA9667	HPDS003	HPRC2135, 24-26	DID1	0.04	13	1.4	0.34	1.5	<50
GCA9668	HPDS004	HPRC2087, 22-24	DID1	0.04	8.2	1.0	0.52	1.0	<50
GCA9669	HPDS005	HPRC3152, 10-12	DID2	0.04	20	2.2	1.1	2.0	<50
GCA9670	HPDS006	HPRC2105, 14-16	DID2	0.03	12	1.3	0.60	1.5	<50
GCA9671	HPDS007	HPRC2218, 20-22	DID2	0.04	17	1.8	0.49	1.6	<50
GCA9672	HPDS008	HPRC3152, 22-24	DID3	0.05	22	2.1	0.76	1.9	<50
GCA9673	HPDS009	HPRC2105, 32-34	DID3	0.03	16	1.8	0.29	3.2	<50
GCA9674	HPDS010	HPRC3013, 22-24	DID3	0.03	13	2.1	0.26	3.8	<50
GCA9675	HPDS011	HPRC2171, 52-54	DID4	0.03	13	1.8	0.32	3.0	<50
GCA9676	HPDS012	HPRC3152, 40-42	DID4	0.02	13	2.2	0.14	3.7	<50
GCA9677	HPDS013	HPRC3013, 24-26	DID4	0.02	12	2.7	0.34	4.9	<50
GCA9678	HPDS014	HPRC2177, 84-86	CID	0.02	21	2.2	0.39	1.6	<50
GCA9679	HPDS015	HPRC3156, 50-52	BID	0.02	6.7	0.74	0.31	0.7	<50
GCA9680	HPDS016	HPRC3013, 34-36	BID	0.02	17	1.3	2.6	1.6	<50
GCA9681	HPDS017	HPRC2105, 42-44	BID	0.03	17	0.78	1.8	1.5	<50
Samples from B	Basement [= E	Below-BoX] (i.e. "waste-	bedrocks")						
GCA9682	HPDS018	HPRC2197, 50-52	Shl	1.0	35	2.8	1.6	2.6	<50
GCA9683	HPDS019	HPRC2197, 52-54	Shl	2.5	48	3.2	2.1	2.7	<50
GCA9684	HPDS020	HPRC2197, 54-56	Bif	0.37	24	0.58	0.41	0.7	66
GCA9685	HPDS021	HPRC3027, 42-44	Shl-(WS)	1.9	44	3.4	1.3	2.9	<50
GCA9686	HPDS022	HPRC3027, 44-46	Shl-(WS)	2.5	37	3.5	1.4	2.6	<50
GCA9687	HPDS023	HPRC3027, 46-48	Bif	0.18	16	0.46	0.19	0.6	100
GCA9688	HPDS024	HPRC2323, 80-82	Shl-(DGS)	1.8	61	3.7	0.82	5.4	<50
GCA9689	HPDS025	HPRC2323, 82-84	Bif	0.09	8.1	0.63	0.06	0.7	<50
GCA9690	HPDS026	HPRC2323, 84-86	Shl-(DGS)	0.67	32	1.1	0.45	1.2	<50
			. ,						

Table 2: Total-Contents of As, Sb, Se, Mo and B in Mine-Waste Samples (Delta)

	TOTAL-ELEN	MENT CONTEN	Г (mg/kg or %)	AVERAGE-	GEOCHEMICAL-ABUNDANCE INDEX			
ELEMENT	RC	DID1	DID2	CRUSTAL	RC	DID1	DID2	
				ABUNDANCE				
	(GCA9665)	(GCA9667)	(GCA9669)	(mg/kg or %)	(GCA9665)	(GCA9667)	(GCA9669)	
Al	2.2%	2.9%	2.7%	8.2%	0	0	0	
Fe	40.2%	50.7%	55.8%	4.1%	3	3	3	
Na	0.033%	0.0095%	0.015%	2.3%	0	0	0	
K	0.20%	0.08%	0.11%	2.1%	0	0	0	
Mg	0.12%	0.06%	0.04%	2.3%	0	0	0	
Ca	0.6%	0.2%	0.2%	4.1%	0	0	0	
Ag	0.06	0.04	0.02	0.07	0	0	0	
Cu	15	12	8	50	0	0	0	
Zn	17	8	9	75	0	0	0	
Cd	0.09	0.05	< 0.02	0.11	0	0	0	
Pb	7.8	11	12	14	0	0	0	
Cr	160	54	110	100	0	0	0	
Ni	10	9	8	80	0	0	0	
Co	2.9	2.2	1.7	20	0	0	0	
Mn	210	160	110	950	0	0	0	
Hg	0.02	< 0.01	< 0.01	0.05	0	0	0	
Sn	1.1	1.7	1.9	2.2	0	0	0	
Sr	31	7.9	7.8	370	0	0	0	
Ba	110	21	35	500	0	0	0	
Th	4.6	6.3	8.4	12	0	0	0	
U	0.81	1.4	1.7	2.4	0	0	0	
T1	0.13	0.04	0.03	0.6	0	0	0	
V	71	110	55	160	0	0	0	
As	11	14	21	1.5	2	3	3	
Bi	0.16	0.21	0.28	0.048	1	2	2	
Sb	1.3	1.7	2.5	0.2	2	3	3	
Se	0.45	0.34	1.1	0.05	3	2	4	
Mo	0.9	1.5	2.0	1.5	0	0	0	
В	<50	<50	<50	10	0	0	0	
Р	500	380	360	1,000	0	0	0	
F	160	160	120	950	0	0	0	

Table 3: Multi-Element-Analysis Results for Mine-Waste Samples (Delta)

Note: Average-crustal abundance of elements based on Bowen (1979), and the Geochemical-Abundance Index (GAI) is based on Förstner *et al.* (1993). Refer Attachment II.

	TOTAL-ELEN	MENT CONTENT	Г (mg/kg or %)	AVERAGE-	GEOCHEMIC	AL-ABUNDANC	E INDEX (GAI)
ELEMENT	DID3	DID4	BID	CRUSTAL	DID3	DID4	BID
				ABUNDANCE			
	(GCA9673)	(GCA9676)	(GCA9681)	(mg/kg or %)	(GCA9673)	(GCA9676)	(GCA9681)
Al	2.3%	0.49%	1.8%	8.2%	0	0	0
Fe	59.1%	61.0%	55.4%	4.1%	3	3	3
Na	0.0033%	0.0053%	0.0027%	2.3%	0	0	0
K	0.10%	0.09%	0.07%	2.1%	0	0	0
Mg	0.04%	0.04%	0.04%	2.3%	0	0	0
Ca	0.2%	0.2%	0.2%	4.1%	0	0	0
Ag	0.08	0.03	0.08	0.07	0	0	0
Cu	1	<1	12	50	0	0	0
Zn	10	11	34	75	0	0	0
Cd	0.02	< 0.02	0.05	0.11	0	0	0
Pb	9.9	5.5	6.0	14	0	0	0
Cr	56	<50	93	100	0	0	0
Ni	5	4	10	80	0	0	0
Co	1.3	1.9	7.3	20	0	0	0
Mn	140	520	440	950	0	0	0
Hg	< 0.01	0.05	0.13	0.05	0	0	1
Sn	2.6	2.5	1.3	2.2	0	0	0
Sr	3.6	2.6	1.8	370	0	0	0
Ba	7.4	9.8	51	500	0	0	0
Th	3.9	1.6	1.8	12	0	0	0
U	0.88	0.38	1.2	2.4	0	0	0
Tl	< 0.02	< 0.02	< 0.02	0.6	0	0	0
V	69	47	58	160	0	0	0
As	16	13	18	1.5	3	3	3
Bi	0.23	0.23	0.13	0.048	2	2	1
Sb	2.1	2.5	1.1	0.2	3	3	2
Se	0.29	0.14	1.8	0.05	2	1	5
Мо	3.2	3.8	1.6	1.5	1	1	0
В	<50	<50	<50	10	0	0	0
Р	480	750	1,800	1,000	0	0	0
F	150	150	260	950	0	0	0

Table 3 (Cont'd):Multi-Element-Analysis Results for Mine-Waste Samples (Delta)
Table 4: Water-Extraction-Testwork Results for Mine-Waste Samples (Delta)

ELEMENT/ PARAMETER	RC (GCA9665)	DID2 (GCA9669)	DID3 (GCA9673)	BID (GCA9680)	BID (GCA9681)	ELEMENT/ PARAMETER	RC (GCA9665)	DID2 (GCA9669)	DID3 (GCA9673)	BID (GCA9680)	BID (GCA9681)
Major-Parameters						Minor-Ions (µg/L)					
pН	8.4	7.4	6.7	6.9	6.9	Cu	<10	<10	<10	<10	<10
EC [µS/cm]	210	46	21	28	35	Ni	<10	<10	<10	<10	10
						Zn	<10	<10	<10	<10	<10
						Co	< 0.1	< 0.1	0.1	< 0.1	< 0.1
Major-Ions (mg/L)						Cd	< 0.02	< 0.02	0.02	< 0.02	< 0.02
						Pb	< 0.5	< 0.5	7.8	3.7	2.7
Na	28	11	1.8	1.3	1.8	Cr	<10	<10	10	<10	<10
K	6.8	1.2	1.4	1.7	1.3	Hg	< 0.1	<0.1	0.1	< 0.1	<0.1
Mg	2.5	< 0.01	0.58	1.0	1.6	As	1.8	0.5	0.2	0.2	0.2
Ca	13	0.05	0.47	0.84	1.7	Sb	0.20	0.04	0.05	0.02	0.02
Cl	5	3	2	2	2	Bi	0.005	< 0.005	< 0.005	< 0.005	< 0.005
SO_4	7	2	<1	1	2	Se	0.5	<0.5	<0.5	< 0.5	<0.5
						В	110	90	30	10	10
Fe	0.10	0.23	< 0.01	< 0.01	< 0.01	Mo	1.1	0.14	< 0.05	0.08	0.07
Al	0.08	0.29	0.02	0.04	0.01	Р	<100	<100	<100	<100	<100
Si	16	20	11	5.8	6.7	Ag	0.01	0.01	0.02	< 0.01	0.02
						Ba	97	46	2.6	2.2	4.2
						Sr	130	0.63	6.7	6.0	8.9
						T1	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
						V	<10	<10	<10	<10	<10
						Sn	0.1	0.3	0.2	0.1	0.1
						U	0.35	0.018	< 0.005	< 0.005	< 0.005
						Th	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
						Mn	<10	<10	<10	<10	<10

Note: All results in mg/L, except for pH and Electrical-Conductivity (EC).

Notes: Water-Extraction Testwork employed crushed-samples (nominal 2-mm), and slurries prepared using deionised-water, and a solid:solution ratio of *c*. 1:2 (w/w). Slurries were bottle-rolled for *c*. 1 day, prior to obtaining water-extracts (via centrifugation and vacuum-filtration) for analysis. Values in parentheses represent duplicates.

Table 5: Clay-Mineralogical and Clay-Surface-Chemistry Results for Mine-Waste Samples (Delta)

	DID1 (G	CA9666)		DID2 (GCA9670)					
hema qua kaoli goeti gibb Ti-oy	ntite rtz nite hite site kide		domi mir acces tra	nant tor ssory ce	hematite goethite kaolinite quartz Ti-oxide			dominant minor accessory trace		
eCEC	%	-Propor	tion of eC	EC	eCEC	%	-Propor	tion of eCl	EC	
[cmol	Na	K	Mg	Ca	[cmol	Na	K	Mg	Ca	
(p+)/kg]					(p+)/kg]					
3.2	24	6	34	36	2.3	34	<1	56	10	

Notes: eCEC = effective-Cation-Exchange Capacity dominant = greater than 50 %; minor = 10-20 %; accessory = 2-10 %; and, trace = less than 2 %

Table 6: Acid-Base-Analysis and Net-Acid-Generation Results for Waste-regolith Samples for Kinetic-Testing (Delta)

GCA-	SITE-			EC-(1:2)	TOTAL-S	SO ₄ -S	SULPHIDE-	TOTAL-C	CO ₃ -C	ANC	NAPP	NAG		ANC/	AFP
SAMPLE	SAMPLE	LITHOTYPE	pH-(1:2)	[mS/cm]	(%)	(%)	S (%)	(%)	(%)		kg H ₂ SO ₄ /	/tonne	NAG-pH	MPA	CATEGORY
NO.	NO.													RATIO	
GCA9728	HPDC001	DID1	6.3	0.12	0.03 (0.03)	<0.01 (<0.01)	0.03	0.08 (0.09)	<0.01 (<0.01)	6 (5)	nc	<0.5	6.2	nc	NAF
GCA9729	HPDC002	DID2	6.5	0.065	0.03	< 0.01	0.03	0.11	0.03	3	nc	<0.5	6.1	nc	NAF
GCA9730	HPDC003	DID3	6.4	0.051	0.04	<0.01	0.04	0.13	0.05	2	nc	<0.5	5.7	nc	NAF
GCA9731	HPDC004	DID4	6.5	0.030	0.03	< 0.01	0.03	0.19	0.09	1	nc	<0.5	5.5	nc	NAF
GCA9732	HPDC005	CID	6.4	0.041	0.02	< 0.01	0.02	0.10	0.02	5	nc	<0.5	6.2	nc	NAF
GCA9733	HPDC006	BID	6.4 (6.4)	0.039 (0.041)	0.03	< 0.01	0.03	0.31	0.18	4	nc	<0.5 (<0.5)	5.5 (5.5)	nc	NAF

Notes: EC = Electrical Conductivity; ANC = Acid-Neutralisation-Capacity; NAPP = Net-Acid-Producing-Potential; AFP = Acid-Formation-Potential; NAG = Net-Acid Generation; nc = not calculated; NAF = Non-Acid-Forming.pH-(1:2) and EC-(1:2) values correspond to pH and EC measured on sample slurries prepared with deionised-water, and a solid:solution ratio of*c*. 1:2 (w/w).All results expressed on a dry-weight basis, except for pH-(1:2), EC-(1:2), and NAG-pH.

Values in parentheses represent duplicates.

	TOTAL-ELEN	MENT CONTENT	Г (mg/kg or %)	AVERAGE-	GEOCHEMIC	GEOCHEMICAL-ABUNDANCE INDEX (GAI			
ELEMENT	DID1	DID2	DID3	CRUSTAL	DID1	DID2	DID3		
				ABUNDANCE					
	(GCA9728)	(GCA9729)	(GCA9730)	(mg/kg or %)	(GCA9728)	(GCA9729)	(GCA9730)		
Al	2.8%	3.1%	2.9%	8.2%	0	0	0		
Fe	46.9%	51.7%	58.9%	4.1%	3	3	3		
Na	0.032%	0.028%	0.011%	2.3%	0	0	0		
K	<0.05%	0.14%	0.06%	2.1%	0	0	0		
Mg	0.10%	0.12%	0.09%	2.3%	0	0	0		
Ca	<0.1%	<0.1%	<0.1%	4.1%	0	0	0		
Ag	0.09	0.10	0.12	0.07	0	0	0		
Cu	15	7	4	50	0	0	0		
Zn	6	7	1	75	0	0	0		
Cd	0.05	< 0.02	0.02	0.11	0	0	0		
Pb	8.1	8.3	7.8	14	0	0	0		
Cr	<50	<50	<50	100	0	0	0		
Ni	5	5	2	80	0	0	0		
Co	3.7	2.0	2	20	0	0	0		
Mn	170	200	120	950	0	0	0		
Hg	< 0.01	< 0.01	< 0.01	0.05	0	0	0		
Sn	0.9	1.2	1.7	2.2	0	0	0		
Sr	4.6	8.5	3.9	370	0	0	0		
Ba	44	36	13	500	0	0	0		
Th	5.3	4.8	3.9	12	0	0	0		
U	0.79	1.2	0.80	2.4	0	0	0		
Tl	0.09	0.13	0.06	0.6	0	0	0		
V	93	83	110	160	0	0	0		
As	9.7	12	16	1.5	2	2	3		
Bi	0.16	0.18	0.20	0.048	1	1	1		
Sb	1.3	1.3	1.7	0.2	2	2	3		
Se	0.80	0.72	0.37	0.05	3	3	2		
Мо	1.1	1.6	2.7	1.5	0	0	0		
В	<50	<50	<50	10	0	0	0		
Р	420	450	570	1,000	0	0	0		
F	140	180	89	950	0	0	0		

Multi-Element-Analysis Results for Waste-regolith Samples for Kinetic-Testing (Delta) Table 7:

Note: Average-crustal abundance of elements based on Bowen (1979), and the Geochemical-Abundance Index (GAI) is based on Förstner *et al.* (1993). Refer Attachment II.

Table 7 (Cont'd):	Multi-Element-Analysis Results for Waste-regolith Samples for Kinetic-Testing (Delta)

	TOTAL-ELEN	MENT CONTEN	Г (mg/kg or %)	AVERAGE-	GEOCHEMIC	AL-ABUNDANC	E INDEX (GAI)
ELEMENT	DID4	CID	BID	CRUSTAL	DID4	CID	BID
				ABUNDANCE			
	(GCA9731)	(GCA9732)	(GCA9733)	(mg/kg or %)	(GCA9731)	(GCA9732)	(GCA9733)
Al	1.4%	3.5%	1.2%	8.2%	0	0	0
Fe	63.5%	49.9%	60.3%	4.1%	3	3	3
Na	0.0052%	0.0063%	0.0022%	2.3%	0	0	0
K	<0.05%	0.08%	0.08%	2.1%	0	0	0
Mg	0.08%	0.14%	0.08%	2.3%	0	0	0
Ca	<0.1%	<0.1%	<0.1%	4.1%	0	0	0
Ag	0.12	0.09	0.09	0.07	0	0	0
Cu	2	9	12	50	0	0	0
Zn	1	6	3	75	0	0	0
Cd	0.03	0.12	0.04	0.11	0	0	0
Pb	5.9	12	5	14	0	0	0
Cr	<50	<50	<50	100	0	0	0
Ni	<1	19	3	80	0	0	0
Co	1.7	3.5	1.8	20	0	0	0
Mn	330	170	120	950	0	0	0
Hg	0.02	0.66	0.10	0.05	0	3	0
Sn	1.9	1.7	1.6	2.2	0	0	0
Sr	2.9	7.5	2.1	370	0	0	0
Ва	11	35	6.2	500	0	0	0
Th	2.4	4.0	1.9	12	0	0	0
U	0.52	2.1	0.73	2.4	0	0	0
Tl	0.05	0.11	0.02	0.6	0	0	0
V	96	110	84	160	0	0	0
As	13	25	19	1.5	3	3	3
Bi	0.22	0.18	0.20	0.048	2	1	1
Sb	1.9	2.3	1.7	0.2	3	3	3
Se	0.35	0.19	1.1	0.05	2	1	4
Мо	2.9	2.3	2.4	1.5	0	0	0
В	<50	<50	<50	10	0	0	0
Р	720	900	1,300	1,000	0	0	0
F	72	180	82	950	0	0	0

Table 8: Mineralogical Results for Waste-regolith Samples for Kinetic-Testing (Delta)

DID1 (GCA9728)		DI (GCA	D2 9729)	DID3 (GCA9730)		
Component	Abundance	Component Abundance		Component	Abundance	
hematite	major	hematite	major	hematite	dominant	
quartz goethite	minor	goethite quartz	minor	goethite	minor	
kaolinite maghemite	accessory	kaolinite maghemite	accessory	kaolinite quartz maghemite	accessory	
		mica	trace	-		

Notes: dominant = greater than 50 %; major = 20-50 %; minor = 10-20 %; accessory = 2-10 %; and, trace = less than 2 %

DID4 (GCA9731)		Cl (GCA	ID 9732)	BID (GCA9733)		
Component	Abundance	Component	Abundance	Component	Abundance	
hematite goethite kaolinite maghemite	dominant major accessory	goethite hematite kaolinite maghemite	major minor accessory	goethite hematite quartz	dominant minor accessory	
quartz		quartz		kaolinite	trace	

<u>DID1 (GCA9728)</u>

ELEMENT/ PARAMETER	PRE- RINSING- CYCLE	WEE	KLY-WEAT	HERING-CY	YCLES (GC.	A9728)
		1	2	3	4	5
Major-Parameters						
pН	7.6	6.8	6.8	7.3	7.2	7.2
EC [µS/cm]	120	47	40	38	36	30
Major-Ions (mg/L)						
Cl	6	<2	<2	<2	<2	<2
SO_4	11	2	1	<1	<1	<1
Na K Mg Ca Fe	21 4.7 0.45 0.30 0.23 0.20	11 2.5 0.75 0.40 0.31	7.9 2.1 0.69 0.29 0.24	8.5 2.3 0.51 0.26 0.23	8.1 1.9 0.46 0.28 0.08 0.40	8.0 1.7 0.36 0.21 0.05
	0.29	0.70	0.68	0.49	0.49	0.28
51	15	10	10	15	15	12
Leachate Wt (kg)	0.73	0.66	0.65	0.66	0.64	0.69

<u>Note</u>: EC = Electrical-Conductivity.

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ELEMENT/ PARAMETER	PRE- RINSING- CYCLE	WEEKLY-WEATHERING-CYCLES (GCA9728)				
		1	2	3	4	5
Minor-Ions (µg/L)						
Cu	<10	<10	<10	<10	<10	10
Ni	<10	<10	<10	20	<10	<10
Zn	20	<10	<10	310	10	<10
Co	0.2	0.3	0.2	< 0.1	< 0.1	8.6
Cd	< 0.02	< 0.02	< 0.02	0.10	< 0.02	0.18
Pb	<0.5	2.0	1.3	2.2	0.9	1.1
Cr	<10	<10	<10	<10	<10	<10
Hg	< 0.1	0.3	< 0.1	< 0.1	0.2	0.5
As	0.7	0.4	0.5	0.6	0.7	1.7
Sb	0.06	0.06	0.04	0.07	0.05	0.22
Bi	0.006	0.005	< 0.005	< 0.005	< 0.005	0.17
Se	0.7	<0.5	<0.5	<0.5	<0.5	1.3
В	200	160	100	100	120	100
Mo	0.24	0.27	0.12	0.52	0.41	0.52
Р	<100	<100	<100	<100	<100	<100
Ag	0.01	0.03	< 0.01	< 0.01	< 0.01	0.17
Ba	16	10	8.2	7.2	9.1	5.5
Sr	2.1	2.8	2.2	2.0	1.7	9.4
T1	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.17
V	<10	<10	<10	<10	<10	<10
Sn	<0.1	0.1	<0.1	< 0.1	< 0.1	0.2
U	0.21	0.29	0.21	0.21	0.17	0.40
Th	< 0.005	0.009	0.009	0.029	0.009	0.18
Mn	<10	<10	<10	<10	<10	<10

DID2 (GCA9729)

<u>Note</u>: The following results are for the <u>Pre-Rinse-Cycle only</u>, since following completion of the drying-phase of the 1st-Weekly-Weathering-Cycle, the flushing-step did not result in any leachate over a 5-week period, due to clogging of the filter-paper at the base of the rock-bed in the column by "ultra-fines". This weathering-column was subsequently abandoned.

ELEMENT/ PARAMETER	GCA9729	ELEMENT/ PARAMETER	GCA9729	
Major-Parameters		Minor-Ions (µg/L)		
рН	7.6	Cu	<10	
EC [µS/cm]	190	Ni	<10	
		Zn	10	
Major-Ions (mg/L)		Со	0.4	
		Cd	< 0.02	
Cl	15	Pb	0.7	
SO_4	19	Cr	<10	
		Hg	< 0.1	
Na	33	As	1.4	
K	4.7	Sb	0.07	
Mg	2.3	Bi	0.005	
Ca	1.4	Se	1.3	
		В	160	
Fe	0.25	Мо	0.25	
Al	0.48	Р	<100	
Si	22	Ag	0.02	
		Ba	17	
		Sr	18	
		T1	0.01	
		V	<10	
		Sn	< 0.1	
		U	0.23	
		Th	0.018	
		Mn	30	
Leachate Wt (kg)	0.66			

<u>Note</u>: EC = Electrical-Conductivity.

<u>DID3 (GCA9730)</u>

<u>Note</u>: The following results are for the <u>Pre-Rinse-Cycle and Cycle-1 only</u>, since following completion of the drying-phase of the 2nd-Weekly-Weathering-Cycle, the flushing-step did not result in any leachate over an 8-week period, due to clogging of the filter-paper at the base of the rock-bed in the column by "ultra-fines". This weathering-column was subsequently abandoned.

ELEMENT/	PRE- RINSING-	WEELY- WEATHERING-
PARAMETER	CYCLE	CYCLES (GCA9730)
		1
Major-Parameters		
pH	7.3	6.6
EC [µS/cm]	91	49
Major-Ions (mg/L)		
Cl	10	4
HCO ₃	17	7
SO_4	10	6
Na	16	8.7
Κ	2.5	1.6
Mg	0.31	0.67
Ca	0.39	0.59
Fe	0.11	0.18
Al	0.12	0.32
Si	9.2	14
Leachate Wt (kg)	0.74	0.55

Leachate Wt (kg)0.74Note: EC = Electrical-Conductivity.

ELEMENT/	PRE- RINSING-	WEELY- WEATHERING-
PARAMETER	CYCLE	CYCLES (GCA9730)
		1
Minor-Ions (µg/L)		
Cu	<10	<10
Ni	<10	20
Zn	20	<10
Co	< 0.1	<0.1
Cd	< 0.02	<0.02
Pb	< 0.5	0.9
Cr	<10	<10
Hg	< 0.1	<0.1
As	0.9	<0.1
Sb	0.03	< 0.01
Bi	0.008	<0.005
Se	1.0	0.7
В	70	70
Mo	0.07	<0.05
Р	<100	<100
Ag	0.03	< 0.01
Ba	7.1	3.6
Sr	3.0	6.0
T1	< 0.01	< 0.01
V	<10	<10
Sn	< 0.1	<0.1
U	< 0.005	0.025
Th	< 0.005	< 0.005
Mn	<10	<10

<u>DID4 (GCA9731)</u>

ELEMENT/ PARAMETER	PRE- RINSING- CYCLE	WEEKLY-WEATHERING-CYCLES (GCA9731)								
		1	2	3	4	5	6			
Major-Parameters										
pН	6.4	6.3	4.4	6.1	6.4	6.3	6.3			
EC [µS/cm]	69	22	28	10	<10	<10	<10			
Major-Ions (mg/L)										
Cl	5	2	<2	<2	<2	<2	<2			
HCO ₃	14	6	<1	4	4	4	4			
SO_4	3	3	3	1.0	2	<1	<1			
Na	9.7	3.2	2.0	1.3	1.1	0.8	0.8			
K	3.3	1.3	1.0	0.8	0.6	0.5	0.8			
Mg	1.3	0.23	0.25	0.16	0.12	0.12	0.10			
Ca	1.4	0.26	0.35	0.15	0.11	0.10	0.12			
Fe	< 0.01	< 0.01	0.21	0.23	0.16	0.18	0.24			
Al	< 0.01	< 0.01	0.19	0.25	0.18	0.20	0.24			
Si	5.5	5.2	8.4	7.8	5.6	4.9	5.6			
Leachate Wt (kg)	0.81	0.80	0.81	0.80	0.80	0.80	0.80			

Note: EC = Electrical-Conductivity.

ELEMENT/ PARAMETER	PRE- RINSING- CYCLE	WEEKLY-WEATHERING-CYCLES (GCA9731)							
		1	2	3	4	5	6		
Minor-Ions (µg/L)									
Cu	<10	<10	<10	<10	<10	<10	<10		
Ni	<10	<10	<10	10	<10	<10	<10		
Zn	<10	<10	<10	<10	<10	<10	<10		
Co	0.2	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1		
Cd	0.07	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02		
Pb	7.5	< 0.5	1.1	<0.5	<0.5	<0.5	< 0.5		
Cr	<10	<10	<10	<10	<10	<10	<10		
Hg	< 0.1	0.6	0.3	0.3	0.2	0.2	0.2		
As	0.4	0.3	0.2	0.2	< 0.1	< 0.1	< 0.1		
Sb	0.04	0.03	0.08	0.03	0.04	< 0.01	< 0.01		
Bi	< 0.005	< 0.005	0.007	< 0.005	< 0.005	< 0.005	< 0.005		
Se	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5		
В	30	10	40	40	30	40	30		
Мо	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05		
Р	<100	<100	<100	<100	<100	<100	<100		
Ag	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01		
Ba	6.5	1.7	9.0	3.6	2.1	13	6.5		
Sr	11	2.1	2.3	1.5	0.82	0.85	0.98		
T1	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01		
V	<10	<10	<10	<10	<10	<10	<10		
Sn	< 0.1	< 0.1	0.1	< 0.1	< 0.1	< 0.1	< 0.1		
U	< 0.005	< 0.005	< 0.005	0.007	< 0.005	< 0.005	< 0.005		
Th	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005		
Mn	<10	<10	<10	<10	<10	<10	<10		

<u>CID (GCA9732)</u>									
ELEMENT/ PARAMETER	PRE- RINSING- CYCLE	WEEKLY-WEATHERING-CYCLES (GCA9732)							
		1	2	3	4	5	6		
Major-Parameters									
pН	6.8	6.9	6.6	6.8	6.5	6.7	6.6		
EC [µS/cm]	190	26	18	24	13	12	11		
Major-Ions (mg/L)									
Cl	11	2	<2	<2	<2	2	<2		
HCO ₃	39	6	7	8	6	6	5		
SO_4	10	3	2	2	1	<1	1		
Na	15	3.1	2.1	2.3	1.5	1.5	1.3		
K	5.5	1.1	1.0	1.4	0.9	0.8	1.0		
Mg	7.2	0.53	0.42	0.60	0.5	0.31	0.24		
Ca	8.7	0.74	0.45	0.67	0.65	0.32	0.24		
Fe	< 0.01	0.22	0.25	0.25	0.25	0.29	0.23		
Si	13	11	12	14	9.4	11	11		
51	15				2.1				
Leachate Wt (kg)	0.66	0.79	0.77	0.76	0.78	0.77	0.83		

<u>Note</u>: EC = Electrical-Conductivity.

ELEMENT/ PARAMETER	PRE- RINSING- CYCLE	WEEKLY-WEATHERING-CYCLES (GCA9732)								
		1	2	3	4	5	6			
Minor-Ions (µg/L)										
Cu	<10	<10	<10	<10	<10	<10	<10			
Ni	<10	<10	10	<10	<10	<10	20			
Zn	<10	10	<10	<10	20	<10	<10			
Co	< 0.1	< 0.1	< 0.1	< 0.1	0.1	< 0.1	< 0.1			
Cd	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02			
Pb	3.5	<0.5	<0.5	1.0	<0.5	0.9	<0.5			
Cr	<10	<10	<10	<10	<10	<10	<10			
Hg	1.4	< 0.1	0.2	0.2	0.2	0.1	< 0.1			
As	0.8	0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1			
Sb	0.03	0.09	0.05	0.01	0.01	0.02	0.03			
Bi	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005			
Se	0.7	<0.5	<0.5	<0.5	<0.5	<0.5	< 0.5			
В	20	<10	30	<10	<10	60	50			
Мо	0.06	0.07	< 0.05	< 0.05	< 0.05	0.08	0.12			
Р	<100	<100	<100	<100	<100	<100	<100			
Ag	< 0.01	< 0.01	< 0.01	< 0.01	0.01	0.78	0.18			
Ва	24	110	6.2	4.2	11	79	24			
Sr	45	4.3	2.4	3.7	3.4	2.1	1.7			
Tl	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01			
V	<10	<10	<10	<10	<10	<10	<10			
Sn	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1			
U	0.013	0.007	< 0.005	0.016	0.034	0.010	0.009			
Th	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005			
Mn	<10	<10	<10	<10	<10	<10	<10			

BID	(GCA	9733)
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ELEMENT/ PARAMETER	PRE- RINSING- CYCLE	WEEKLY-WEATHERING-CYCLES (GCA9733)							
		1	2	3	4	5	6		
Major-Parameters									
pН	6.7	6.3	6.4	6.3	6.3	6.4	6.4		
EC [µS/cm]	110	31	30	21	16	15	12		
Major-Ions (mg/L)									
Cl	7	3	<2	<2	<2	<2	<2		
HCO ₃	19	4	5	4	4	4	4		
SO_4	3	4	6	4	3	3	2		
Na	7.0	1.6	1.2	0.7	0.5	0.6	0.5		
K	5.4	1.3	1.3	1.1	0.8	0.9	0.6		
Mg	4.3	1.3	1.3	0.85	0.71	0.82	0.64		
Ca	4.0	1.1	1.1	0.74	0.58	0.61	0.52		
Fe	< 0.01	< 0.01	0.04	0.03	0.04	0.21	0.15		
Al	< 0.01	< 0.01	0.09	0.03	0.04	0.22	0.20		
Si	3.6	4.5	7.8	7.6	5.0	6.6	6.1		
Leachate Wt (kg)	0.77	0.79	0.81	0.79	0.78	0.82	0.76		

Note: EC = Electrical-Conductivity.

ELEMENT/ PARAMETER	PRE- RINSING- CYCLE	WEEKLY-WEATHERING-CYCLES (GCA9733)								
		1	2	3	4	5	6			
Minor-Ions (µg/L)										
Cu	<10	<10	<10	<10	<10	<10	<10			
Ni	<10	<10	<10	<10	<10	<10	<10			
Zn	<10	<10	20	20	10	<10	<10			
Co	1.0	0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1			
Cd	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02			
Pb	1.8	0.8	<0.5	2.4	0.9	0.7	<0.5			
Cr	<10	<10	<10	<10	<10	<10	<10			
Hg	< 0.1	< 0.1	0.2	0.1	0.2	0.3	0.2			
As	1.3	1.1	0.4	0.2	< 0.1	0.1	< 0.1			
Sb	0.07	0.03	0.01	0.02	< 0.01	< 0.01	< 0.01			
Bi	0.02	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005			
Se	0.5	<0.5	0.5	<0.5	<0.5	<0.5	<0.5			
В	<10	<10	20	60	<10	40	30			
Мо	0.1	0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05			
Р	<100	<100	<100	<100	<100	<100	<100			
Ag	0.05	< 0.01	< 0.01	< 0.01	< 0.01	0.06	< 0.01			
Ba	7.6	2.1	1.6	2.0	0.83	11	18			
Sr	26	6.3	6.6	4.7	3.2	3.5	3.2			
T1	0.03	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01			
V	<10	<10	<10	<10	<10	<10	<10			
Sn	<0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1			
U	0.016	< 0.005	< 0.005	< 0.005	0.012	< 0.005	< 0.005			
Th	0.011	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005			
Mn	<10	<10	<10	<10	<10	<10	<10			

Table 10: Acid-Base-Analysis and Net-Acid-Generation Results for Waste-bedrock Samples for Kinetic-Testing (Delta)

GCA-			EC-(1:2)	TOTAL-S	SO ₄ -S	SULPHIDE-	TOTAL-C	CO ₃ -C	ANC	NAPP	NAG		ANC/	AFP
SAMPLE	LITHOTYPE	pH-(1:2)	[mS/cm]	(%)	(%)	S (%)	(%)	(%)	kg	H ₂ SO ₄ /t	onne	NAG-pH	MPA	CATEGORY
NO.													RATIO	
GCA9682/83	Shl	3.7	1.4	1.9 (1.9)	0.30 (0.30)	1.6	2.6 (2.6)	1.8 (1.8)	35 (34)	15	19	3.1	<1	PAF
GCA9685/86	Shl-(WS)	4.8	1.5	2.2	0.22	2.0	3.8	3.1	65	-3.8	18	4.2	1.0	PAF
GCA9688/90	Shl-(DGS)	5.9 (5.9)	1.1 (1.1)	1.3	0.08	1.3	2.3	1.9	64	-24	9.5 (9.5)	3.6 (3.5)	1.6	PAF

Notes: EC = Electrical Conductivity; ANC = Acid-Neutralisation-Capacity; NAPP = Net-Acid-Producing-Potential; AFP = Acid-Formation-Potential; NAG = Net-Acid Generation; PAF = Potentially-Acid-Forming.pH-(1:2) and EC-(1:2) values correspond to pH and EC measured on sample slurries prepared with deionised-water, and a solid:solution ratio of*c*. 1:2 (w/w).

All results expressed on a dry-weight basis, except for pH-(1:2), EC-(1:2), and NAG-pH.

Values in parentheses represent duplicates.

	TOTAL-ELE	MENT CONTEN	Г (mg/kg or %)	AVERAGE-	GEOCHEMIC	GEOCHEMICAL-ABUNDANCE INDEX (GAI)				
ELEMENT	Shl	Shl-(WS)	Shl-(DGS)	CRUSTAL	Shl	Shl-(WS)	Shl-(DGS)			
				ABUNDANCE						
	(GCA9682/83	(GCA9685/86)	(GCA9688/89)	(mg/kg or %)	(GCA9682/83	(GCA9685/86)	(GCA9688/89)			
Al	4.7%	4.0%	3.4%	8.2%	0	0	0			
Fe	14.6%	20.1%	19.3%	4.1%	1	2	2			
Na	0.013%	0.0093%	0.015%	2.3%	0	0	0			
K	5.8%	5.4%	4.5%	2.1%	1	1	1			
Mg	0.66%	1.2%	1.1%	2.3%	0	0	0			
Ca	0.3%	0.5%	0.4%	4.1%	0	0	0			
Ag	0.2	0.2	0.1	0.07	1	1	0			
Cu	44	50	26	50	0	0	0			
Zn	68	130	120	75	0	0	0			
Cd	0.20	0.21	0.41	0.11	0	0	1			
Pb	19	16	22	14	0	0	0			
Cr	68	170	<50	100	0	0	0			
Ni	34	43	26	80	0	0	0			
Co	19	24	14	20	0	0	0			
Mn	3,500	6,900	2,000	950	1	2	0			
Hg	0.17	0.17	0.23	0.05	1	1	2			
Sn	1.4	1.4	1.8	2.2	0	0	0			
Sr	14	8.3	9.0	370	0	0	0			
Ba	250	230	230	500	0	0	0			
Th	8.1	6.4	8.4	12	0	0	0			
U	2.8	2.5	2.6	2.4	0	0	0			
T1	0.70	0.75	2.0	0.6	0	0	1			
V	73	69	31	160	0	0	0			
As	44	40	47	1.5	4	4	4			
Bi	0.38	0.31	0.51	0.048	2	2	3			
Sb	3.3	3.6	2.6	0.2	3	4	3			
Se	1.3	1.1	0.62	0.05	4	4	3			
Мо	2.8	2.7	3.4	1.5	0	0	1			
В	120	120	120	10	3	3	3			
Р	320	830	550	1,000	0	0	0			
F	330	590	360	950	0	0	0			

Table 11: Multi-Element-Analysis Results for Waste-bedrock Samples for Kinetic-Testing (Delta)

Note: Average-crustal abundance of elements based on Bowen (1979), and the Geochemical-Abundance Index (GAI) is based on Förstner *et al.* (1993). Refer Attachment II.

Table 12: Mineralogical Results for Waste-bedrock Samples for Kinetic-Testing (Delta)

Shl (GCA9682/83		Shl-((GCA9	(WS) 685/86)	Shl-(DGS) (GCA9688/90)			
Component	Abundance	Component Abundance		Component	Abundance		
quartz	dominant	quartz	dominant	quartz	dominant		
K-feldspar stilpnomelane	minor	K-feldspar stilpomelane	minor	K-feldspar stilpomelane	minor		
pyrite siderite chlorite	accessory	pyrite siderite chlorite	accessory	pyrite siderite chlorite	accessory		

Notes:

dominant = greater than 50 %; minor = 10-20 %; and, accessory = 2-10 %

Electron-micro-probe analyses of different <u>siderite-grains</u> during the SEM investigation showed the following indicative composition, viz.

- <u>GCA9682/83</u>: $(Fe_{0.71}Mg_{0.12}Mn_{0.02}Ca_{0.02})CO_3$
- <u>GCA9685/86</u>: $(Fe_{0.75}Mg_{<0.01}Mn_{0.05}Ca_{0.02})CO_3$
- <u>GCA9688/90</u>: $(Fe_{0.77}Mg_{0.10}Mn_{0.01}Ca_{0.02})CO_3$

Table 13: Column-Leachate-Analysis Results for Waste-bedrock Samples (Delta)

Shl (GCA9682/83)

ELEMENT/ PARAMETER	PRE- RINSING- CYCLE	- WEEKLY-WEATHERING-CYCLES (GCA9682/83)							
		1	2	3	4	5	6		
Major-Parameters									
pН	3.0	6.4	6.3	5.1	4.7	5.0	4.9		
EC [µS/cm]	3,200	1,300	950	970	890	910	1100		
acidity (mg H ₂ SO ₄ /L)	430	14	13	9	8	7	6		
Major-Ions (mg/L)									
C1	6	35	44	64	66	48	3		
SO_4	2,200	810	610	610	570	540	580		
Na K Mg Ca	2.3 72 270 160	1.1 19 140 48	0.7 15 93 36	0.6 15 91 33	0.5 14 84 31	0.4 14 85 31	0.4 13 97 33		
Fe	100	0.46	0.09	0.11	0.05	0.02	0.02		
Al	22	0.11	0.03	0.11	0.08	0.01	< 0.01		
Mn	150	57	40	34	32	32	31		
Si	15	2.4	2.0	2.1	2.0	2.0	1.8		
Minor-Ions (μg/L) As	4.2	0.9	0.5	0.6	0.9	1.0	0.8		
Cu	330	<10	<10	<10	<10	<10	<10		
Zn	1,400	50	30	20	20	20	10		
Leachate Wt (kg)	2.25	0.72	0.73	0.73	0.71	0.75	0.69		

<u>Note</u>: EC = Electrical-Conductivity.

<u>Shl-(WS) [GCA9685/86]</u>

ELEMENT/ PARAMETER	PRE- RINSING- CYCLE									
		1	2	3	4	5	6			
Major-Parameters										
pН	4.6	5.6	4.3	4.2	6.4	6.0	7.1			
EC [µS/cm]	1,700	860	890	940	780	860	920			
acidity (mg H ₂ SO ₄ /L)	31	5	8	11	10	6	9			
Major-Ions (mg/L)										
Cl	5	64	83	93	35	26	<2			
SO_4	1,100	550	550	680	480	520	490			
Na	1.2	0.3	0.3	0.4	0.4	0.4	0.3			
K	59	5.2	4.8	5.9	6.3	6.9	8.1			
Mg	140	84	85	91	70	79	76			
Ca	100	39	38	42	37	39	44			
Fe	1.9	< 0.01	0.04	< 0.01	< 0.01	< 0.01	< 0.01			
Al	2.9	0.08	0.02	0.06	0.02	0.06	< 0.01			
Mn	78	17	17	18	22	26	38			
Si	4.2	0.44	0.43	0.46	0.46	0.46	0.38			
Minor-Ions (µg/L)										
As	0.9	0.5	0.5	0.6	0.5	0.3	0.4			
Cu	60	<10	<10	<10	<10	<10	<10			
Zn	540	20	20	30	20	20	20			
Leachate Wt (kg)	5.13	0.74	0.73	0.75	0.76	0.75	0.74			

ELEMENT/ PARAMETER	PRE- RINSING- CYCLE	PRE- NSING- WEEKLY-WEATHERING-CYCLES (GCA9688/90) YCLE								
		1	2	3	4	5	6			
Major-Parameters										
pH	7.9	7.4	7.7	7.4	7.4	7.4	7.7			
EC [µS/cm]	1,400	610	570	610	610	750	700			
acidity (mg H_2SO_4/L)	9	8	9	7	8	6	5			
Major-Ions (mg/L)										
Cl	8	42	20	8	<2	2	<2			
${ m SO}_4$	670	350	290	300	280	360	330			
Na	4.2	0.8	0.7	1.0	1.1	1.4	1.3			
K	96	14	14	18	19	27	29			
Mg	96	43	39	41	38	46	41			
Ca	85	42	39	44	43	53	49			
Fe	0.03	< 0.01	< 0.01	< 0.01	0.01	< 0.01	< 0.01			
Al	0.01	< 0.01	0.02	0.02	< 0.01	< 0.01	< 0.01			
Mn	11	1.9	2.4	3.3	4.1	6.5	8.3			
Si	6.4	2.9	2.9	3.3	3.2	3.6	3.6			
Minor-Ions (µg/L)										
As	1.2	0.7	0.5	0.8	0.7	0.6	0.5			
Cu	<10	<10	<10	<10	<10	<10	<10			
Zn	90	60	20	10	20	20	20			
Leachate Wt (kg)	0.98	0.74	0.74	0.72	0.75	0.73	0.71			

Shl-(DGS) [GCA9688/90]

Table 14: Acid-Base-Analysis and Net-Acid-Generation Results for Mine-Waste Samples (Eagle)

GCA-	SITE-	DRILLHOLE &			EC-(1:2)	TOTAL-S	SO ₄ -S	SULPHIDE-	TOTAL-C	СО3-С	ANC	NAPP	NAG	_	ANC/	AFP
SAMPLE	SAMPLE	DOWN-HOLE	LITHOTYPE	pH-(1:2)	[mS/cm]	(%)	(%)	S (%)	(%)	(%)	k	g H ₂ SO ₄ /t	onne	NAG-pH	MPA	CATEGORY
NO.	NO.	INTERVAL (m)													RATIO	
Samples from	m Above-BoX	(= "waste-regoliths"														
GCA9691	HPES001	HPRC4169, 16-18	RC	7.0	0.22	0.02 [0.009]	< 0.01	0.02	0.06	0.02	4	nc	1.0	6.5	nc	NAF
GCA9692	HPES002	HPRC4153, 34-36	DID1	7.2	0.023	0.02 [0.007]	< 0.01	0.02	0.06	0.02	4	nc	<0.5	6.0	nc	NAF
GCA9693	HPES003	HPRC4113, 20-22	DID2	7.5	0.019	0.02 [0.013]	< 0.01	0.02	0.09	0.01	3	nc	<0.5	6.0	nc	NAF
GCA9694	HPES004	HPRC4113, 24-26	DID3	7.5	0.018	0.02 [0.015]	< 0.01	0.02	0.10	0.02	3	nc	1.2	6.0	nc	NAF
GCA9695	HPES005	HPRC4153, 48-50	DID4	7.1 (7.1)	0.024 (0.023)	0.02 [0.013]	< 0.01	0.02	0.16	0.02	3	nc	0.7	6.0	nc	NAF
GCA9696	HPES006	HPRC4137, 80-82	CID	6.9	0.034	0.02 [0.009]	< 0.01	0.02	0.24	0.06	5	nc	<0.5	6.0	nc	NAF
GCA9697	HPES007	HPRC4155, 58-60	CID	7.1	0.032	0.01 [0.004]	< 0.01	0.01	0.08	0.02	4	nc	<0.5	5.7	nc	NAF
GCA9698	HPES008	HPRC4169, 56-58	CID	7.1	0.022	0.01 [0.015]	< 0.01	0.01	0.23	0.11	11	nc	0.9	5.3	nc	NAF
GCA9699	HPES009	HPRC4072, 38-40	BID	7.0	0.020	0.02 [0.025]	< 0.01	0.02	0.37	0.14	5	nc	<0.5	6.2	nc	NAF
Samples from	m Basement [= Below-BoX] (i.e. "wa	<u>iste-bedrocks")</u>													
GCA9700	HPES010	HPRC4093, 34-36	Shl	6.8	0.044	0.16 [0.158]	< 0.01	0.16	0.43	< 0.01	8	-3.1	<0.5 (<0.5)	6.4 (6.5)	1.6	NAF
GCA9701	HPES011	HPRC4093, 36-38	Shl	5.9	0.32	0.01 [0.012]	< 0.01	0.01	0.84	< 0.01	6	nc	<0.5	5.0	nc	NAF
GCA9702	HPES012	HPRC4093, 38-40	Bif	2.6	3.1	2.1 [2.37]	0.53	1.6	0.67	< 0.01	-11	60	49	2.4	<1	PAF
GCA9703	HPES013	HPRC4000, 54-56	Bif	5.0	0.49	0.26 [0.255]	0.02	0.24	0.96	0.60	9	-1.6	1.2	5.9	1.2	NAF
GCA9704	HPES014	HPRC4000, 56-58	Shl	4.7	0.78	1.1 [1.14]	0.09	1.1	2.9	1.9	26	7.7	1.4	5.1	<1	PAF
GCA9705	HPES015	HPRC4000, 58-60	Shl	5.1 (5.0)	0.62 (0.68)	0.81 [0.914]	0.06	0.75	3.3	1.7	21 (25)	2.0	1.5	5.6	<1	PAF
GCA9706	HPES016	HPRC4019, 22-24	Shl	6.1	0.085	<0.01 [0.004]	< 0.01	< 0.01	0.12	< 0.01	7	nc	<0.5	6.9	nc	NAF
GCA9707	HPES017	HPRC4019, 24-26	Shl	6.1	0.059	0.01 [0.027]	< 0.01	0.01	0.14	0.05	6	nc	<0.5	7.9	nc	NAF
GCA9708	HPES018	HPRC4019, 26-28	Bif	4.7	1.3	2.7 [2.7]	0.20	2.5	3.8	3.1	26	51	17	3.8	<1	PAF

Notes: EC = Electrical Conductivity; ANC = Acid-Neutralisation-Capacity; NAPP = Net-Acid-Producing-Potential; AFP = Acid-Formation-Potential; NAG = Net-Acid Generation; nc = not calculated;

NAF = Non-Acid-Forming; PAF = Potentially-Acid Forming.

pH-(1:2) and EC-(1:2) values correspond to pH and EC measured on sample slurries prepared with deionised-water, and a solid:solution ratio of c. 1:2 (w/w). All results expressed on a dry-weight basis, except for pH-(1:2), EC-(1:2), and NAG-pH. Values in round-parentheses represent duplicates.

N.B. Total-S values in square-parentheses correspond to results from Exploration-Database.

GCA-	SITE-	DRILLHOLE &		SULPHIDE-	TOTAL-As	TOTAL-Sb	TOTAL-Se	TOTAL-Mo	TOTAL-B
SAMPLE	SAMPLE	DOWN-HOLE	LITHOTYPE	S (%)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
NO.	NO.	INTERVAL (m)							
Samples from	<u>m Above-Bo</u> 2	<u> X (= "waste-regoliths"</u>							
GCA9691	HPES001	HPRC4169, 16-18	RC	0.02	9.0	1.2	0.36	1.8	<50
GCA9692	HPES002	HPRC4153, 34-36	DID1	0.02	7.7	1.1	0.26	1.7	<50
GCA9693	HPES003	HPRC4113, 20-22	DID2	0.02	9.7	1.3	0.58	1.4	<50
GCA9694	HPES004	HPRC4113, 24-26	DID3	0.02	13	1.6	0.24	2.1	<50
GCA9695	HPES005	HPRC4153, 48-50	DID4	0.02	11	1.3	0.67	1.8	<50
GCA9696	HPES006	HPRC4137, 80-82	CID	0.02	11	0.74	1.4	1.0	<50
GCA9697	HPES007	HPRC4155, 58-60	CID	0.01	21	1.3	0.61	1.7	<50
GCA9698	HPES008	HPRC4169, 56-58	CID	0.01	18	1.2	1.2	2.1	<50
GCA9699	HPES009	HPRC4072, 38-40	BID	0.02	21	1.3	3.9	1.2	<50
Samples from	m Basement	<u>[= Below-BoX] (i.e. "wa</u>	<u>iste-bedrocks")</u>						
GCA9700	HPES010	HPRC4093, 34-36	Shl	0.16	36	2.9	1.7	2.6	<50
GCA9701	HPES011	HPRC4093, 36-38	Shl	0.01	43	3.6	1.2	3.4	<50
GCA9702	HPES012	HPRC4093, 38-40	Bif	1.6	38	4.0	1.7	3.0	<50
GCA9703	HPES013	HPRC4000, 54-56	Bif	0.24	25	2.3	0.77	2.9	<50
GCA9704	HPES014	HPRC4000, 56-58	Shl	1.1	42	3.2	0.52	2.9	<50
GCA9705	HPES015	HPRC4000, 58-60	Shl	0.75	51	3.6	0.56	3.4	<50
GCA9706	HPES016	HPRC4019, 22-24	Shl	< 0.01	44	3.9	0.51	2.8	<50
GCA9707	HPES017	HPRC4019, 24-26	Shl	0.01	44	3.0	0.83	3.1	<50
GCA9708	HPES018	HPRC4019, 26-28	Bif	2.5	49	3.7	1.3	2.9	<50

Table 15: Total-Contents of As, Sb, Se, Mo and B in Mine-Waste Samples (Eagle)

	TOTAL-E	LEMENT	AVERAGE-	GEOCHI	EMICAL-
ELEMENT	CONTENT (mg/kg or %)	CRUSTAL	ABUNDANCE	INDEX (GAI)
	Bif	Bif	ABUNDANCE	Bif	Bif
	(GCA9702)	(GCA9708)	(mg/kg or %)	(GCA9702)	(GCA9708)
Al	3.9%	3.8%	8.2%	0	0
Fe	24.0%	20.0%	4.1%	2	2
Na	0.0083%	0.0081%	2.3%	0	0
K	5.1%	5.1%	2.1%	1	1
Mg	0.21%	1.2%	2.3%	0	0
Ca	0.2%	0.5%	4.1%	0	0
Ag	0.11	0.12	0.07	0	0
Cu	28	32	50	0	0
Zn	130	86	75	0	0
Cd	0.06	0.18	0.11	0	0
Pb	20	18	14	0	0
Cr	250	330	100	1	1
Ni	40	42	80	0	0
Со	13	21	20	0	0
Mn	260	4,700	950	0	2
Hg	0.24	0.22	0.05	2	2
Sn	1.5	1.3	2.2	0	0
Sr	7.1	7.7	370	0	0
Ba	190	220	500	0	0
Th	7.7	7.8	12	0	0
U	2.4	2.5	2.4	0	0
Tl	0.70	0.75	0.6	0	0
V	58	46	160	0	0
As	40	49	1.5	4	4
Bi	0.37	0.37	0.048	2	2
Sb	4.2	3.8	0.2	4	4
Se	1.7	1.3	0.05	5	4
Mo	2.9	2.8	1.5	0	0
В	<50	<50	10	0	0
Р	690	660	1,000	0	0
F	1,200	460	950	0	0

Table 16: Multi-Element-Analysis Results for Mine-Waste Samples (Eagle)

Note: Average-crustal abundance of elements based on Bowen (1979), and the Geochemical-Abundance Index (GAI) is based on Förstner *et al.* (1993). Refer Attachment II.

Table 17: Water-Extraction-Testwork Results for Mine-Waste Samples (Eagle)

	Above-BoX		Below-BoX	(Basement)		Abov	e-BoX	Below-BoX (Basement)	
ELEMENT/	CID	BID	Bif	Bif	ELEMENT/	CID	BID	Bif	Bif
PARAMETER	(GCA9696)	(GCA9699)	(GCA9702)	(GCA9708)	PARAMETER	(GCA9696)	(GCA9699)	(GCA9702)	(GCA9708)
Major-Parameters					Minor-Ions (µg/L)				
pH	6.8	6.7	2.5	4.9	Cu	<10	<10	1,600	<10
EC [µS/cm]	31	23	4,100	2,400	Ni	<10	<10	2,200	680
					Zn	<10	<10	790	150
					Со	< 0.1	< 0.1	990	310
Major-Ions (mg/L)					Cd	< 0.02	< 0.02	4.9	8.6
					Pb	1.5	1.5	270	24
Na	1.7	1.4	0.5	1.7	Cr	<10	<10	1,200	<10
K	1.2	1.3	1.3	30	Hg	<0.1	<0.1	0.5	<0.1
Mg	1.2	0.92	170	280	As	0.1	0.2	49	1.2
Ca	1.4	0.53	110	99	Sb	0.02	0.02	0.53	0.03
Cl	2	2	2	2	Bi	< 0.005	< 0.005	< 0.005	< 0.005
${ m SO}_4$	1	2	3,100	1,600	Se	<0.5	< 0.5	4.0	8.1
					В	20	30	<10	<10
Fe	< 0.01	< 0.01	650	10	Мо	0.14	0.18	0.45	1.4
Al	< 0.01	0.04	160	1.2	Р	<100	<100	3,500	<100
Si	6.2	7.4	9.3	5.5	Ag	< 0.01	< 0.01	0.02	< 0.01
					Ba	3.5	2.3	3.5	27
					Sr	6.4	4.5	20	96
					T1	< 0.01	< 0.01	0.12	0.54
					V	<10	<10	370	<10
					Sn	0.1	0.1	0.2	0.1
					U	< 0.005	< 0.005	6.8	0.25
					Th	< 0.005	< 0.005	18	0.026
					Mn	<10	<10	7,500	92,000

Note: All results in mg/L, except for pH and Electrical-Conductivity (EC).

<u>Notes</u>: Water-Extraction Testwork employed crushed-samples (nominal 2-mm), and slurries prepared using deionised-water, and a solid:solution ratio of c. 1:2 (w/w). Slurries were bottle-rolled for c. 1 day, prior to obtaining water-extracts (via centrifugation and vacuum-filtration) for analysis. Values in parentheses represent duplicates.

Table 18: Clay-Mineralogical and Clay-Surface-Chemistry Results for Mine-Waste Samples (Eagle)

	RC (G	CA9691)			DID1 (GCA969	2)		
hem qua kaol	atite artz inite		maj	jor 10r	her զւ		major			
kaolinite goethite Ti-oxide			tra	се	kao go Ti-	olinite ethite oxide		acce	ssory	
eCEC	%	-Propor	tion of eC	EC	eCEC	%	-Propor	ortion of eCEC		
[cmol (p+)/kg]	Na	K	Mg	Ca	[cmol Na K (p+)/kg]			Mg	Ca	
3.5	23	4	44	29	2.0	19	<1	41	40	

Notes: eCEC = effective-Cation-Exchange Capacity major = 20-50 %; minor = 10-20 %; accessory = 2-10 %; and, trace = less than 2 %

	DID2 (G	GCA9693	3)			CID (G	CA9697)			
hem kaol goet qua	hematite kaolinite goethite quartz Ti-oxide			nant sory	go kac qı Ti-	ethite blinite lartz oxide		major minor accessory		
Ti-o	xide		tra	ce						
eCEC	%	-Propor	tion of eC	EC	eCEC	%	-Proporti	on of eC	EC	
[cmol (p+)/kg]	Na	K	Mg	Ca	[cmol Na K (p+)/kg]			Mg	Ca	
1.6	54	<1	28	18	3.4 17 <1			43	40	

Notes:

 $\overline{eCEC} = effective-Cation-Exchange Capacity}$

dominant = greater than 50 %; major = 20-50 %; minor = 10-20 %; accessory = 2-10 %; and, trace = less than 2 %

Table 19: Acid-Base-Analysis and Net-Acid-Generation Results for Mine-Waste Samples (Champion)

GCA-	SITE-	DRILLHOLE &			EC-(1:2)	TOTAL-S	SO ₄ -S	SULPHIDE-	TOTAL-C	CO ₃ -C	ANC	NAPP	NAG		ANC/	AFP
SAMPLE	SAMPLE	DOWN-HOLE	LITHOTYPE	pH-(1:2)	[mS/cm]	(%)	(%)	S (%)	(%)	(%)	kg l	H ₂ SO ₄ /ton	ne	NAG-pH	MPA	CATEGORY
NO.	NO.	INTERVAL (m)													RATIO	
Samples from	n Above-BoX (= "w	vaste-regoliths"														
GCA9709	HPCS001	HPRC0585, 2-4	RC	5.9	0.18	<0.01 [0.007]	< 0.01	< 0.01	0.05	< 0.01	6	nc	1.2	6.0	nc	NAF
GCA9710	HPCS002	HPRC0641, 10-12	DID1	6.8	0.071	0.02 [0.016]	< 0.01	0.02	0.06	< 0.01	5	nc	<0.5	6.5	nc	NAF
GCA9711	HPCS003	HPRC0585, 28-30	DID2	6.0	0.080	0.02 [0.015]	< 0.01	0.02	0.10	0.03	5	nc	<0.5	5.8	nc	NAF
GCA9712	HPCS004	HPRC0641, 42-44	DID3	6.0	0.043	0.03 [0.021]	< 0.01	0.03	0.11	0.04	5	nc	< 0.5	5.5	nc	NAF
GCA9713	HPCS005	HPRC0641, 46-48	DID4	6.1	0.035	0.02 [0.018]	< 0.01	0.02	0.11	< 0.01	4	nc	<0.5	5.6	nc	NAF
GCA9715	HPCS007	HPRC0326, 30-32	BID	6.7 (6.7)	0.037 (0.036)	0.02 [0.013]	0.01	0.01	0.37	0.03	5	nc	<0.5	5.3	nc	NAF
Samples from	n Basement [= Beld	w-BoX] (i.e. "waste-be	drocks")													
GCA9716	HPCS008	HPRC0739a, 18-20	Shl	6.6	0.052	<0.01 [0.019]	< 0.01	< 0.01	0.16	< 0.01	5	nc	< 0.5	6.7	nc	NAF
GCA9717	HPCS009	HPRC0739a, 20-22	Shl	4.2	0.69	1.4 [1.31]	0.13	1.3	1.3	0.73	10	30	20	2.9	<1	PAF
GCA9718	HPCS010	HPRC0739a, 22-24	Shl	4.5	1.6	3.0 [2.11]	0.23	2.8	3.5	2.8	28	58	28 (27)	3.5 (3.6)	<1	PAF
GCA9719	HPCS011	HPRC0345, 50-52	Shl-(WS)	2.4	2.9	0.67 [0.729]	0.20	0.47	1.2	< 0.01	-12	27	43	2.5	<1	PAF
GCA9720	HPCS011-skin			2.7	1.5	2.0	0.49	1.6	1.5	0.03	-2	51	20	2.8	<1	PAF
GCA9721	HPCS012	HPRC0345, 52-54	Shl-(WS)	2.6	2.7	1.1 [0.969]	0.61	0.49	1.8	0.02	-9	24	23	2.7	<1	PAF
GCA9722	HPCS012-skin			2.5	2.0	0.75	0.36	0.39	1.9	< 0.01	-8	20	21	2.7	<1	PAF
GCA9723	HPCS013	HPRC0345, 54-56	Shl-(WS)	2.7	1.4	0.41 [0.785]	0.21	0.20	1.4	0.02	-3	9.2	9.5	3.1	<1	PAF
GCA9724	HPCS013-skin			2.8	1.1	0.51	0.17	0.34	1.3	< 0.01	-5	16	13	2.9	<1	PAF
GCA9725	HPCS014	HPRC0757, 68-70	Shl	5.7 (5.7)	1.1 (1.1)	1.4 [1.26]	0.09	1.4	3.3	1.6	21	nc	12	3.7	nc	NAF
GCA9726	HPCS015	HPRC0757, 70-72	Shl	6.1	0.77	0.89 [0.744]	0.06	0.83	3.4	2.2	35 (38)	nc	< 0.5	6.9	nc	NAF
GCA9727	HPCS016	HPRC0757, 72-74	Shl	5.5	1.4	1.4 [1.21]	0.14	1.3	1.7	0.99	20	20	6.7	3.4	<1	PAF

Notes: EC = Electrical Conductivity; ANC = Acid-Neutralisation-Capacity; NAPP = Net-Acid-Producing-Potential; AFP = Acid-Formation-Potential; NAG = Net-Acid Generation; nc = not calculated; NAF = Non-Acid-Forming; PAF = Potentially-Acid Forming. pH-(1:2) and EC-(1:2) values correspond to pH and EC measured on sample slurries prepared with deionised-water, and a solid:solution ratio of *c*. 1:2 (w/w). All results expressed on a dry-weight basis, except for pH-(1:2), EC-(1:2), and NAG-pH. Values in round-parentheses represent duplicates.

N.B. Total-S values in square-parentheses correspond to results from Exploration-Database.

Table 20: Total-Contents of As, Sb, Se, Mo and B in Mine-Waste Samples (Champion)

GCA-	SITE-	DRILLHOLE &		SULPHIDE-	TOTAL-As	TOTAL-Sb	TOTAL-Se	TOTAL-Mo	TOTAL-B
SAMPLE	SAMPLE	DOWN-HOLE	LITHOTYPE	S (%)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
NO.	NO.	INTERVAL (m)							
Samples from	<u>n Above-BoX (= "wa</u>	ste-regoliths"							
GCA9709	HPCS001	HPRC0585, 2-4	RC	< 0.01	8.1	0.94	0.28	0.6	<50
GCA9710	HPCS002	HPRC0641, 10-12	DID1	0.02	12	1.2	0.59	1.1	<50
GCA9711	HPCS003	HPRC0585, 28-30	DID2	0.02	9.5	1.4	0.49	2.0	<50
GCA9712	HPCS004	HPRC0641, 42-44	DID3	0.03	8.6	1.3	0.56	1.8	<50
GCA9713	HPCS005	HPRC0641, 46-48	DID4	0.02	6.5	1.3	0.59	1.7	<50
GCA9715	HPCS007	HPRC0326, 30-32	BID	0.01	27	1.5	2.6	2.2	<50
Samples from	<u>m Basement [= Belov</u>	v-BoX] (i.e. "waste-bedr	<u>ocks")</u>						
GCA9716	HPCS008	HPRC0739a, 18-20	Shl	< 0.01	44	5.2	0.29	2.3	<50
GCA9717	HPCS009	HPRC0739a, 20-22	Shl	1.3	40	3.8	0.98	2.4	<50
GCA9718	HPCS010	HPRC0739a, 22-24	Shl	2.8	38	4.2	1.6	2.7	<50
GCA9719	HPCS011	HPRC0345, 50-52	Shl-(WS)	0.47	50	3.9	0.91	2.9	<50
GCA9720	HPCS011-skin			1.6	91	5.6	2.6	3.4	<50
GCA9721	HPCS012	HPRC0345, 52-54	Shl-(WS)	0.49	70	4.6	1.1	3.6	<50
GCA9722	HPCS012-skin			0.39	54	4.3	0.82	3.6	<50
GCA9723	HPCS013	HPRC0345, 54-56	Shl-(WS)	0.20	49	3.0	0.74	3.1	<50
GCA9724	HPCS013-skin			0.34	57	3.4	0.76	3.1	<50
GCA9725	HPCS014	HPRC0757, 68-70	Shl	1.4	55	4.1	0.72	3.9	<50
GCA9726	HPCS015	HPRC0757, 70-72	Shl	0.83	54	2.9	0.85	3.1	<50
GCA9727	HPCS016	HPRC0757, 72-74	Shl	1.3	43	3.8	2.8	3.6	<50

	TOTAL-F	CLEMENT	AVERAGE-	GEOCHI	EMICAL-
ELEMENT	CONTENT	(mg/kg or %)	CRUSTAL	ABUNDANCE	INDEX (GAI)
	Shl-(WS)	Shl-(WS)	ABUNDANCE	Shl-(WS)	Shl-(WS)
	(GCA9719)	(GCA9723)	(mg/kg or %)	(GCA9719)	(GCA9723)
Al	3.8%	4.6%	8.2%	0	0
Fe	20.0%	19.4%	4.1%	2	2
Na	0.013%	0.017%	2.3%	0	0
K	2.2%	3.9%	2.1%	0	0
Mg	0.09%	0.15%	2.3%	0	0
Ca	0.2%	0.2%	4.1%	0	0
Ag	0.14	0.14	0.07	0	0
Cu	22	20	50	0	0
Zn	53	40	75	0	0
Cd	0.04	< 0.02	0.11	0	0
Pb	19	21	14	0	0
Cr	200	99	100	0	0
Ni	20	15	80	0	0
Co	4.9	3.3	20	0	0
Mn	930	370	950	0	0
Hg	0.17	0.17	0.05	1	1
Sn	1.6	1.8	2.2	0	0
Sr	27	27	370	0	0
Ba	280	420	500	0	0
Th	6.9	8.4	12	0	0
U	2.4	2.8	2.4	0	0
Tl	0.52	0.71	0.6	0	0
V	63	80	160	0	0
As	51	49	1.5	5	4
Bi	0.36	0.41	0.048	2	3
Sb	3.9	3.1	0.2	4	3
Se	0.91	0.74	0.05	4	3
Мо	2.8	2.8	1.5	0	0
В	<50	<50	10	0	0
Р	530	440	1,000	0	0
F	460	630	950	0	0

Table 21: Multi-Element-Analysis Results for Mine-Waste Samples (Champion)

Note: Average-crustal abundance of elements based on Bowen (1979), and the Geochemical-Abundance Index (GAI) is based on Förstner *et al.* (1993). Refer Attachment II.

Table 22: Water-Extraction-Testwork Results for Mine-Waste Samples (Champion)

	Below-BoX	(Basement)		Below-BoX (Basement)		
ELEMENT/ PARAMETER	Shl-(WS) (GCA9719)	Shl-(WS) (GCA9723)	ELEMENT/ PARAMETER	Shl-(WS) (GCA9719)	Shl-(WS) (GCA9723)	
Major-Parameters			Minor-Ions (µg/L)			
pH	2.3	2.6	Cu	1,100	710	
EC [µS/cm]	4,100	1,600	Ni	1,400	480	
			Zn	1,500	450	
			Со	710	420	
Major-Ions (mg/L)			Cd	2.7	1.1	
			Pb	68	40	
Na	0.7	0.9	Cr	660	120	
K	0.5	13	Hg	< 0.1	< 0.1	
Mg	45	31	As	110	7.8	
Ca	16	8	Sb	0.61	0.08	
Cl	2	3	Bi	0.005	< 0.005	
SO_4	3,000	690	Se	<0.5	<0.5	
			В	<10	<10	
Fe	550	11	Мо	1.4	0.56	
Al	200	57	Р	600	<100	
Si	12	22	Ag	0.03	< 0.01	
			Ba	13	23	
			Sr	15	23	
			T1	0.08	2.2	
			V	90	<10	
			Sn	0.2	0.1	
			U	25	5.4	
			Th	75	6.6	
			Mn	61,000	28,000	

Note: All results in mg/L, except for pH and Electrical-Conductivity (EC).

Notes: Water-Extraction Testwork employed crushed-samples (nominal 2-mm), and slurries prepared using deionised-water, and a solid:solution ratio of *c*. 1:2 (w/w). Slurries were bottle-rolled for *c*. 1 day, prior to obtaining water-extracts (via centrifugation and vacuum-filtration) for analysis. Values in parentheses represent duplicates.

Table 23: Clay-Mineralogical and Clay-Surface-Chemistry Results for Mine-Waste Samples (Champion)

DID1 (GCA9710)					DID2 (GCA9711)				
hematite quartz			ma	jor	hematite			dominant major	
kaolinite goethite Ti-oxide			accessory trace		kaolinite goethite quartz Ti-oxide		minor accessory trace		
eCEC %-Propor			tion of eCEC		eCEC	%-Proporti		ion of eCEC	
[cmol (p+)/kg]	Na	K	Mg	Ca	[cmol (n+)/kg]	Na	K	Mg	Ca
3.1	57	6	17	20	2.4	14	<1	59	27

Notes: eCEC = effective-Cation-Exchange Capacity dominant = greater than 50 %; major = 20-50 %; minor = 10-20 %; accessory = 2-10 %; and, trace = less than 2 %

FIGURES

Graeme Campbell & Associates Pty Ltd

Figure 1



pH-Buffering Curves for Waste-bedrock Samples from Delta-Pit

Note:

The H₂SO₄-addition rates employed in the auto-titrations correspond to sulphide-oxidation rates (SORs) up to *c*. 10^6 mg SO₄/kg/flush (= *c*. 10^4 kg H₂SO₄/tonne/year for weekly flushing-drying-cycles) <u>under weathering conditions near-optimal for sulphide-oxidation</u> (viz. typical moisture/aeration-regimes, on a weekly basis, in which sulphide-oxidation is limited by neither the O₂-supply [via diffusion], nor H₂O-supply/flushing).

These SORs are therefore up to 10^5 - 10^6 **faster** than those typical for the circum-neutral weathering, under near-optimal conditions, of mine-wastes which contain "minute/trace-sulphides" that are not hyper-reactive (e.g. framboidal-pyrites, and marcasites).

Figure 2



pH-Buffering Curve for Waste-bedrock Sample from Champion-Pit

Note:

The H₂SO₄-addition rates employed in the auto-titrations correspond to sulphide-oxidation rates (SORs) up to *c*. 10^6 mg SO₄/kg/flush (= *c*. 10^4 kg H₂SO₄/tonne/year for weekly flushing-drying-cycles) <u>under weathering conditions near-optimal for sulphide-oxidation</u> (viz. typical moisture/aeration-regimes, on a weekly basis, in which sulphide-oxidation is limited by neither the O₂-supply [via diffusion], nor H₂O-supply/flushing).

These SORs are therefore up to 10^5 faster than those typical for the circum-neutral weathering, under near-optimal conditions, of mine-wastes which contain "trace-sulphides" that are not hyper-reactive (e.g. framboidal-pyrites, and marcasites).

ATTACHMENT I

STATISTICS OF SULPHUR-OCCURRENCES AND DETAILS OF SAMPLING PROGRAMME

Graeme Campbell & Associates Pty Ltd



MEMO

То	Graeme Campbell	Date	26/8/2011			
Company	FMS	Pages				
Сс	Mick Anstey					
From	Graeme McDonald					
Re	Mine Waste Characterisation Study – Sample Selection					

Introduction

In May 2011 Graeme Campbell & Associates Pty Ltd were contracted to undertake a Geochemical Characterisation study of Mine-Waste Samples at the Flinders Mines Pilbara Iron Ore Project (PIOP). I was asked by Mick Anstey to liaise with Graeme Campbell to assist with the selection of samples to be used in the study.

The Pilbara project is located within the Mount Bruce 1:250 000 map sheet. Geological mapping shows the bedrock geology in the region to be the upper parts of the Hamersley Group, a Precambrian sequence dominated by Banded Iron Formation (BIF), shales and chert. In particular the outcropping geology is dominated by members of the Brockman Iron Formation, namely the Whaleback Shale Member, and the Dales Gorge and Joffre Banded Iron Formation (BIF) Members. The majority of drilling penetrates the Whaleback Shale and Dales Gorge units. Within the Blacksmith tenement there are five major valleys, or channels, incised into the bedrock geology; Ajax, Blackjack, Champion, Delta and Eagle. Exploration by Flinders has focussed on exploring these channel systems for Detrital Iron Deposits (DID), Channel Iron Deposits (CID) and the Brockman Iron Formation for Bedded Iron Deposits (BID), both beneath and on the margins of the channels.

This memo documents the sample selection process and methodology.

Sulphur Statistics

The presence of sulphur, particularly in the form of sulphides, is a good indicator of the acid forming potential of different rock types. Therefore, the S values determined by XRF as part of our routine sample analysis were investigated as a tool to targeting particular problematic lithologies.

Figure 1 displays S(%) distribution histograms for a range of different lithologies. Recent Colluvium (RC), Detrital Iron Deposit (DID), Channel Iron Deposit (CID) and Bedded Iron Deposit (BID) lithologies essentially shown normal distributions with low mean Sulphur values of 0.01 – 0.022%. Basement lithologies of Banded Iron Formation (BIF) and Shale display positively skewed populations, possibly reflecting a mixing between the two as they can be difficult to identify when logging on a 2m scale. The BIF samples have a mean sulphur value of 0.016% and a maximum of 1.72%. The shales have a much higher mean sulphur value of 0.055% compared to all other samples and a maximum value of 2.59%. Table 1 summarises these results. Based on this analysis the shale units that are below the economic mineralisation have the most elevated sulphur values and when logging these units visible sulphide in the form of pyrite has been noted in some holes. Further investigation has shown the Whaleback Shale to have on average higher sulphur values than the shales within the Dales Gorge BIF unit.

Lithology	Mean Sulphur (%)	Max Sulphur (%)						
RC	0.011	0.269						
DID	0.015	0.176						
CID	0.010	0.063						
BID	0.022	0.441						
BIF	0.016	1.72						
Shale	0.055	2.59						

Table 1 : Summary of sulphur values for different lithologies.

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Figure 1 : Sulphur distribution histograms for a range of different lithologies



Figure 1 cont:

Sample Locations

Samples were collected across the three main deposits of Delta, Eagle and Champion. They were selected on the basis of lithology and sulphur content with the aim of providing a good representation of the whole project area. A larger number of samples were collected from Delta as this currently represents the area to be mined first. A number of the high sulphur samples were also selected. Drillhole locations are shown in Figure 2.

Sample Collection

Samples were collected from 2m downhole intervals derived from reverse circulation (RC) drilling. Sample piles had been sitting on the surface for up to 3 years, however most holes were less than 2 years old. The minimum amount of sample collected was 2-3kg with up to 5kg collected where possible. In each case the top few centimetres of material (skin) was removed and a grab sample of the "core" of the pile was taken. This process is demonstrated in the sequence of photographs shown in Figure 3. For a small number of high sulphur samples the outer skin was also collected as demonstrated in Figure 4.

In total 60 samples were collected for static testwork (and 3 "skin" samples) and 18 (6 composites) for kinetic testwork. 33 of the static samples were from above BoX and 27 were from basement units below BoX. All sample details are contained within Table 2.



 $\label{eq:Figure 2} Figure \ 2: \ Location \ of \ drillholes \ from \ which \ samples \ were \ collected.$



Figure 3 : A sequence of photos demonstrating the sampling technique. The outer skin of the pile is moved to the side (top) exposing the inner core (middle) and the sample is then taken (bottom).


Figure 4 : Outer skin of sample pile is collected as it is removed from this high sulphur Whaleback Shale sample.

Table 2 : Sample details

Delta Kinetic (above BoX)

- sin middle farst	o ponty	Internal	1 (2kg) - A .	amala	Interval 2 (2kg)	Beample	1 Interval 2	(2kg) - C	amala	1
Composite Sample	Lithology	Hole ID	Denth (m)	S %	Hole ID Denth (m) S%	Hole ID De	anth (m)	s oc	ł
HPDC001	DID1	H0001119	2+o 10	0.017	H00010 D00011	nij 270	HD073097	70+++ 17	001	ł
HPDC002	DID2	HOPCIDES	101010	0.017	Upperside 10101	0.01	HORCINO	16+0 20	0.02	1
HPDC003	DID3	HPRC3014	2010 20	0.015	HPRC2171 12 to 12	a nni	HPRC2105	301022	0.015	1
HPDC004	DID4	HPRCania	76+0.79	0.010	HDRC2171	7 DD1	HDRC2154	40 to 67	0.012	1
HPDC005	CID	HPRC2179	64to 66	0.006	HPRC2177 93+- 9	4 0.000	HPRC2177	20 to 72	0.004	1
HPDC005	BID	HPRC3014	30 to 32	0.024	HPRC2171 EDto 5	2 0.000	HPRC2104	40 to 47	0.027	1
in Buccu	912	HITESDAT	30 10 31	0.02.	The notice of the other of	C 0.010	Tingetter	in the field	0.0 61	-
Delta Static (above	BoXi	2 - 3 Kg sa	moles (No SI	kin)						
Single Sample	Lithology	Hole ID	Denth (m)	5 %	Comments					
HPDS001	PC	H02C1170	4++5	0.011	1000000000					
HPDS002	DID1	HDRC2170	78to 30	0.017						
HPDS003	DID1	HPRC2135	74 to 25	0.015						
HPDS004	DID1	HPRC 2087	271024	0.025						
HPDS005	DID2	HDRC3157	10 to 12	0.02						
HPDS006	DID2	HPRC2105	14 to 16	0.016						
HPDS007	DID2	HPRC2218	20 to 22	0.021						
HPDS008	DID3	HPRC3152	22 to 24	0.079						
HPDS009	DID3	HPRC2105	32 to 34	0.016						
HPDS010	DID3	HPBC 3013	22 to 24	0.014						
HPDS011	DID4	HDEC2173	53 10 54	0.01						
HPDS012	DID4	HDRC3152	40 fo 47	0.01						
HPDS013	DID4	HPRC3013	24 to 25	0.013						
HPDS014	CID	HPRC2177	B4to RF	0.005						
HPDS015	BID	HPRCRISE	501052	0.003						
HPDS016	BID	HPRCR012	341036	0.000						
HPDS017	BID	HPBC2105	4210.44	0.03						
	315	Luneand	STR AND THE		-					
Eagle Static (above	BoX)	2 - 3 Ke sa	mples (No SI	kin)						
Single Sample	Lithology	Hole ID	Depth (m)	5%	Comments					
HPES001	RC	HPRC4169	16 to 18	2000						
HPES002	DID1	HPRC4153	34 to 36	0.007						
HPES003	DID2	HPRC4113	20 to 22	0.013						
HPES004	DID3	HPRC4113	24 to 26	0.015						
HPES005	DID4	HPRC4153	48 to 50	0.013						
HPES006	CID	HPRC4137	80 to 82	0.009						
HPES007	CID	HPRC4155	58 to 50	0.004						
HPES008	CID	HPRC4169	56 to 58	0.015						
HPES009	BID	HPRC4072	38 to 40	0.025						
		-			-					
Champion Static (al	oove BoX)	2 - 3 Kg sa	mples (No Sl	kin)						
Single Sample	Lithology	Hole ID	Depth (m)	5%	Comments					
HPCS001	RC	HPRC0585	2to4	0.007						
HPCS002	DID1	HPRC0641	10to17	0.016						
HPCS003	DID2	HPRCOSES	28 to 30	0.015						
HPCS004	DID3	HPRC/0641	42 to 44	0.071						
HPCS005	DID4	HPRCORAI	46 to 4R	0.018						
HPCS006	CID	HPRC0757	48 to 50	0.004						
HPCS007	BID	HPRC0326	30 to 32	0.013	1					
	S			0						
Delta Static (Basem	ent)	2 - 3 Kg sa	mples (No SI	kin)						
Single Sample	Lithology	Hole ID	Depth (m)	5%	Comments					
HPDS018	Shi	HPRC2197	50 to 52	1.04						
HPDS019	Shi	HPRC2197	52 to 54	2.35						
HPDS020	Bif	HPRC2197	54 to 56	0.387	and the second se					
HPDS021	Shi	HPRC3027	42 to 44	143	Whaleback Shale					
HPDS022	Shi	HPRC3027	44 to 45	2.5	Whaleback Shale					
HPDS023	Bif	HPRC3027	46 to 48	0.197	Construction of the local of th					
HPDS024	Shi	HPRC2 323	BD to R7	1.58	# 9 Dales Gorge Sh	ale				
HPDS025	Bif	HPRC2323	BZ to R4	0.176	a a star sou be sh					
HPDS026	Shi	HPRC2 323	84 to 85	0.531	# 8 Dales Gorge Sh	ale				
Contraction of the second		L		0.444						
Eagle Static (Basem	ent)	2 - 3 Kg sa	mples (No SI	kin)						
Single Sample	Lithology	Hole ID	Depth (m)	5%	Comments					
HPES010	Shi	HDRCADD	341075	0.017						
HPES011	Shi	Hppcyopa	36+0.30	0.012						
HPES012	Bif	HPRCADO	381040	237						
HPES013	Bif	HPRCADDO	541055	0.755						
HPES014	Shi	црослове	564259	3.1.4						
HPES015	shi	Horeinne	58 to 50	0.014						
HPESOIG	shi	HDRCADAR	374-74	0.914						
LIDESO17	shi	HPRC4019	221024	0.004						
IDESM 9	SIII Di€	HPRC4019	24 to 26	0.027						
DFE2018	DIT	HPRC4019	26 to 28	27						
Champelor Statt, In		3.98-		(In)						
Champion Static (Ba	asementj	2 - 3 Kg sa	mpies (No SI	KIN)	b		Francis			
single sample	Lithology	noie ID	Depth (m)	3%	comments	Skin	sample			
HPCS008	shi	HPRC0739a	18 to 20	0.019						
HPCS009	Shi	HPRC0739a	20 to 22	1.31						
HPCS010	Shi	HPRC0739a	22 to 24	2.11	and a company		Vincenter and			
HPCS011	Shi	HPRC0345	50 to 52	0.729	Whaleback Shale	Yes	HPCS011 Skir	n		
HPCS012	Shi	HPRC0345	52 to 54	0.969	Whaleback Shale	Yes	HPCS012 Skin	n		
HPCS013	Shi	HPRC0345	54 to 56	0.785	Whaleback Shale	Yes	HPCS013 Ski	n		
HPCS014	Shi	HPRC0757	68 to 70	1.26						
HPCS015	Shl	HPRC0757	70 to 72	0.744						
HPCS016	Shl	HPRC0757	72 to 74	1.21						

ATTACHMENT II

TESTWORK METHODS

Graeme Campbell & Associates Pty Ltd

ATTACHMENT II

TESTWORK METHODS

The testwork methods outlined below are proven approaches to 'static-testing' and 'kinetic-testing' within the Australian, and international mining-industries (e.g. Price 2009; Stewart *et al.* 2006; AMIRA 2002; Morin and Hutt 1997).¹ The MEND-document prepared by Price (2009), and *c.* 10-20 years in the making by an experienced practitioner, is an invaluable source of information on testing methods on mine-waste geochemistry. There is also the Global-Acid-Rock-Drainage-Guide (GARD Guide) which is an INAP initiative (go to: www.gardguide.com). However, in terms of comprehensiveness, structure, and clarity, the document by Price (2009) is recommended.

Part of the acid-base-account (ABA) testing, and all of the multi-element analyses, and clay-surface-chemical determinations, are carried out by Genalysis Laboratory Services Pty Ltd [GLS] (Maddington). Specialised ABA-testing, and kinetic-testing, is undertaken by GCA (Bridgetown). Characterisation of rock- and clay-mineralogy is carried out by Roger Townend & Associates (Malaga).

Samples are crushed to 2mm (nominal) in a jaw/rolls-crusher, and pulverised to $75\mu m$ (nominal), for specific tests, as required. These sample-splits are referred to herein as "crushings" and "pulps", respectively.

It should be noted that the testwork methods described below are routinely employed in work programmes undertaken by GCA. However, the testwork methods described are generic, and specific tests may not necessarily be undertaken in a given study.

1.0 ACID-BASE-CHEMISTRY AND SALINITY TESTWORK

Acid-base chemistry and salinity are assessed by determining:

- pH and Electrical-Conductivity (EC) on sample slurries;
- Total-Sulphur (Total-S), and Sulphate-Sulphur (SO₄-S);
- Acid-Neutralisation-Capacity (ANC), and CO₃-C;
- Net-Acid-Producing-Potential (NAPP); and,
- Net-Acid-Generation (NAG).

Relevant details of the testwork methods employed are discussed below. Further details are presented in the laboratory reports.

¹ 'Static'-testing' corresponds to "whole-rock" analyses and tests.

1.1 pH-(1:2) and EC-(1:2) Tests

Measurements of pH and EC are performed on slurries prepared using deionised-water, and a solid:water ratio of c. 1:2 (w/w). The slurries are allowed to age for c. 24 hours, prior to measuring pH and EC.² These tests are performed on the crushings.

<u>pH-(1:2)</u> and <u>EC-(1:2)</u> values provide a measure of the inherent acidity/alkalinity and salinity.³

1.2 Total-S and SO₄-S

<u>Total-S</u> is determined by Leco combustion (@ 1300 °C) with detection of evolved $SO_{2(g)}$ by infra-red spectroscopy. <u>SO₄-S</u> is determined by the Na₂CO₃-Extraction Method (Berigari and Al-Any 1994; Lenahan and Murray-Smith 1986).⁴ The difference between Total-S and SO₄-S indicates the <u>Sulphide-S</u> (strictly Non-Sulphate-S) value. The Total-S and SO₄-S tests are performed on pulps.

1.3 Acid-Consuming Properties

1.3.1 ANC

ANC is determined by a procedure based on that of Sobek *et al.* (1978) which is the "standard" ANC-testing method (AMIRA 2002; Morin and Hutt 1997).

Samples (as crushings) are reacted with dilute HCl for *c*. 2 hours at 80-90 °C, followed by back-titration with NaOH to a pH=7 end-point to determine the amount of acid consumed.⁵ The simmering step for *c*. 2 hours differs from the Sobek *et al.* procedure wherein test-mixtures are heated to near boiling until reaction is deemed to be complete, followed by boiling for one minute. In terms of the dissolution of carbonate- and primary-silicate-minerals, this variation to the Sobek *et al.* method is inconsequential.

The Sobek *et al.* (1978) procedure subjects samples to both strongly-acidic conditions (e.g. pH of 1-2), and a near-boiling temperature. Provided excess acid is added, the dissolution of carbonate-minerals is near-quantitative, and traces of primary-silicates

 $^{^2\,}$ The slurries are stirred at the beginning of the testwork, and once again immediately prior to measuring pH and EC.

³ The pH-(1:2) values approximate the "Abrasion-pH" values for identifying minerals in the field (e.g. Stevens and Carron 1948).

⁴ The Na₂CO₃-reagent extracts SO₄ which occurs as soluble sulphates, and calcium sulphates (e.g. gypsum and anhydrite). It also extracts SO₄ sorbed to the surfaces of sesquioxides, clays and primary-silicates. However, SO₄ present as barytes (BaSO₄) is <u>not</u> extracted, and SO₄ associated with jarositic-type and alunitic-type compounds is incompletely extracted.

⁵ A few drops of 30 % (w/w) H_2O_2 are added to the test mixtures as the pH=7 end-point is approached, so that Fe(II) forms released by the acid-attack of ferroan-carbonates (and -silicates) are oxidised to Fe(III) forms (which then hydrolyse to "Fe(OH)₃"). This step ensures that the resulting ANC values are not unduly biased "on-the-high-side", due to the release of Fe(II) during the acid-digestion step (AMIRA 2002), provided that the ferroan-carbonate content is not excessive (e.g. siderite-C values less than 1.5 % [Stewart *et al.* 2006]).

also dissolve. However, at circum-neutral-pH (viz. pH 6-8) relevant to mine-waste and environmental management, the dissolution of primary-silicates is kinetically limiting (e.g. see review-monograph by White and Brantley [1995]).

In the absence of inhibiting alteration-rims, dissolution rates of mafic/felsic-silicates generally equate to H_2SO_4 -consumption rates 'of-the-order' 10^{-11} - 10^{-12} moles/m²/s. Accordingly, for particle-sizes within the sub-mm range, circum-neutral-dissolution rates of primary-silicates correspond to Sulphide-Oxidation Rates (SORs) 'of-the-order' 1-10 mg SO₄/kg/week (= *c*. 0.1-1.0 kg H₂SO₄/tonne/year).⁶ In practice, circum-neutral buffering through the surface-hydrolysis/dissolution of primary-silicates is therefore restricted to <u>both</u> particle-gradings akin to "rock-flour" (viz. sub-mm), <u>and</u> slow rates of sulphide-oxidation (e.g. as exhibited by "trace-sulphides" which are not atypically reactive).⁷

Despite aggressive-digestion conditions, the ANC values determined by the Sobek *et al.* (1978) method allow an informed "screening" of acid-consuming properties, especially when due regard is given to groundmass-mineralogy (Morin and Hutt 1997). Jambor *et al.* (2005, 2002, 2000) list 'Sobek-ANC' values for different types of primary-silicates which assists interpretation of ANC-testwork results.

That the ANC value is <u>not</u> an intrinsic property of a sample of geologic media, but rather the outcome of the particular ANC-testwork method employed, is shown by Morin and Hutt (2009).

 CO_3 -C is the difference between the Total-C and Total-Organic-C (TOC). Total-C is measured by Leco combustion (@ 1300 °C) with detection of evolved $CO_{2(g)}$ by infrared spectroscopy. TOC is determined by Leco combustion on a sub-sample which had been treated with strong HCl to decompose carbonate-minerals. Pulps are used for these determinations.

1.3.3 pH-Buffering Properties

pH-Buffering properties are determined via a Metrohm[®] 736 Titrino auto-titrator, and 0.05 M-H₂SO₄. Auto-titrations comprise regular addition of H_2SO_4 to decrease the pH values of the test-suspensions (prepared using pulps) to 3.0 typically over the course of

⁶ SORs of this magnitude (at circum-neutral-pH) would typically only be recorded for the oxidation of "trace-sulphides" (e.g. Sulphide-S contents less than *c*. 0.5 %) which are not hyper-reactive, and so excludes *inter alia* framboidal-pyrite, and marcasite.

⁷ Primary-particle-sizes within the "rock-flour" range is a given for process-tailings-solids. In the case of mine-wastes, despite its usually small weight-based abundance, this size-fraction is invariably the main seat of geochemical-weathering reactions within waste-dumps, and thereby the main "source-term" for solute generation (e.g. Price and Kwong 1997). Such "rock-flour" occurs in two forms: that obtained via dry-sieving, and that associated with the surfaces of clasts of wide-ranging sizes, and which can only be obtained via wet-sieving.

c. 1 day.⁸ Despite taking up to 1 day to complete, the H_2SO_4 -addition rates employed in the auto-titrations are 'orders-of-magnitude' <u>faster</u> than the sulphide-oxidation rates typically observed under "ambient-weathering" conditions.

1.4 NAPP Calculations

NAPP values are calculated from Total-S, SO₄-S and ANC values, assuming that <u>all</u> of the Sulphide-S occurs in the form of pyrite, and/or pyrrhotite. NAPP values facilitate assessment of Acid-Formation Potential (AFP).

The complete-oxidation of pyrite (and/or marcasite) may be described by:

 $FeS_2 + 15/4 O_2 + 7/2 H_2 O = 2H_2 SO_4 + "Fe(OH)_3"$

The complete-oxidation of pyrrhotite may be described by:

$$"FeS" + 9/2O_2 + 5/2H_2O = H_2SO_4 + "Fe(OH)_3"$$

Since pyrrhotite is non-stoichiometric, expressing it as "FeS" is approximate (Janzen *et al.* 2000). Elemental-S may also be produced during pyrrhotite weathering (Nicholson and Scharer 1994), especially at low-pH. However, Elemental-S is ultimately oxidised to H_2SO_4 .

It may be shown that, if the Sulphide-S (in %S) occurs as pyrite/pyrrhotite, then the amount of acid (in kg H_2SO_4 /tonne) produced through complete-oxidation is given by <u>**30.6 x %S**</u>. That is, the same conversion-factor of 30.6 applies for both pyrite-, and pyrrhotite-oxidation.

<u>Note</u>: The above treatment of oxidation-reaction stoichiometry is restricted to oxidation by 'atmospheric-O₂' which is the dominant oxidant at circum-neutral-pH. A different oxidation-stoichiometry applies under acidic conditions (e.g. pH less than 3-4) where soluble-Fe(III) forms prevail, and then function as the chief oxidant (e.g. Rimstidt and Newcomb 1993).

Mechanistic aspects of pyrite- and pyrrhotite-oxidation were reviewed by Rimstidt and Vaughan (2003), and Belzile *et al.* (2004), respectively.

1.5 NAG Tests

The NAG Test is a direct measure of the potential for acid-production through sulphideoxidation, and also provides an indication of the reactivity of the sulphide-minerals, and the availability of alkalinity-forms (AMIRA 2002; Miller *et al.* 1997, 1994). Since this test is performed on pulps, sulphide-grains are fully liberated, and available for reaction.

⁸ In titrating to a pH=3.0 end-point, any Fe(II) released through acid attack of ferroan-carbonates and -silicates is <u>not</u> quantitatively oxidised to Fe(III), and subsequently hydrolysed/precipitated to "Fe(OH)₃". The equivalent of *c*. 0.5 kg H₂SO₄/tonne is generally required to decrease the pH of the "solution-only" to pH=3.0. <u>No</u> correction is made for this "electrolyte-consumption" of H₂SO₄.

The sample is reacted with H_2O_2 to oxidise sulphide-minerals, and allow the produced acid to react with the acid-neutralising components (chiefly carbonate-minerals). The results from NAG testwork supplement the NAPP-based assessment of AFP (Stewart *et al.* 2006; Shaw 2005; Morin and Hutt 1997).

The NAG-testing methodology used by GCA is the <u>'Static-NAG Test'</u> in its "singleaddition" mode, with NaOH-titration to a pH=7 end-point (AMIRA 2002; Miller *et al.* 1994, 1997). The Start-pH of the 15 % (v/v) H₂O₂ solution (prepared from A.R.-grade H₂O₂) is adjusted to pH=4.5 using 0.1 M-NaOH. The boiling treatment to decompose residual, unreacted-H₂O₂ following overnight reaction is carried out in two stages (viz. boiling for *c*. 2 hours initially, cooling and addition of 1 mL of 0.02 M-CuSO₄, followed by boiling for a further *c*. 2 hours). The addition of Cu(II) catalyses the decomposition of unreacted-H₂O₂, and thereby prevents "positive-blank" values (McElnea and Ahern 2004; O'Shay *et al.* 1990).⁹

Prior to the boiling steps, the pH values of the test-suspensions are measured. Such pH values reflect buffering under ambient conditions without accelerated dissolution of groundmass-minerals through boiling. In the interpretation of NAG-testwork results, it is important to note the pH values prior to the boiling steps, especially for lithotypes characterised by "trace-sulphides" (e.g. Sulphide-S within the sub-% range), and ANC values less than *c*. 10-20 kg H₂SO₄/tonne (e.g. a groundmass devoid of carbonate-minerals). The rates of "peroxide-oxidation" are orders-of-magnitude faster than those of "ambient-oxidation" (viz. SORs recorded in kinetic-testing employing Weathering-Columns). If circum-neutral-pH is to prevail during NAG testwork, then the rate of acid-consumption must be proportionately faster than that for "ambient-oxidation", and is essentially restricted to buffering by reactive-carbonate-minerals (e.g. calcites, dolomites, and ankerites). This aspect must be borne in mind when interpreting NAG-testwork results, especially for samples that contain "trace-sulphides" in a carbonate-deficient groundmass.

2.0 MULTI-ELEMENT ANALYSES

The total content of a wide range of major- and minor-elements are determined through the use of various digestion and analytical techniques. The respective detection-limits are appropriate for environmental investigations.

Element enrichments are identified using the *Geochemical Abundance Index (GAI)*.¹⁰ The GAI quantifies an assay result for a particular element in terms of the average-

⁹ Where samples contain sufficient Cu(II), then Cu(II) forms will be released to solution during reaction with H_2O_2 , especially at low-pH.

¹⁰ The GAI was developed by Förstner *et al* (1993), and is defined as:

 $GAI = \log_2 \left[C_n / (1.5 \times B_n) \right]$

where:

 C_n = measured content of n-th element in the sample.

 B_n = "background" content of the n-th element in the sample.

crustal-abundance of that element.¹¹ The latter corresponds to the typical composition of soils, regoliths and bedrocks derived from <u>unmineralised</u> terrain.

The GAI (based on a log-2 scale) is expressed in 7 integer increments (viz. 0 to 6). A GAI of 0 indicates that the content of the element is less than, or similar to, the average-crustal-abundance; a GAI of 3 corresponds to a 12-fold enrichment above the average-crustal-abundance; and so forth, up to a GAI of 6 which corresponds to a 96-fold, or greater, enrichment above average-crustal-abundances.

3.0 MINERALOGY AND CLAY-SURFACE CHEMISTRY

The semi-quantitative mineralogy, and clay-surface chemistry (generally restricted to waste-regoliths, oxide-ores, and/or soils), are determined using methods routinely used in geology, and soil science.

Indicative abundances of mineral fall into one of the following broad classes, viz.

• major 20-50	%
• minor 10-20	%
 accessory 2-10 % trace less th 	6 an 2 %

Randomly- and preferentially-oriented specimens are prepared, and variously treated with sodium-hexametaphosphate (dispersant), ethylene-glycol, and heating, to quantify non-expansive, and expansive (e.g. smectites), varieties of clay-minerals.

The Effective-Cation-Exchange Capacity (eCEC), and suite of Exchangeable-Cations, are determined by different methods for samples (as crushings) of non-calcareous and calcareous materials (Rengasamy and Churchman 1999). In both cases, soluble-salts are initially removed via pre-washing using a "mixed-organic-solvent" (viz. ethylene-glycol and ethanol). Method 15A2 in Rayment and Higginson (1992) is then employed for non-calcareous samples to determine eCEC, and Exchangeable-Sodium Percentage (ESP). In the case of calcareous samples, a method based on that described by Pierce and Morris (2004) is used, and prevents the dissolution of carbonate-minerals (e.g. calcites and dolomites).¹² After the initial pre-washing step above, extraction is carried out with 1 M-NH₄Cl buffered at pH=8.5 in an ethanolic-aqueous solution. Without such precautions to suppress dissolution of carbonate-minerals, the eCEC is biased "on-the-high-side", and ESP biased "on-the-low-side". Depending on the abundance and nature of the carbonate-minerals, the magnitude of this bias can be marked.

¹¹ The average-crustal-abundances of the elements for the GAI calculations are based on the values listed in Bowen (1979).

¹² The procedure described by Pierce and Morris (2004) is closely related to that originally developed by Tucker (1974).

4.0 SOLUBILITY OF MAJOR/MINOR-ELEMENTS

4.1 Water-Extraction Testwork

Water-Extraction Testwork on the crushings is performed via the bottle-roll technique, and using deionised-water. The test-slurries have a solid:solution ratio of *c*. 1:2 (w/w), and are bottle-rolled for *c*. 1 day before being left to "still-stand" for *c*. 1 day to allow suspended mineral-fines to settle. The resulting supernatants are decanted, vacuum-filtered (0.45μ m-membrane), and preserved, as appropriate, for specific analyses. Where required, centrifuging at *c*. 4,000 G for 30 minutes is undertaken to expedite solid-solution separation for vacuum-filtration. The Water-Extraction Testwork is performed in the GCA-Testing Laboratory.

4.2 Na₂EDTA-Extraction Testwork

Na₂EDTA-Extraction Testwork (at pH=6) is carried out on the crushings, based on the method described by Clayton and Tiller (1979). The test-slurries have a solid:solution ratio of *c*. 1:2 (w/w), and are bottle-rolled for *c*. 7 days. This testwork provides a measure of the "metal-pool" potentially available for uptake by biota (e.g. absorption by plant roots).

5.0 **REFERENCES**

- AMIRA International Ltd, 2002, "ARD Test Handbook", Prepared by Ian Wark Research Institute, and Environmental Geochemistry International Pty Ltd
- Belzile N, Chen Y-W, Cai M-F and Li Y, 2004, "A Review on Pyrrhotite Oxidation", *Journal of Geochemical Exploration*, <u>84</u>:65-76
- Berigari MS and Al-Any FMS, 1994, "Gypsum Determination in Soils by Conversion to Water-Soluble Sodium Sulfate", *Soil Science Society of America Journal*, <u>58</u>:1624-1627
- Bowen HJM, 1979, "Environmental Chemistry of the Elements", Academic Press, New York Clayton PM and Tiller KG, 1979, "A Chemical Method for the Determination of the Heavy Metal
- Content of Soils In Environmental Studies", Division of Soils, Technical Paper No. 41, CSIRO Förstner U, Ahlf W and Calmano W, 1993, "Sediment Quality Objectives and Criteria Development in Germany", *Water Science & Technology*, 28:307-316
- Jambor JL, Dutrizac JE and Chen TT, 2000, "Contribution of Specific Minerals to the Neutralization Potential in Static Tests", pp. 551-565 in "Proceedings from the Fifth International Conference on Acid Rock Drainage", Volume I, Denver
- Jambor JL, Dutrizac JE, Groat LA and Raudsepp M, 2002, "Static Tests of Neutralization Potentials of Silicate and Aluminosilicate Minerals", *Environmental Geology*, <u>43</u>:1-17
- Jambor JL, Dutrizac JE and Raudsepp M, 2005, "Neutralization Potentials of Some Common and Uncommon Rocks, and Some Pitfalls in NP Measurements", in "Challenges in the Prediction of Drainage Chemistry", Proceedings of the 12th Annual British Columbia – MEND ML/ARD Workshop
- Janzen MP, Nicholson RV and Scharer JM, 2000, "Pyrrhotite Reaction Kinetics: Reaction Rates for Oxidation by Oxygen, Ferric Iron, and for Nonoxidative Dissolution", *Geochimica et Cosmochimica Acta*, <u>64</u>:1511-1522
- Jerz JK and Rimstidt JD, 2004, "Pyrite Oxidation in Moist Air", Geochimica et Cosmochimica Acta, <u>68</u>:701-714
- Lenahan WC and Murray-Smith R de L, 1986, "Assay and Analytical Practice in the South African Mining Industry", The South African Institute of Mining and Metallurgy Monograph Series M6, Johannesburg
- McElnea AE and Ahern CR, 2004, "Peroxide pH (pH_{ox}), Titratable Peroxide Acidity (TPA) and Excess Acid Neutralising Capacity (ANC_E) – Method Codes 23B, 23G and 23Q", Chapter 3 in "Acid

Sulfate Soils Laboratory Methods Guidelines", Eds Ahern CR, McElnea AE and Sullivan LA, Department of Natural Resources, Mines and Energy, Indooroopilly, Queensland

- Miller SD, Jeffery JJ and Donohue TA, 1994, "Developments in Predicting and Management of Acid Forming Mine Wastes in Australia and Southeast Asia", pp. 177-184 in "Proceedings of the International Land Reclamation and Mine Drainage Conference and Third International Conference on the Abatement of Acidic Drainage", Pittsburgh
- Miller S, Robertson A and Donohue T, 1997, "Advances in Acid Drainage Prediction Using the Net Acid Generation (NAG) Test", pp. 535-547 in "Proceedings of the Fourth International Conference on Acid Rock Drainage", Vancouver
- Morin KA and Hutt NM, 1997, "Environmental Geochemistry of Minesite Drainage: Practical Theory and Case Studies", MDAG Publishing, Vancouver
- Morin KA and Hutt NM, 2009, "On the Nonesense of Arguing the Superiority of an Analytical Method for Neutralization Potential", Mine Drainage Assessment Group (MDAG), Internet Case Study #32 (go to: www.mdag.com)
- Nicholson RV and Scharer JM, 1994, "Laboratory Studies of Pyrrhotite Oxidation Kinetics", pp. 14-30 in Alpers CN and Blowes DW (eds), "Environmental Geochemistry of Sulfide Oxidation", ACS Symposium Series 550, American Chemical Society, Washington D.C.
- O'Shay T, Hossner LR and Dixon JB, 1990, "A Modified Hydrogen Peroxide Method for Determination of Potential Acidity in Pyritic Overburden", *Journal of Environmental Quality*, <u>19</u>:778-782
 Pierce CG and Morris S, 2004, "Comparison of Extraction Techniques for Measuring Exchangeable
- Pierce CG and Morris S, 2004, "Comparison of Extraction Techniques for Measuring Exchangeable Cations in Calcareous Soils", *Australian Journal of Soil Research*, <u>42</u>:301-311
- Price W, 2009, "Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials", MEND Report 1.20.1
- Price W and Kwong YTJ, 1997, "Waste Rock Weathering, Sampling and Analysis: Observations from the British Columbia Ministry of Employment and Investment Database", pp. 31-45 in "Proceedings of the Fourth International Conference on Acid Rock Drainage", Vancouver
- Rayment GE and Higginson FR, 1992, "Australian Laboratory Handbook of Soil and Water Chemical Methods", Inkata Press, Melbourne
- Rengasamy P and Churchman GJ, 1999, "Cation Exchange Capacity, Exchangeable Cations and Sodicity", Chapter 9, pp. 147-170 in Peverill KI, Sparrow LA, and Reuter DJ (eds), "Soil Analysis: An Interpretation Manual", CSIRO Publishing, Collingwood
- Rimstidt JD and Vaughan DJ, 2003, "Pyrite Oxidation: A State-of-the-Art Assessment of Reaction Mechanism", *Geochimica et Cosmochimica Acta*, 67:873-880
- Shaw S, 2005, "Case Studies and Subsequent Guidelines for the Use of the Static NAG Procedure", Presentation A.4 in "Proceedings of the 12th Annual British Columbia – MEND ML/ARD Workshop on "Challenges in the Prediction of Drainage Chemistry", November 30 to December 1, 2005, Vancouver, British Columbia
- Sobek AA, Schuller WA, Freeman JR and Smith RM, 1978, "Field and Laboratory Methods Applicable to Overburdens and Minesoils", EPA-600/2-78-054
- Stevens RE and Carron MK, 1948, "Simple Field Test for Distinguishing Minerals by Abrasion pH", *American Mineralogist*, <u>33</u>:31-49
- Stewart WA, Miller SD and Smart R, 2006, "Advances in Acid Rock Drainage (ARD) Characterisation of Mine Wastes", pp. 2098-2117 in "Proceedings from the Seventh International Conference on Acid Rock Drainage", St. Louis, Missouri
- Tucker BM, 1974, "Laboratory Procedures for Cation Exchange Measurements on Soils", Division of Soils Technical Paper No. 23, CSIRO, Melbourne
- White AF and Brantley SL (eds.), 1995, "Chemical Weathering Rates of Silicate Minerals", Reviews in Mineralogy, Volume 31, Mineralogical Society of America, Washington, D.C.

KINETIC-TESTING METHODOLOGY EMPLOYED IN THE GCA-TESTING LABORATORY

1.0 WEATHERING-COLUMNS

• The (short) weathering-columns allow assessment of reaction dynamics under aeration and moisture regimes which are near-optimal for sulphide-oxidation.

The sample-bed-lengths in the columns are typically within the range 5-7 cm.

The weathering-columns, and the geometry of the gantry housing the columns and flood-lamps (see Plate 1a), are based on those described in AMIRA (2002).¹

The main departures from AMIRA (2002) are:

- the power, and operation, of the flood-lamps in order to constrain the maximum/minimum-temperatures of the sample-beds during the drying-phase; and,
- the use of weekly-weathering-cycles (i.e. weekly-flushing), and a greater rate of deionised-water addition during flushing.

Salient details of the above are discussed below.

1.1 Sample-Bed-Temperature Control

- The gantry housing the weathering-columns is located in a modern, high-ceiling (*c*. 10 m), workshop-type area fitted with roof-venting-whirlygigs, but without air-conditioning.² Accordingly, ambient-temperatures vary both diurnally, and seasonally, under the Mediterranean climate of Bridgetown in the south-west of WA.
- In order to constrain variations in the sample-bed-temperatures, 80W-floodlamps are employed, and turned-on intermittently during the night-time (via automatic-timers) as follows (see Plate 1b):
 - June to September
 - 9 hrs: 17.00-19.00, 22.00-24.00, 2.00-5.00, and, 7.00-9.00

¹ Six (6) flood-lamps are employed per ten (10) weathering-columns to ensure that the "end-columnpairs" receive the same daily heat-loads as the other "internal-column-pairs" (c.f. the use of 4 flood-lamps per 10 columns, as per AMIRA [2002], where the "end-column-pairs" receive reduced daily heat-loads).

 $^{^2}$ To routinely operate multiple (e.g. 20-30+) heat-lamps simultaneously to dewater multiple columns, and then to "air-condition" the working area via refrigerated-air-conditioning, would be environmentally irresponsible.

October to May

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6 hrs: 22.00-24.00, 2.00-5.00, and, 8.00-9.00

The above differs from that described in AMIRA (2002) where 150W-floodlamps are turned-on continuously during the daytime for c. 8-10 hrs. Although it is implied in AMIRA (2002) that this setup maintains a surface-temperature of c. 30-35 °C, this is not the case under the conditions of our laboratory.

GCA-research (unpublished) using columns instrumented with thermistors and soil-moisture sensors, and automatically logged hourly (see Plate 2), has shown that, during the latter stages of drying when residual-moisture contents are attained, the methodology described in AMIRA (2002) results in summer-peak-temperatures (for *c*. 1-2 hrs in mid-afternoon) up to *c*. 70-80 °C in the top *c*. 10 mm on the side of columns closest to the centre of the flood-lamps (i.e. near-lamp-side). However, with the 80W-flood-lamps operated intermittently during the night-time, the near-lamp-side temperature in the top *c*. 10 mm ranges up to *c*. 40 °C only on extreme-summer-days. Since the peak-temperature is in the top *c*. 10 mm on the near-lamp-side, the remainder of the sample-bed has temperatures ranging up to no greater than 30-40 °C.

Likewise, during winter, the operation of the 80W-flood-lamps during the nighttime ensures that the basal-section of the sample-beds on the far-lamp-side have winter-peak-temperatures typically above 10-15 °C during the coldest nights. The flood-lamps are operated 9 hrs per day during winter (c.f. 6 hrs per day for the rest of year) to ensure that sulphide-oxidation is not limited by restricted evaporative-drying.³

Summarising, under the conditions employed in the GCA-Testing Laboratory, use of the 80W-flood-lamps operated intermittently has been proved to constrain the maximum temperature of the sample-beds to within 30-40 °C during the latter stages of the drying-phase, even on extreme-summer days.

In terms of assessing the temperature dependence of sulphide-oxidation rates (SORs), the winter- and summer-peak-SORs broadly correspond to meantemperatures of 20 °C, and 30 °C, respectively. Therefore, where SORs have more-or-less stabilised during kinetic-testing (as often observed during circumneutral-weathering), the difference between the peak-seasonal-SORs, together with the peak-seasonal-temperature variation of 10 °C, then allows estimation of the activation-energy (E_a) for sulphide-oxidation specific to the tested-lithotype.⁴ Such lithotype-specific estimates of E_a serve as useful input to geochemical modelling of sulphide-oxidation at field-scale.

³ Pan-evaporation (E_{pan}) rates are routinely determined, and range from 3-5 mm/day over the winterpeak, to 6-8 mm/day over the summer-peak.

⁴ In practice, it generally means that the kinetic-testing programme would need to run for at least 1-2 years in order to capture the seasonal-extremes of "stable-SORs" for E_a estimation.

1.2 Weekly-Weathering-Cycles

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• The columns are weighed each day to track the rate, and extent, of dewatering.⁵

Where the attainment of residual-moisture contents is not desired (e.g. for minesites in well-watered settings), an addition of 0.10-0.20 kg of deionised-water is added to "wet" (but not "flush") the sample-beds part way through the dryingphase of each weathering-cycle.

- The flood-lamps are operated intermittently commencing on Monday, Tuesday, Wednesday, and Thursday evenings/nights (i.e. flood-lamps operated over four nights during each weathering-cycle). The flushing-step is undertaken latemorning on Fridays, and corresponds to a "flood-addition" of deionised-water. Where required, the top 5-10 mm of the sample-bed-surface is worked-over with a spatula to fill-in, and seal-over, any cracks developed during the drying-phase, and thereby prevent inefficient leaching from "breakthrough", and "by-pass".
- The AMIRA (2002) procedure involves the wetting of the sample-beds at the end of Week-1, Week-2, and Week-3, and then flushing at the end of Week-4 to produce leachates for analysis (i.e. 4-weekly-flushing regime with weekly-wetting between). The rate of deionised-water addition (viz. 0.10 kg deionised-water per kg solids) in the wetting-step is typically shy of "field-capacity" (enhanced by the seepage-face-lower-boundary condition), so there is generally no drainage.

Weekly-weathering-cycles (i.e. flushing with leachate collection on a weekly basis) are employed in the GCA procedure.

1.00 kg of deionised-water is employed for flushing, corresponding to 0.66 kg of deionised-water per kg of solids (i.e. 1.00 kg of deionised-water used to flush 1.50 kg [dry-solids-equivalent] of sample). This rate of water addition exceeds the 0.40 kg per kg solids advocated in AMIRA (2002) which occurs every 4-weeks (c.f. *c.* 2.7 kg of deionised-water per kg solids over 4-weeks herein).

The weekly-flushing regime, and rate of deionised-water addition, employed by GCA is similar to that typically employed in "humidity-cell" testing in Canada, and the USA (Price 2006; Morin and Hutt 1997; ASTM 2007).

• The residence-time of water during the flushing-step is generally ranges up to *c*. 12 hrs, as governed by sample texture.

 $^{^5}$ Due to the "sub-decimetre" thickness of the sample-beds, and the seepage-face-lower-boundary condition, the actual-evaporation rates (E_{actual}) are typically close to the corresponding E_{pan} rates until residual-moisture/suctions are approached.

• The leachates are collected in beakers beneath the columns, and the so-collected leachates are left to "age" under ambient conditions until Monday when the next weathering-cycle commences.

All leachates are weighed (for mass-balance calculations), prior to Leachate-pH and Leachate-EC values being determined, followed by vacuum-filtering (0.45- μ m-membrane), and preservation, as appropriate, for the determination of specific analytes.

Prior to commencing the weathering-cycles, the GCA-columns are subjected to a thorough pre-rinsing treatment using deionised-water to elute pre-existing solutes. Pre-rinsing is continued using 1.00-kg lots of deionised-water until the Electrical-Conductivity (EC) value of the "last-incremental-leachate" (e.g. last 100 mL) is less than c. 300-500 μ S/cm. This pre-rinsing step facilitates interpretation of the kinetic-testing results overall.

2.0 **REFERENCES**

•

- AMIRA International Ltd, 2002, "ARD Test Handbook", Prepared by Ian Wark Research Institute, and Environmental Geochemistry International Pty Ltd
- ASTM, 2007, "Standard Test Method for Laboratory Weathering of Solid Materials Using a Humidity Cell", ASTM D 5744-07.
- Morin KA and Hutt NM, 1997, "Environmental Geochemistry of Minesite Drainage: Practical Theory and Case Studies", MDAG Publishing, Vancouver
- Price W, 2009, "Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials", MEND Report 1.20.1



Plate 1a: Typical Weathering-Column Assembly

Layout and configuration-geometry as per AMIRA (2002).



Plate 1b: Seasonal and Diurnal Schedule for Operation of 80W-Flood-Lamps.

Required variation to AMIRA (2002) in order to constrain maximum-temperatures of sample-beds to within 30-40 $^{\rm o}C.$



Plate 2: GCA-Research Project: Instrumented-Weathering-Column with -4.75mm Fraction of Trace-Sulphide/Calcareous-Basalt-waste-bedrock Sample.

Circum-neutral Weathering.

Volumetric-Water Content (VWC) of upper-half and lower-half of sample-beds logged hourly using calibrated MP406-sensors.

Temperature of top c. 10 mm, and bottom c. 10 mm, on both the near-lamp-side, and far-lamp-side (as seen in front of columns in photograph), logged hourly using thermistors.

Daily-pan-evaporation rates determined via daily weighing of perspex-container to the left of columns.

ATTACHMENT III

ACID-FORMATION POTENTIAL (AFP):

CALCULATED PARAMETERS AND CLASSIFICATION CRITERIA

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ATTACHMENT III

ACID-FORMATION POTENTIAL (AFP):

CALCULATED PARAMETERS AND CLASSIFICATION CRITERIA

<u>Notes</u>: The geochemically-based parameters, and AFP-classification criteria, indicated below apply equally to samples of mine-wastes (e.g. waste-regoliths and waste-bedrocks), low-grade-ores, and process-tailings-solids. The generic descriptor "test-sample" is employed below.

1.0 CALCULATED PARAMETERS

<u>Maximum-Potential-Acidity (MPA)</u> values (in kg H_2SO_4 /tonne) of test-samples are typically calculated by multiplying the Sulphide-S values (in %) by 30.6. The multiplication-factor of 30.6 reflects both the reaction stoichiometry for the complete-oxidation of pyrite, by O₂ to "Fe(OH)₃" and H₂SO₄, and the different weight-based units of %, and kg H₂SO₄/tonne.

<u>Net-Acid-Producing-Potential (NAPP)</u> values (in kg H_2SO_4 /tonne) are calculated from the corresponding MPA and <u>Acid-Neutralisation-Capacity (ANC)</u> values (i.e. NAPP = MPA - ANC).

2.0 CLASSIFICATION CRITERIA

In terms of AFP, test-samples may be classified into one of the following categories, viz.

- Non-Acid Forming (NAF)
- <u>Potentially-Acid Forming (PAF)</u>

There are **no** unifying, "standard" criteria for classifying the AFP of test-samples (e.g. Price 2009; AMIRA 2002), and reflects the diversity of sulphide- and gangue-mineral assemblages within (un)mineralised-lithotypes of varying weathering- and alteration-status. Rather, criteria for classifying AFP may need to be tailored to deposit-specific geochemistry, mineralogy, and site-specific climate.

The AFP-classification criteria often employed at mining-operations worldwide are:

- <u>NAF</u>: Sulphide-S < 0.3 %. For Sulphide-S \ge 0.3 %, <u>both</u> a negative NAPP value, <u>and</u> an ANC/MPA ratio \ge 2.0
- **<u>PAF</u>**: For Sulphide-S \ge 0.3 %, any positive-NAPP value; negative-NAPP value with an ANC/MPA ratio < 2.0

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In assessing AFP, lithotypes from hard-rock mines with Sulphide-S values less than 0.3 % are unlikely to acidify (e.g. pH less than 4-5) through sulphide-oxidation. This position holds especially where the groundmass hosting the "trace-sulphides" is <u>not</u> simply quartz, soil-clays, and/or sesquioxides (Price *et al.* 1997), and where the sulphide-minerals are <u>not</u> hyper-reactive varieties (e.g. framboidal-pyrite). A "cut-off" of 0.3 % for Sulphide-S also accords with the findings of kinetic-testing, since the late-1980s, by Dr. Graeme Campbell for test-samples of diverse mineralogy in terms of sulphide-weathering dynamics, and solubility behaviour.

The risk posed by PAF-lithotypes during the active-mine-life is governed primarily by the duration of the <u>lag-phase</u> (i.e. the period during which sulphide-oxidation occurs, but acidification does <u>not</u> develop, due to circum-neutral buffering by gangue-phases [chiefly reactive-carbonate-minerals]).¹ Although the duration of the lag-phase for mine-wastes at field-scale cannot be accurately predicted *a priori*, estimates may still be needed to identify threshold exposure-times for the safe handling of PAF-lithotypes. Lag-phase duration may be estimated via kinetic-testing (viz. Weathering-Columns), and consideration of the moisture/aeration/thermal-regimes of exposed (i.e. uncovered) mine-wastes under the site's climatic conditions. In the absence of results from kinetic-testing, experience permits "first-pass" estimates of sulphide-oxidation rates and lag-phase duration to be made from the results of static-testing, and thereby classify PAF-lithotypes into **PAF-[Short-Lag]** and **PAF-[Long-Lag]** sub-categories. Such "first-pass" estimations are necessarily provisional, and subject to revision, in the light of the outcomes of kinetic-testing, and field observations.

3.0 REFERENCES

- AMIRA International Ltd, 2002, "ARD Test Handbook", Prepared by Ian Wark Research Institute, and Environmental Geochemistry International Pty Ltd
- Price W, 2009, "Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials", MEND Report 1.20.1
- Price WA, Morin K and Hutt N, 1997, "Guidelines for the Prediction of Acid Rock Drainage and Metal Leaching for Mines in British Columbia: Part II. Recommended Procedures for Static and Kinetic Testing", pp. 15-30 in "Proceedings of the Fourth International Conference on Acid Rock Drainage", Volume I, Vancouver

 $^{^1}$ SO₄ is still produced by sulphide-oxidation during the lag-phase, and appreciable amounts of solubleforms of certain minor-elements (e.g. Ni and As) may be released at circum-neutral-pH during lag-phase weathering. However, in the latter case, the mine-wastes would need to be sufficiently enriched in Total-Ni and Total-As to begin with.

ATTACHMENT IV

LABORATORY REPORTS

Graeme Campbell & Associates Pty Ltd

Note:

The laboratory-reports in the following pages correspond to the static-testing programme carried out on the sixty-three (63) "individual-samples" of waste-regoliths and waste-bedrocks variously derived from the Delta-Pit, Eagle-Pit, and Champion-Pit.

Graeme Campbell & Associates Pty Ltd



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6-9-2011

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WA

OUR REFERENCE 22969

YOUR REFERENCE: 1112

XRD/PLM /SEM ANALYSIS OF EIGHT ROCK PULPS.

R & D TOWNEND

MINERAL	GCA9666	GCA9670	GCA9691	GCA9692
HEMATITE	DOMINANT	DOMINANT	MAJOR	MAJOR
QUARTZ	MINOR	ACCESSORY	MAJOR	MAJOR
GOETHITE	ACCESSORY	MINOR	MINOR	ACCESSORY
GIBBSITE	TRACE			
KAOLINITE	ACCESSORY?	ACCESSORY?	MINOR	ACCESSORY?
TI OXIDE	TRACE	TRACE	TRACE	TRACE

MINERAL	GCA9693	GCA9697	GCA9710	GCA9711
HEMATITE	DOMINANT	ACCESSORY	MAJOR	DOMINANT
QUARTZ	ACCESSORY	MINOR	MAJOR	ACCESSORY
GOETHITE	ACCESSORY	MAJOR	ACCESSORY	ACCESSORY
KAOLINITE	ACCESSORY?	MINOR	ACCESSORY?	MINOR?
TI OXIDE	TRACE	ACCESSORY	TRACE	TRACE

COMMENT

The kaolinite quantification values with a question mark above are samples that did not have kaolinite identified by XRD. The XRD traces of the samples found kaolinite only in samples GCA9691 and GCA9697. The geochemistry of the samples indicated alumina levels of between 4.23% and 14.16%. The previous two samples mentioned had the greatest alumina levels. Due to iron background interference kaolinite (and other low concentration minerals) identification may be inhibited by XRD.

SEM examination of the polished sections, of goethite containing grains, consistently found silica and alumina. All analyses found silica greater than alumina. This would indicate with strong confidence the presence of kaolin and/or kaolin plus quartz or some alumino silicate.

Further XRD analysis can be undertaken using a specialized tube to reduce the interference effects of iron. This may resolve the issue of the alumino silicates within the samples.

Roger Townend and Hssociates





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JOB INFORMATION

JOB CODE	143.0/1107090
No. of SAMPLES	62
CLIENT O/N	GCA 1112
PROJECT	PIOP Flinders mine
STATE	Ex pulp
DATE RECEIVED	24/05/2011
DATE COMPLETED	9/06/2011

LEGEND

>

- X = Less than Detection Limit
- N/R = Sample Not Received
 - = Result Checked
- () = Result still to come
- I/S = Insufficient Sample for Analysis
- E6 = Result X 1,000,000
- UA = Unable to Assay
 - = Value beyond Limit of Method

The samples were received as pulp (-75µm nominal) and crushings (-2mm nominal) 'splits' ex job 1106867

Results of analysis on:

Element		С	TOC+C	C-CO3	S	S-SO4
Method		/CSA	C71/CSA	/CALC	/CSA	S72/GR
Detection		0.01	0.01	0.01	0.01	0.01
Units		%	%	%	%	%
Sample Name						
Control Blank		0.01	Х	0.01	0.01	Х
GCA9665		0.16	0.05	0.11	0.02	Х
GCA9665	check	0.17	0.06	0.11	0.01	Х
GCA9666		0.07	0.05	0.02	0.03	Х
GCA9667		0.08	0.06	0.02	0.04	Х
GCA9668		0.06	0.07	-0.01	0.04	Х
GCA9669		0.1	0.06	0.04	0.04	Х
GCA9670		0.09	0.04	0.05	0.03	Х
GCA9671		0.09	0.04	0.05	0.04	Х
GCA9672		0.1	0.08	0.02	0.05	Х
GCA9673		0.11	0.08	0.03	0.03	Х
GCA9674		0.11	0.05	0.06	0.03	Х
GCA9675		0.18	0.08	0.1	0.03	Х
GCA9676		0.11	0.06	0.05	0.02	Х
GCA9677		0.15	0.05	0.1	0.02	0.01
GCA9678		0.19	0.06	0.13	0.02	Х
GCA9679		0.14	0.05	0.09	0.02	Х
GCA9680		0.45	0.26	0.19	0.02	Х
GCA9681		0.31	0.16	0.15	0.03	Х
GCA9682		2.21	0.63	1.58	1.13	0.23
GCA9683		3.1	0.81	2.29	2.61	0.31

GLS Job Code 143.0/1107090

Element		С	TOC+C	C-CO3	S	S-SO4
Method		/CSA	C71/CSA	/CALC	/CSA	S72/GR
Detection		0.01	0.01	0.01	0.01	0.01
Units		%	%	%	%	%
GCA9684		3.7	0.17	3.53	0.39	0.02
GCA9685		3.52	0.68	2.84	2.02	0.22
GCA9685	check	3.52	0.68	2.84	2.01	0.21
GCA9686		4.01	0.6	3.41	2.62	0.23
GCA9687		3.16	0.07	3.09	0.18	Х
GCA9688		1.63	0.66	0.97	1.87	0.14
GCA9689		1	0.06	0.94	0.09	Х
GCA9690		3.09	0.04	3.05	0.69	0.02
GCA9691		0.06	0.04	0.02	0.02	Х
GCA9692		0.06	0.04	0.02	0.02	Х
GCA9693		0.09	0.08	0.01	0.02	X
GCA9694		0.1	0.08	0.02	0.02	X
GCA9695		0.16	0.00	0.02	0.02	X
GCA9696		0.10	0.14	0.02	0.02	X
GCA9697		0.24	0.06	0.00	0.02	X
GCA9698		0.00	0.00	0.02	0.01	X
CCA9690		0.23	0.12	0.11	0.01	X
GCA9099		0.37	0.23	0.14	0.02	
GCA9700		0.43	0.43	0	0.10	0.03 V
GCA9701		0.67	0.67	0	0.01	∧ 0.52
GCA9702		0.07	0.07	0	2.06	0.53
GCA9703		0.96	0.36	0.6	0.26	0.02
GCA9704		2.9	0.94	1.96	1.02	0.09
GCA9705		3.16	1.4	1.76	0.79	0.07
GCA9705	check	3.23	1.36	1.87	0.81	0.06
GCA9706		0.12	0.12	0	X	X
GCA9707		0.14	0.09	0.05	0.01	X
GCA9708	-	3.73	0.59	3.14	2.66	0.2
GCA9709		0.05	0.05	0	X	X
GCA9710		0.06	0.07	-0.01	0.02	X
GCA9711		0.1	0.07	0.03	0.02	Х
GCA9712		0.11	0.07	0.04	0.03	Х
GCA9713		0.11	0.11	0	0.02	Х
GCA9715		0.37	0.34	0.03	0.02	0.01
GCA9716		0.16	0.18	Х	Х	Х
GCA9717		1.22	0.49	0.73	1.32	0.13
GCA9718		3.42	0.53	2.89	2.95	0.23
GCA9719		1.18	1.18	0	0.67	0.2
GCA9720		1.49	1.46	0.03	1.95	0.49
GCA9721	ļ	1.78	1.76	0.02	1.06	0.61
GCA9722	ļ	1.86	1.9	-0.04	0.75	0.36
GCA9723		1.34	1.32	0.02	0.41	0.21
GCA9724		1.24	1.25	Х	0.51	0.17
GCA9725	ļ	3.23	1.62	1.61	1.36	0.09
GCA9726		3.37	1.11	2.26	0.89	0.06
GCA9726	check	3.35	1.12	2.23	0.85	0.06
GCA9727		1.62	0.63	0.99	1.31	0.14
MA-1b		2.46			1.25	
MA-3a		2.65			1.14	
SO4 STD A						0.57
SO4 STD B						1.22
TOC-1			1.6			

- 1. Total-S and Total-C were determined on the pulps
- Total-C and Total-S was determined using an induction furnace according to Genalysis method number MPL_W043. The samples are ignited in oxygen ~1700C and the CO2 and SO2 measured by infrared detectors
- **3.** S-SO4 was determined on the pulps by precipitation of BaSO4 according to Genalysis method number ENV_W039, after digestion with Na2CO3
- TOC+C (acid insoluble carbon compounds and elemental carbon) by a C&S analyser after removal of carbonates and soluble organic carbon using hot hydrochloric acid according to Genalysis method number MPL_W046.

sample		Fizz	volume	HCI	NaOH	Colour	pН	ANC	ANC
name		Rate	ml	М	М	Change	Drop	soln pH	(kgH2SO4/t)
GCA9665		0	8	0.558	0.188	N		1.4	16
GCA9665	check	0	8	0.558	0.188	N		1.4	19
GCA9666		0	8	0.558	0.188	N		1.3	4
GCA9667		0	8	0.558	0.188	N		1.4	3
GCA9668		0	8	0.558	0.188	N		1.4	4
GCA9669		0	8	0.558	0.188	N		1.4	3
GCA9670		0	8	0.558	0.188	N		1.4	3
GCA9671		0	8	0.558	0.188	N		1.4	3
GCA9672		0	8	0.558	0.188	N		1.4	3
GCA9673		0	8	0.558	0.188	N		1.3	4
GCA9674		0	8	0.558	0.188	N		1.4	4
GCA9675		0	8	0.558	0.188	N		1.4	4
GCA9676		0	8	0.558	0.188	N		1.4	3
GCA9677		0	8	0.558	0.188	N		1.4	3
GCA9678		0	8	0.558	0.188	N		1.4	4
GCA9679		0	8	0.558	0.188	N		1.4	3
GCA9680		0	8	0.558	0.188	N		1.4	6
GCA9681		0	8	0.558	0.188	N		1.4	5
GCA9682		0	20	0.558	0.481	N	2.4	1.1	25
GCA9683		0	20	0.558	0.481	N	2.2	1.4	34
GCA9684		0	20	0.558	0.481	Y	2.5	1.8	45
GCA9685		0	20	0.558	0.481	Y	2.2	1.4	22
GCA9685	check	0	20	0.558	0.481	Y	2.2	1.4	26
GCA9686		0	20	0.558	0.481	Y	2.2	1.6	33
GCA9687		0	20	0.558	0.481	Y	2.3	1.5	42
GCA9688		0	8	0.558	0.188	Y	2.5	1.8	17
GCA9689		0	8	0.558	0.188	Y	2.9	1.6	24
GCA9690		0	20	0.558	0.481	Y	2.2	1.5	27
GCA9691		0	8	0.558	0.188	Ν		1.5	4
GCA9692		0	8	0.558	0.188	N		1.3	4
GCA9693		0	8	0.558	0.188	N		1.3	3
GCA9694		0	8	0.558	0.188	N		1.3	3
GCA9695		0	8	0.558	0.188	N		1.3	3
GCA9696		0	8	0.558	0.188	N		1.4	5
GCA9697		0	8	0.558	0.188	N		1.4	4
GCA9698		0	8	0.558	0.188	N		1.6	11
GCA9699		0	8	0.558	0.188	N		1.4	5
GCA9700		0	8	0.558	0.188	N		1.4	8
GCA9701		0	8	0.558	0.188	Ν		1.4	6
GCA9702		0	8	0.558	0.188	N		1.5	-11
GCA9703		0	8	0.558	0.188	Ν	2.7	1.6	9
GCA9704		0	20	0.558	0.481	Y	2.5	1.3	26
GCA9705		0	20	0.558	0.481	Y	2.4	1.3	21

Results of analysis on:

sample		Fizz	volume	HCI	NaOH	Colour	pН	ANC	ANC
name		Rate	ml	М	М	Change	Drop	soln pH	(kgH2SO4/t)
GCA9705	check	0	20	0.558	0.481	Y	2.3	1.5	25
GCA9706		0	8	0.558	0.188	Ν		1.5	7
GCA9707		0	8	0.558	0.188	Ν		1.4	6
GCA9708		0	20	0.558	0.481	Y	2.2	1.6	26
GCA9709		0	8	0.558	0.188	Ν		1.5	6
GCA9710		0	8	0.558	0.188	Ν		1.4	5
GCA9711		0	8	0.558	0.188	Ν		1.4	5
GCA9712		0	8	0.558	0.188	Ν		1.3	5
GCA9713		0	8	0.558	0.188	Ν		1.4	4
GCA9715		0	8	0.558	0.188	N		1.4	5
GCA9716		0	8	0.558	0.188	Ν	0.0	1.3	5
GCA9717		0	8	0.558	0.188	Ν	2.4	1.7	10
GCA9718		0	20	0.558	0.481	Y	2.2	1.6	28
GCA9719		0	8	0.558	0.188	Ν	2.8	1.4	-12
GCA9720		0	8	0.558	0.188	N	3.5	1.5	-2
GCA9721		0	8	0.558	0.188	Ν	3.9	1.4	-9
GCA9722		0	8	0.558	0.188	N	2.9	1.5	-8
GCA9723		0	8	0.558	0.188	N	0.0	1.4	-3
GCA9724		0	8	0.558	0.188	Ν	3.2	1.3	-5
GCA9725		0	20	0.558	0.481	Y	2.4	1.3	21
GCA9726		0	20	0.558	0.481	Y	2.3	1.3	35
GCA9726	check	0	20	0.558	0.481	Y	2.3	1.5	38
GCA9727		0	8	0.558	0.188	Ν	2.5	1.8	20

Notes:

1. ANC was determined on 2g of the crushings -. Acid concentrations are as stated.

2. Colour change: Y indicates the appearance of a green colouration as the pH=7 endpoint was approached. N indicates no colour change. Two drops of 30 % hydrogen peroxide are added to each sample as the endpoint is approached to oxidise any ferrous iron.

- 3. pH drop : Result reported when the pH drops to a value below 4 on addition of peroxide
- 4. This "Bulk-ANC" static-testing procedure is based on AMIRA (2002), according to Genalysis method number ENV_W035

Element		As	В	Мо	Sb	Se
Method		4A/MS	FP1/OE	4A/MS	4A/MS	SE1/MS
Detection		0.5	50	0.1	0.05	0.01
Units		ppm	ppm	ppm	ppm	ppm
Sample Name						
Control Blank		Х	Х	Х	Х	Х
GCA9665		8.8	Х	0.7	0.98	0.45
GCA9665	check	8.4	Х	0.8	0.97	0.47
GCA9666		8.6	Х	0.9	0.99	0.28
GCA9667		12.3	Х	1.5	1.38	0.34
GCA9668		8.2	Х	1	1	0.52
GCA9669		19.4	Х	2	2.15	1.07
GCA9670		11.2	Х	1.5	1.25	0.6
GCA9671		16.1	Х	1.6	1.71	0.49
GCA9672		21.3	Х	1.9	2.08	0.76
GCA9673		15.4	Х	3.2	1.75	0.29
GCA9674		12.4	Х	3.8	2.01	0.26
GCA9675		12.1	Х	3	1.74	0.32
GCA9676		12.2	Х	3.7	2.18	0.14
GCA9677		11.4	Х	4.9	2.68	0.34
GCA9678		20.7	Х	1.6	2.12	0.39
GCA9679		6.7	Х	0.7	0.74	0.31
GCA9680		16.9	Х	1.6	1.22	2.59
GCA9681		16.7	Х	1.5	0.78	1.71

GLS Job Code 143.0/1107090

Element		As	В	Мо	Sb	Se
Method		4A/MS	FP1/OE	4A/MS	4A/MS	SE1/MS
Detection		0.5	50	0.1	0.05	0.01
Units		ppm	ppm	ppm	ppm	ppm
Sample Name						
GCA9682		34.2	Х	2.6	2.77	1.57
GCA9683		47.2	Х	2.7	3.16	2.01
GCA9684		23.6	66	0.7	0.58	0.41
GCA9685		43.7	Х	2.8	3.36	1.2
GCA9685	check	43.9	Х	2.9	3.37	1.25
GCA9686		36.5	Х	2.6	3.42	1.32
GCA9687		15.9	100	0.6	0.46	0.19
GCA9688		60.8	X	5.4	3.62	0.82
GCA9689		8.1	х	0.7	0.63	0.06
GCA9690		31.2	X	1.2	1.03	0.45
GCA9691		9	X	1.8	1 13	0.36
GCA9692		77	X	1.0	1.03	0.26
GCA9693		9.7	X	1.1	1.00	0.58
GCA9694		12.2	X	21	1.24	0.30
GCA9695		10.7	X	1.8	1.0	0.24
GCA9095		10.7	× ×	1.0	0.74	1.21
GCA9690		20.1	× ×	17	1.07	0.61
GCA9097		20.1	× ×	1.7	1.27	0.01
GCA9698		18	X	Z.1	1.13	1.11
GCA9699		20.1	X	1.2	1.20	3.85
GCA9700		30.0	X	2.0	2.85	1.02
GCA9701		42.1	X	3.4	3.57	1.11
GCA9702		37.4	X	3	3.98	1.64
GCA9703		25	X	2.9	2.23	0.77
GCA9704		41.3	X	2.9	3.2	0.52
GCA9705		49.6	X	3.4	3.53	0.56
GCA9705	check	50.3	Х	3.4	3.53	0.56
GCA9706		44	X	2.8	3.81	0.51
GCA9707		43.6	X	3.1	2.99	0.83
GCA9708		48.5	Х	2.9	3.63	1.22
GCA9709		8.1	X	0.6	0.94	0.28
GCA9710		11.1	Х	1.1	1.18	0.59
GCA9711		9.5	Х	2	1.34	0.49
GCA9712		8.6	Х	1.8	1.25	0.56
GCA9713		6.5	Х	1.7	1.22	0.59
GCA9715		26.6	Х	2.2	1.41	2.57
GCA9716		44	Х	2.3	5.13	0.29
GCA9717		39.5	Х	2.4	3.78	0.98
GCA9718		37.3	Х	2.7	4.17	1.55
GCA9719		49.2	Х	2.9	3.88	0.91
GCA9720	ļ	90.2	Х	3.4	5.54	2.58
GCA9721		69.5	Х	3.6	4.57	1.08
GCA9722		53.9	Х	3.6	4.21	0.82
GCA9723		48.7	Х	3.1	2.99	0.74
GCA9724		56.2	Х	3.1	3.31	0.76
GCA9725		54.3	Х	3.9	4.06	0.72
GCA9726		53.3	Х	3.1	2.81	0.85
GCA9726	check	53.5	Х	3.2	2.89	0.84
GCA9727		42.7	Х	3.6	3.76	2.78
AMIS0076		542.7		8.5	51	
AMIS0076			Х			
AMIS0082			Х			
AMIS0085		68.6		3.8	9.42	
MPL-4		643.4		8.9	171.46	
OREAS 97.01						0.68
OREAS 97.01						0.66

Element	As	В	Мо	Sb	Se
Method	4A/MS	FP1/OE	4A/MS	4A/MS	SE1/MS
Detection	0.5	50	0.1	0.05	0.01
Units	ppm	ppm	ppm	ppm	ppm
Sample Name					
OREAS 97.01					0.65
Control Blank	Х		Х	0.11	
Control Blank		Х			
Control Blank					Х
Acid Blank	Х		Х	Х	
Acid Blank		Х			

Notes:

The results have been determined according to Genalysis methods codes: Digestions: MPL_W001 (4A/), 4 acid digest using HF MPL_W005 (SE1/) precipitation of Se from an aqua regia digest MPL_W011 (FP1/), peroxide fusion followed by HCl digest of melt Analytical Finishes: ICP_W004 (/OE), ICP_W005 (/MS) The results included the assay of blanks and international reference standards AMIS0085 AMIS0076 and AMIS0082 Genalysis in-house standards MPL-4 and OREAS 97.01 The results are expressed as parts per million by mass in the dried and prepared material.

NATA ENDORSED DOCUMENT

Company Accreditation Number 3244

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NATA Signatory: Ann Evers

Ann Evers

Date: 9/06/2011



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Dr G Campbell CAMPBELL, GRAEME and ASSOCIATES PO Box 247 BRIDGETOWN WA 6255

JOB INFORMATION

JOB CODE	143.0/1107355
No. of SAMPLES	1
CLIENT O/N	GCA 1112
PROJECT	PIOP Flinders mine
STATE	solid
DATE RECEIVED	31/05/2011
DATE COMPLETED	14/06/2011

LEGEND

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- X = Less than Detection Limit
- N/R = Sample Not Received
 - = Result Checked
 - = Result still to come
- I/S = Insufficient Sample for Analysis
- E6 = Result X 1,000,000
- UA = Unable to Assay
 - = Value beyond Limit of Method

The sample was received as solid which required drying and crushing to a nominal -2mm. A split was taken and fine pulverised in a zirconia bowl to give (-75µm nominal) pulp

Results of analysis on:

Element		С	TOC+C	C-CO3	S	S-SO4
Method		/CSA	C71/CSA	/CALC	/CSA	S72/GR
Detection		0.01	0.01	0.01	0.01	0.01
Units		%	%	%	%	%
Sample Name						
Control Blank		Х	Х		Х	Х
GCA9714		3.31	1.5	1.81	1.28	0.04
GCA9714	check	3.24	1.51	1.73	1.17	0.05
MA-1b		2.46			1.21	
SO4 STD A						0.59
SO4 STD B						1.31
TOC-1			1.54			

- 1. Total-S and Total-C were determined on the pulps
- Total-C and Total-S was determined using an induction furnace according to Genalysis method number MPL_W043. The samples are ignited in oxygen ~1700C and the CO2 and SO2 measured by infrared detectors
- S-SO4 was determined on the pulps by precipitation of BaSO4 according to Genalysis method number ENV_W039, after digestion with Na2CO3
- TOC+C (acid insoluble carbon compounds and elemental carbon) by a C&S analyser after removal of carbonates and soluble organic carbon using hot hydrochloric acid according to Genalysis method number MPL_W046.

15 Davison Street, Maddington WA 6109 PO Box 144, Gosnells WA 6990 T +61 8 9251 8100 I F +61 8 9251 8110 ABN 32 008 787 237 www.intertek.com www.genalysis.com.au

GLS Job Code 143.0/1107355

Results of analysis on:

sample		Fizz	volume	HCI	NaOH	Colour	pН	ANC	ANC
name		Rate	ml	М	М	Change	Drop	soln pH	(kgH2SO4/t)
GCA9714		0	20	0.558	0.481	Ν	2.4	1.3	23
GCA9714	check	0	20	0.558	0.481	Ν	2.6	1.3	26

Notes:

- 1. ANC was determined on 2g of the crushings -. Acid concentrations are as stated.
- Colour change: Y indicates the appearance of a green colouration as the pH=7 endpoint was approached. N indicates no colour change. Two drops of 30 % hydrogen peroxide are added to each sample as the endpoint is approached to oxidise any ferrous iron.
- 3. pH drop : Result reported when the pH drops to a value below 4 on addition of peroxide
- 4. This "Bulk-ANC" static-testing procedure is based on AMIRA (2002), according to Genalysis method number ENV_W035

Element		As	В	Мо	Sb	Se
Method		4A/MS	FP1/OE	4A/MS	4A/MS	SE1/MS
Detection		0.5	50	0.1	0.05	0.01
Units		ppm	ppm	ppm	ppm	ppm
Sample Name						
Control Blank		Х	Х	Х	Х	Х
GCA9714		54.8	Х	3.4	3.91	0.6
GCA9714	check	57	Х	3.5	4.01	0.46
MPL-4		664.4		9	179.33	
CRM No. 782-1			Х			
OREAS 97.01						0.67
Control Blank		Х		Х	0.11	
Control Blank			Х			
Control Blank						Х
Acid Blank		Х		Х	Х	
Acid Blank			х			

Notes:

The results have been determined according to Genalysis methods codes: Digestions: MPL_W001 (4A/), 4 acid digest using HF MPL_W005 (SE1/) precipitation of Se from an aqua regia digest MPL_W011 (FP1/), peroxide fusion followed by HCl digest of melt Analytical Finishes: ICP_W004 (/OE), ICP_W005 (/MS) The results included the assay of blanks and international reference standards CRM No 782-1 Genalysis in-house standards MPL-4 and OREAS 97.01 The results are expressed as parts per million by mass in the dried and prepared material.

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NATA Signatory: Ann Evers

Ann Evers

Date: 14/06/2011



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Graeme Campbell & Associates Pty Ltd

Laboratory Report pH-(1:2) & EC-(1:2) TESTWORK

SAMPLE	SAMPLE	SAMPLE +	nU (1.2)	EC-(1:2)
n O .		VEICUT (~)	рп-(1:2)	(µs/cm)
CCA0((5	(g)		0 0	160
GCA9665	30.0	60.0	8.0	100
GCA9667	30.0	60.0	<u>8.0</u>	83 29
GCA9667	30.0	60.0	7.9	54
GCA9668	30.0	60.0	7.7	52
GCA9609	30.0	60.0	7.6	22
GCA9670	30.0	60.0	7.0	28
GCA9672	30.0	60.0	7.0	29
GCA9672	30.0	60.0	7.3	90 30
GCA9674	30.0	60.0	6.8	100
GC 49675	30.0	60.0	7.1	32
GCA9675 1	30.0	60.0	7.1	32
GC 49676	30.0	60.0	7.2	<u> </u>
GCA9677	30.0	60.0	7.2	43
GCA9678	30.0	60.0	6.8	71
GC A 9670	30.0	60.0	7.0	/1
GCA9679	30.0	60.0	7.0	42
GCA9080	30.0	60.0	0.8	47
GCA9681	30.0	60.0	6.9	47
GCA9682	30.0	60.0	4.4	1,200
GCA9684	30.0	60.0	5.0	1,000
GCA9685	30.0	60.0	0.1	1 400
GCA9685 1	30.0	60.0	4.0	1,400
GCA9083-1	30.0	60.0	4.0	1,400
GCA9687	30.0	60.0	5.5	1,800
GCA9687	30.0	60.0	5.6	1 200
GC 49689	30.0	60.0	5.0	320
GCA9690	30.0	60.0	6.6	410
GCA9691	30.0	60.0	7.0	220
GCA9692	30.0	60.0	7.0	220
GCA9693	30.0	60.0	7.5	19
GCA9694	30.0	60.0	7.5	19
GCA9695	30.0	60.0	7.5	24
GCA9695-1	30.0	60.0	7.1	23
GCA9696	30.0	60.0	6.9	34
GCA9697	30.0	60.0	7.1	32
GCA9698	30.0	60.0	7.1	22
GCA9699	30.0	60.0	7.0	20
GCA9700	30.0	60.0	6.8	44
GCA9701	30.0	60.0	5.9	320
GCA9702	30.0	60.0	2.6	3 100
GCA9703	30.0	60.0	5.0	490
GCA9704	30.0	60.0	4 7	780
GCA9705	30.0	60.0	5.1	620
GCA9705-1	30.0	60.0	5.0	680
GCA9706	30.0	60.0	61	85
GCA9707	30.0	60.0	61	59
GCA9708	30.0	60.0	4 7	1 300
GCA9709	30.0	60.0	59	180
GCA9710	30.0	60.0	6.8	71
GCA9711	30.0	60.0	6.0	80
GCA9712	30.0	60.0	6.0	43

SAMPLE NO.	SAMPLE WEIGHT	SAMPLE + DEIONW	pH-(1:2)	EC-(1:2) (µS/cm)
	(g)	WEIGHT (g)	1 ()	· · /
GCA9713	30.0	60.0	6.1	35
GCA9714	30.0	60.0	6.1	570
GCA9715	30.0	60.0	6.7	37
GCA9715-1	30.0	60.0	6.7	36
GCA9716	30.0	60.0	6.6	52
GCA9717	30.0	60.0	4.2	690
GCA9718	30.0	60.0	4.5	1,600
GCA9719	30.0	60.0	2.4	2,900
GCA9720	30.0	60.0	2.7	1,500
GCA9721	30.0	60.0	2.6	2,700
GCA9722	30.0	60.0	2.5	2,000
GCA9723	30.0	60.0	2.7	1,400
GCA9724	30.0	60.0	2.8	1,100
GCA9725	30.0	60.0	5.7	1,100
GCA9725-1	30.0	60.0	5.7	1,100
GCA9726	30.0	60.0	6.1	770
GCA9727	30.0	60.0	5.5	1,400

Note: EC = Electrical-Conductivity. Testwork performed on the as-supplied 'pulp' samples (nominal -75 μ m). pH-(1:2) and EC-(1:2) values correspond to pH and EC values of suspensions with a solid:solution ratio of *c*. 1:2 (w/w) pri-(1.2) and EC-(1.2) values correspond to pri and EC values of suspensions with a solution ratio prepared using deionised-water. Drift in pH-glass-electrode less than 0.1 pH unit between commencement, and completion, of testwork. Drift in EC-electrode less than 5 μ S/cm between commencement, and completion, of testwork. Testwork performed in a constant-temperature room (viz. 21 +/- 2-3 °C).

Dr GD Campbell 17th May 2011

Laboratory Report

NET-ACID-GENERATION (NAG) TESTWORK

Sample	Sample Weight	Comments	pH of Test Mixture	A	Test Mixture fter Boiling Step	Titre [0.1 M-	NAG (kg H2SO4/
Number	(g)		Before Boiling Step	pН	EC (µS/cm)	NaOH] (mL)	tonne)
GCA9665	3.0	Reaction peaked overnight	6.9	8.3	130	-	<0.5
GCA9666	3.0	Reaction peaked overnight	5.8	6.5	27	0.30	<0.5
GCA9667	3.0	Reaction peaked overnight	5.5	6.1	17	0.10	<0.5
GCA9668	3.0	Reaction peaked overnight	5.7	6.2	22	0.20	<0.5
GCA9669	3.0	Reaction peaked overnight	5.4	5.9	19	0.10	<0.5
GCA9670	3.0	Reaction peaked overnight	5.3	6.0	21	0.30	<0.5
GCA9671	3.0	Reaction peaked overnight	5.3	5.9	19	0.20	<0.5
GCA9672	3.0	Reaction peaked overnight	5.3	5.4	22	0.30	<0.5
GCA9673	3.0	Reaction peaked overnight	5.2	5.4	16	0.20	<0.5
GCA9674	3.0	Reaction peaked overnight	5.4	5.9	23	0.10	<0.5
GCA9675	3.0	Reaction peaked overnight	5.0	5.2	14	0.20	<0.5
GCA9676	3.0	Reaction peaked overnight	5.2	5.0	24	0.30	<0.5
GCA9677	3.0	Reaction peaked overnight	5.3	5.5	20	0.30	<0.5
GCA9678	3.0	Reaction peaked overnight	5.3	6.0	20	0.10	<0.5
GCA9679	3.0	Reaction peaked overnight	5.3	6.0	20	0.20	<0.5
GCA9680	3.0	Reaction peaked overnight	5.4	5.9	20	0.30	<0.5
GCA9681	3.0	Reaction peaked overnight	5.6	5.6	21	0.20	<0.5
GCA9682	3.0	Reaction peaked overnight	3.1	3.7	670	1.40	2.3
GCA9682-1	3.0	Reaction peaked overnight	3.1	3.7	570	1.90	3.2
BLANK1	3.0	Reaction peaked overnight	5.7	7.2	68	-	<0.5

Notes: Test conditions based on those described by Miller *et al.* (1997), and AMIRA (2002) for the 'Static-NAG-Test' in its "Single-Additon-Mode". The pH of the 15 % (v/v) H_2O_2 solution was adjusted to 4.5 using 0.1 M-NaOH prior to commencing the NAG Tests. Following an overnight-reaction period, the test-mixtures were boiled for *c.* 2 hours. Then, after allowing the test-mixtures to cool, *c.* 1.0 mL of 0.016 M-CuSO₄ solution was added, and the test-mixtures again boiled for *c.* 2 hours. The addition of Cu(II) catalyses the decomposition of any residual, unreacted- H_2O_2 in the test-mixtures (McElnea and Ahern 2004; O'Shay *et al.* 1990). K-Feldspar was employed for the Blank.

Dr GD Campbell 12th June 2011

Laboratory Report

NET-ACID-GENERATION (NAG) TESTWORK

Sample	Sample Weight	Comments	pH of Test Mixture	Δ	Test Mixture fter Boiling Step	Titre	NAG (kg H2SO4/
Number	(g)		Before Boiling Step	pH	EC (µS/cm)	NaOH] (mL)	tonne)
GCA9683	3.0	Reaction peaked overnight	2.7	3.6	1,200	14.00	23
GCA9684	3.0	Reaction peaked overnight	7.2	7.5	250	-	<0.5
GCA9685	3.0	Reaction peaked overnight	3.0	4.2	1,100	5.80	9.5
GCA9686	3.0	Reaction peaked overnight	2.9	4.0	1,100	9.80	17
GCA9687	3.0	Reaction peaked overnight	8.1	8.0	240	-	<0.5
GCA9688	3.0	Reaction peaked overnight	2.5	2.7	2,000	17.00	28
GCA9689	3.0	Reaction peaked overnight	7.7	8.0	130	-	<0.5
GCA9690	3.0	Reaction peaked overnight	4.8	7.7	380	-	<0.5
GCA9691	3.0	Reaction peaked overnight	5.6	6.5	30	0.60	1.0
GCA9692	3.0	Reaction peaked overnight	5.4	6.0	24	0.20	<0.5
GCA9693	3.0	Reaction peaked overnight	5.3	6.0	19	0.20	<0.5
GCA9694	3.0	Reaction peaked overnight	5.2	6.0	24	0.70	1.2
GCA9695	3.0	Reaction peaked overnight	5.2	6.0	20	0.40	0.7
GCA9696	3.0	Reaction peaked overnight	5.3	6.0	24	0.20	<0.5
GCA9697	3.0	Reaction peaked overnight	5.3	5.7	16	0.30	<0.5
GCA9698	3.0	Reaction peaked overnight	5.1	5.3	14	0.50	0.9
GCA9699	3.0	Reaction peaked overnight	5.6	6.2	24	0.20	<0.5
GCA9700	3.0	Reaction peaked overnight	6.1	6.4	42	0.30	<0.5
GCA9700-1	3.0	Reaction peaked overnight	6.1	6.5	39	0.20	<0.5
BLANK2	3.0	Reaction peaked overnight	5.8	7.1	59	-	<0.5

Notes: Test conditions based on those described by Miller *et al.* (1997), and AMIRA (2002) for the 'Static-NAG-Test' in its "Single-Additon-Mode". The pH of the 15 % (v/v) H₂O₂ solution was adjusted to 4.5 using 0.1 M-NaOH prior to commencing the NAG Tests. Following an overnight-reaction period, the test-mixtures were boiled for *c*. 2 hours. Then, after allowing the test-mixtures to cool, *c*. 1.0 mL of 0.016 M-CuSO₄ solution was added, and the test-mixtures again boiled for *c*. 2 hours. The addition of Cu(II) catalyses the decomposition of any residual, unreacted-H₂O₂ in the test-mixtures (McElnea and Ahern 2004; O'Shay *et al.* 1990). K-Feldspar was employed for the Blank.

Dr GD Campbell 12th June 2011
Laboratory Report

NET-ACID-GENERATION (NAG) TESTWORK

Sample	Sample Weight	Comments	pH of Test Mixture	Α	Test Mixture fter Boiling Sten	Titre [0.1 M-	NAG (kg H₂SO₄/
Number	(g)		Before Boiling Step	рН	EC (µS/cm)	NaOH] (mL)	tonne)
GCA9701	3.0	Reaction peaked overnight	4.7	5.0	120	0.10	<0.5
GCA9702	3.0	Reaction peaked overnight	2.3	2.4	2,600	29.90	49
GCA9703	3.0	Reaction peaked overnight	4.8	5.9	190	0.70	1.2
GCA9704	3.0	Reaction peaked overnight	3.5	5.1	480	0.80	1.4
GCA9705	3.0	Reaction peaked overnight	3.5	5.6	490	0.90	1.5
GCA9706	3.0	Reaction peaked overnight	6.4	6.9	62	-	<0.5
GCA9707	3.0	Reaction peaked overnight	8.4	7.9	38	-	<0.5
GCA9708	3.0	Reaction peaked overnight	3.0	3.8	1,100	9.90	17
GCA9709	3.0	Reaction peaked overnight	6.0	6.0	39	0.70	1.2
GCA9710	3.0	Reaction peaked overnight	5.8	6.5	35	0.10	<0.5
GCA9711	3.0	Reaction peaked overnight	5.3	5.8	19	0.20	<0.5
GCA9712	3.0	Reaction peaked overnight	5.2	5.5	20	0.30	<0.5
GCA9713	3.0	Reaction peaked overnight	5.1	5.6	19	0.30	<0.5
GCA9714	3.0	Reaction peaked overnight	2.9	3.7	690	7.10	12
GCA9715	3.0	Reaction peaked overnight	5.2	5.3	22	0.30	<0.5
GCA9716	3.0	Reaction peaked overnight	7.4	6.7	31	0.20	<0.5
GCA9717	3.0	Reaction peaked overnight	2.7	2.9	1,200	11.80	20
GCA9718	3.0	Reaction peaked overnight	2.6	3.5	1,300	16.70	28
GCA9718-1	3.0	Reaction peaked overnight	2.6	3.6	1,300	16.50	27
BLANK3	3.0	Reaction peaked overnight	5.8	7.2	69	-	<0.5

Notes: Test conditions based on those described by Miller *et al.* (1997), and AMIRA (2002) for the 'Static-NAG-Test' in its "Single-Additon-Mode". The pH of the 15 % (v/v) H_2O_2 solution was adjusted to 4.5 using 0.1 M-NaOH prior to commencing the NAG Tests. Following an overnight-reaction period, the test-mixtures were boiled for *c.* 2 hours. Then, after allowing the test-mixtures to cool, *c.* 1.0 mL of 0.016 M-CuSO₄ solution was added, and the test-mixtures again boiled for *c.* 2 hours. The addition of Cu(II) catalyses the decomposition of any residual, unreacted- H_2O_2 in the test-mixtures (McElnea and Ahern 2004; O'Shay *et al.* 1990). K-Feldspar was employed for the Blank.

Dr GD Campbell 12th June 2011

Laboratory Report

NET-ACID-GENERATION (NAG) TESTWORK

Sample	Sample Weight	Comments	pH of Test Mixture	pH of Test Test Mixture Mixture After Boiling Step			NAG (kg H2SO4/
Number	(g)		Before Boiling Step	pН	EC (µS/cm)	NaOH] (mL)	tonne)
GCA9719	3.0	Reaction peaked overnight	2.4	2.5	2,700	26.20	43
GCA9720	3.0	Reaction peaked overnight	2.7	2.8	1,100	12.00	20
GCA9721	3.0	Reaction peaked overnight	2.7	2.7	1,500	13.80	23
GCA9722	3.0	Reaction peaked overnight	2.7	2.7	1,400	12.40	21
GCA9723	3.0	Reaction peaked overnight	2.9	3.1	560	5.80	9.5
GCA9724	3.0	Reaction peaked overnight	2.7	2.9	830	7.80	13
GCA9725	3.0	Reaction peaked overnight	2.9	3.7	650	7.20	12
GCA9726	3.0	Reaction peaked overnight	5.1	6.9	420	_	<0.5
GCA9727	3.0	Reaction peaked overnight	2.9	3.4	1,100	4.10	6.7

Notes: Test conditions based on those described by Miller *et al.* (1997), and AMIRA (2002) for the 'Static-NAG-Test' in its "Single-Additon-Mode". The pH of the 15 % (v/v) H₂O₂ solution was adjusted to 4.5 using 0.1 M-NaOH prior to commencing the NAG Tests. Following an overnight-reaction period, the test-mixtures were boiled for *c*. 2 hours. Then, after allowing the test-mixtures to cool, *c*. 1.0 mL of 0.016 M-CuSO₄ solution was added, and the test-mixtures again boiled for *c*. 2 hours. The addition of Cu(II) catalyses the decomposition of any residual, unreacted-H₂O₂ in the test-mixtures (McElnea and Ahern 2004; O'Shay *et al.* 1990). K-Feldspar was employed for the Blank.

Dr GD Campbell 12th June 2011

Laboratory Report

pH-BUFFERING TESTWORK (GCA9684)

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H ₂ SO ₄ /tonne)	рН
0.00	0.0	7.2
0.40	2.0	5.5
0.80	3.9	4.3
1.20	5.9	3.8
1.60	7.8	3.5
2.00	9.8	3.4
2.40	12	3.2
2.80	14	3.1
3.20	16	3.0
3.60	18	3.0
1	1	

Note: Titration performed using a Metrohm® 736 Titrino auto-titrator, and 0.05 M-H₂SO₄. Equilibration time

Note: Intration performed using a Metronm 736 fifting auto-titrator, and 0.05 M-H₂SO₄. Equilibration time between titrant additions was 15 minutes. 1.00 g of pulped sample initially dispersed in 150 mL of deionised-water. Test mixture in contact with air, at ambient temperature, and continuously stirred. <u>Calibration of pH-Glass Electrode</u>: Immediately prior to titration: asymmetry potential = 3 mV (pH=7.00); slope-point = 172 mV (pH=4.00); 94.7 % of Nernstian response for 25 °C. Immediately following titration: pH=7.00 buffer read pH=7.02 and pH=4.00 buffer read pH=4.03. These discrepancies represent drift in pH-Glass electrode response during course of auto-titration.

Dr GD Campbell 16th June 2011

Laboratory Report

pH-BUFFERING TESTWORK (GCA9690)

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H ₂ SO ₄ /tonne)	рН
0.00	0.0	7.1
0.40	2.0	4.9
0.80	3.9	3.9
1.20	5.9	3.6
1.60	7.8	3.4
2.00	9.8	3.2
2.40	12	3.1
2.80	14	3.0
3.20	16	3.0

Note: Titration performed using a Metrohm[®] 736 Titrino auto-titrator, and 0.05 M-H₂SO₄. Equilibration time between titrant additions was 15 minutes. 1.00 g of pulped sample initially dispersed in 150 mL of deionised-water. Test mixture in contact with air, at ambient temperature, and continuously stirred.

<u>Calibration of pH-Glass Electrode</u>: Immediately prior to titration: asymmetry potential = 3 mV (pH=7.00); slope-point = 177 mV (pH=4.00); 97.9 % of Nernstian response for 25 °C. Immediately following titration: pH=7.00 buffer read pH=7.02 and pH=4.00 buffer read pH=4.03. These discrepancies represent drift in pH-Glass electrode response during course of auto-titration.

Dr GD Campbell 16th June 2011

Laboratory Report

pH-BUFFERING TESTWORK (GCA9726)

Cumulative Volume of Acid	Cumulative Acid Consumption	nH
Added (mL)	(kg H ₂ SO ₄ /tonne)	pii
0.00	0.0	7.3
0.40	2.0	6.5
0.80	3.9	5.6
1.20	5.9	5.0
1.60	7.8	4.5
2.00	9.8	4.0
2.40	12	3.8
2.80	14	3.6
3.20	16	3.4
3.60	18	3.3
4.00	20	3.2
4.40	22	3.1
4.80	24	3.1
5.20	25	3.0

Note: Titration performed using a Metrohm[®] 736 Titrino auto-titrator, and 0.05 M-H₂SO₄. Equilibration time between titrant additions was 15 minutes. 1.00 g of pulped sample initially dispersed in 150 mL of deionised-water.

Test mixture in contact with air, at ambient temperature, and continuously stirred.

<u>Calibration of pH-Glass Electrode</u>: Immediately prior to titration: asymmetry potential = 4 mV (pH=7.00); slope-point = 177 mV (pH=4.00); 97.9 % of Nernstian response for 25 °C. Immediately following titration: pH=7.00 buffer read pH=7.02 and pH=4.00 buffer read pH=4.03. These discrepancies represent drift in pH-Glass electrode response during course of auto-titration.

Dr GD Campbell 16th June 2011





ANALYTICAL REPORT

Dr G. CAMPBELL CAMPBELL, GRAEME and ASSOCIATES PO Box 247 BRIDGETOWN, W.A. 6255 AUSTRALIA

JOB INFORMATION

JOB CODE	:	143.0/1110718
No. of SAMPLES	:	10
No. of ELEMENTS	:	32
CLIENT O/N	:	GCA1112 (Job 1 of 1)
SAMPLE SUBMISSION No.	:	
PROJECT	:	PIOP, Flinders Mine
STATE	:	Ex-Pulp
DATE RECEIVED	:	13/06/2011
DATE COMPLETED	:	29/07/2011
DATE PRINTED	:	29/07/2011
PRIMARY LABORATORY	:	Genalysis Main Laboratory

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LEGEND

Х	= Less than Detection Limit
N/R	= Sample Not Received
*	= Result Checked
()	= Result still to come
I/S	= Insufficient Sample for Analysis
E6	= Result X 1,000,000
UA	= Unable to Assay
>	= Value beyond Limit of Method
OV	= Value over-range for Package

SAMPLE DETAILS

DISCLAIMER

Genalysis Laboratory Services Pty Ltd wishes to make the following disclaimer pertaining to the accompanying analytical results.

Genalysis Laboratory Services Pty Ltd disclaims any liability, legal or otherwise, for any inferences implied from this report relating to either the origin of, or the sampling technique employed in the collection of, the submitted samples.

SIGNIFICANT FIGURES

It is common practice to report data derived from analytical instrumentation to a maximum of two or three significant figures. Some data reported herein may show more figures than this. The reporting of more than two or three figures in no way implies that the third, fourth and subsequent figures may be real or significant.

Genalysis Laboratory Services Pty Ltd accepts no responsibility whatsoever for any interpretation by any party of any data where more than two or three significant figures have been reported.

SAMPLE STORAGE DETAILS

GENERAL CONDITIONS

SAMPLE STORAGE OF SOLIDS

Bulk Residues and Pulps will be stored for 60 DAYS without charge. After this time all Bulk Residues and Pulps will be stored at a rate of \$3.30 per cubic metre per day until your written advice regarding collection or disposal is received. Expenses related to the return or disposal of samples will be charged to you at cost. Current disposal cost is charged at \$100.00 per cubic metre.

SAMPLE STORAGE OF SOLUTIONS

Samples received as liquids, waters or solutions will be held for 60 DAYS free of charge then disposed of, unless written advice for return or collection is received.

NOTES

*** NATA ENDORSED DOCUMENT ****

Company Accreditation Number 3244

The contents of this report have been prepared in accordance with the terms of NATA accreditation and as such should only be reproduced in full.

The analysis results reported herein have been obtained using the following methods and conditions:

The samples as listed were received as being 'Tailing-Solids' which had been dried and pulverised in a zirconia bowl as per Genalysis job number 143_0_1107964.

The results have been determined according to Genalysis methods codes : Digestions : MPL_W001 (4A/), ENV_W012 (FC7/SIE), MPL_W011 (FP1/), MPL_W008 (HG1/).

Analytical Finishes: ICP_W004 (/OE), ICP_W005 (/MS), and AAS_W004 (/CV).

The results included the assay of blanks and international reference standards STSD-2 and AMIS0140 and Genalysis in-house standards HgSTD-3 and OREAS 97.01

The results are expressed as parts per million or percent by mass in the dried and prepared material.

NATA Signatory: A Evers Chief CHemist

Date: 29/07/2011 This document is issued in accordance with NATA's accreditation requirements.

			ANA	LYS	IS					
ELEMENTS	Ag	AI	As	В	Ва	Bi	Ca	Cd	Co	Cr
UNITS	ppm	%	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm
DETECTION LIMIT	0.01	0.01	0.5	50	0.1	0.01	0.1	0.02	0.1	50
DIGEST	4A/	FP1/	4A/	FP1/	4A/	4A/	FP1/	4A/	4A/	FP1/
ANALYTICAL FINISH	MS	OE	MS	OE	MS	MS	OE	MS	MS	OE
SAMPLE NUMBERS										
0001 GCA9665	0.06	2.14	10.8	Х	109.1	0.16	0.6	0.09	2.9	151
0002 GCA9667	0.04	2.87	13.3	Х	21.0	0.21	0.2	0.05	2.2	54
0003 GCA9669	0.02	2.61	20.2	Х	34.8	0.28	0.2	Х	1.7	105
0004 GCA9673	0.08	2.24	16.0	Х	7.4	0.23	0.2	0.02	1.3	56
0005 GCA9676	0.03	0.49	12.8	Х	9.8	0.23	0.2	Х	1.9	Х
0006 GCA9681	0.08	1.79	18.0	Х	50.8	0.13	0.2	0.05	7.3	93
0007 GCA9702	0.11	3.90	39.2	Х	182.6	0.37	0.2	0.06	12.9	244
0008 GCA9708	0.12	3.73	48.6	Х	212.1	0.37	0.5	0.18	20.1	330
0009 GCA9719	0.14	3.77	50.1	Х	273.1	0.36	0.2	0.04	4.9	199
0010 GCA9723	0.14	4.58	48.2	Х	416.8	0.41	0.2	Х	3.3	99
CHECKS										
0001 GCA9665	0.04	2.23	9.7	Х	107.8	0.14	0.6	0.02	2.9	103
STANDARDS										
0001 AMIS0140		0.73		Х			0.3			485
0002 HgSTD-3										
0003 MPL-4	14.92		688.4		175.4	15.58		4.93	80.1	
0004 STSD-2										
BLANKS										
0001 Control Blank	Х	Х	Х	Х	0.7	0.01	Х	Х	Х	Х
0002 Control Blank	0.06		Х		0.2	0.02		Х	х	
0003 Control Blank		Х		Х			0.2			Х
0004 Control Blank										
0005 Acid Blank	0.04		Х		0.2	Х		Х	Х	
0006 Acid Blank		Х		Х			Х			Х
0007 Acid Blank										

			ANA	LYS	IS					
ELEMENTS	Cu	F	Fe	Hg	к	Mg	Mn	Мо	Na	Ni
UNITS	ppm	ppm	%	ppm	%	%	ppm	ppm	ppm	ppm
DETECTION LIMIT	1	50	0.01	0.01	0.05	0.01	1	0.1	20	1
DIGEST	4A/	FC7/	FP1/	HG1/	FP1/	FP1/	4A/	4A/	4A/	4A/
ANALYTICAL FINISH	OE	SIE	OE	CV	OE	OE	OE	MS	OE	OE
SAMPLE NUMBERS										
0001 GCA9665	15	153	40.19	0.02	0.20	0.12	203	0.9	323	10
0002 GCA9667	12	153	50.63	Х	0.08	0.06	157	1.5	95	9
0003 GCA9669	8	111	55.75	Х	0.11	0.04	109	2.0	149	8
0004 GCA9673	1	147	59.11	Х	0.10	0.04	139	3.2	33	5
0005 GCA9676	Х	141	61.00	0.05	0.09	0.04	515	3.8	53	4
0006 GCA9681	12	259	55.38	0.13	0.07	0.04	435	1.6	27	10
0007 GCA9702	28	1147	23.94	0.24	5.01	0.21	253	2.9	83	40
0008 GCA9708	32	454	19.91	0.22	5.03	1.13	4645	2.8	81	42
0009 GCA9719	22	454	19.57	0.17	2.14	0.09	923	2.8	127	20
0010 GCA9723	20	627	19.31	0.17	3.89	0.15	365	2.8	168	15
CHECKS										
0001 GCA9665	16	187	41.37	0.03	0.24	0.13	207	0.8	328	10
STANDARDS										
0001 AMIS0140			1.62		0.35	0.13				
0002 HgSTD-3				0.35						
0003 MPL-4	1504						1506	8.6	4.42%	1546
0004 STSD-2		1057								
BLANKS										
0001 Control Blank	1	54	Х	Х	Х	Х	1	Х	Х	Х
0002 Control Blank	3						2	Х	22	Х
0003 Control Blank			0.03		0.13	х				
0004 Control Blank				Х						
0005 Acid Blank	1						3	х	х	Х
0006 Acid Blank			Х		Х	Х				
0007 Acid Blank				х						

			AN/	ALYS	IS					
ELEMENTS	Р	Pb	S	Sb	Si	Sn	Sr	Th	TI	U
UNITS	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm
DETECTION LIMIT	50	0.5	50	0.05	0.1	0.1	0.05	0.01	0.02	0.01
DIGEST	4A/	4A/	4A/	4A/	FP1/	4A/	4A/	4A/	4A/	4A/
ANALYTICAL FINISH	OE	MS	OE	MS	OE	MS	MS	MS	MS	MS
SAMPLE NUMBERS										
0001 GCA9665	496	7.8	69	1.21	15.7	1.1	30.06	4.52	0.13	0.81
0002 GCA9667	376	10.4	115	1.61	7.4	1.7	7.84	6.21	0.04	1.39
0003 GCA9669	357	11.1	175	2.41	5.6	1.9	7.72	8.34	0.03	1.67
0004 GCA9673	473	9.9	120	2.07	2.7	2.6	3.56	3.87	Х	0.88
0005 GCA9676	743	5.5	61	2.50	1.0	2.5	2.51	1.53	Х	0.38
0006 GCA9681	1770	6.0	204	1.06	1.3	1.3	1.77	1.76	Х	1.14
0007 GCA9702	687	19.4	1.93%	4.15	21.2	1.5	7.08	7.68	0.70	2.38
0008 GCA9708	653	18.0	2.52%	3.74	20.4	1.3	7.61	7.80	0.75	2.46
0009 GCA9719	524	18.2	5637	3.88	27.4	1.6	26.44	6.82	0.52	2.32
0010 GCA9723	431	20.5	3487	3.04	25.6	1.8	26.87	8.34	0.71	2.78
CHECKS										
0001 GCA9665	493	7.4	69	1.10	15.8	1.0	29.68	4.45	0.12	0.80
STANDARDS										
0001 AMIS0140					46.0					
0002 HgSTD-3										
0003 MPL-4	1690	1475.4	1.16%	165.99		2.5	135.02	88.19	8.01	10.99
0004 STSD-2										
BLANKS										
0001 Control Blank	Х	Х	Х	Х	Х	Х	Х	Х	Х	Х
0002 Control Blank	Х	1.0	Х	0.17		0.3	0.14	0.03	Х	Х
0003 Control Blank					Х					
0004 Control Blank										
0005 Acid Blank	Х	0.6	Х	0.15		0.3	0.08	0.01	Х	0.02
0006 Acid Blank					Х					
0007 Acid Blank										

			ANALYSIS
ELEMENTS	V	Zn	
UNITS	ppm	ppm	
DETECTION LIMIT	1	1	
DIGEST	4A/	4A/	
ANALYTICAL FINISH	OE	OE	
SAMPLE NUMBERS			
0001 GCA9665	71	17	
0002 GCA9667	106	8	
0003 GCA9669	55	9	
0004 GCA9673	69	10	
0005 GCA9676	47	11	
0006 GCA9681	58	34	
0007 GCA9702	58	122	
0008 GCA9708	46	86	
0009 GCA9719	63	53	
0010 GCA9723	80	40	
CHECKS			
0001 GCA9665	72	15	
STANDARDS			
0001 AMIS0140			
0002 HgSTD-3			
0003 MPL-4	141	1021	
0004 STSD-2			
BLANKS			
0001 Control Blank	1	Х	
0002 Control Blank	2	2	
0003 Control Blank			
0004 Control Blank			
0005 Acid Blank	2	х	
0006 Acid Blank			
0007 Acid Blank			

METHOD CODE DESCRIPTION

4A/MS

Genalysis Main Laboratory

Multi-acid digest including Hydrofluoric, Nitric, Perchloric and Hydrochloric acids in Teflon Tubes. Analysed by Inductively Coupled Plasma Mass Spectrometry.

4A/OE

Genalysis Main Laboratory

Multi-acid digest including Hydrofluoric, Nitric, Perchloric and Hydrochloric acids in Teflon Tubes. Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.

FC7/SIE Genalysis Main Laboratory

Alkaline fusion (Nickel crucible) specific for Fluorine. Analysed by Specific Ion Electrode.

FP1/OE Genalysis Main Laboratory

Sodium peroxide fusion (Nickel crucibles) and Hydrochloric acid to dissolve the melt. Analysed by Inductively Coupled PI

HG1/CV Genalysis Main Laboratory

Low temperature Perchloric acid digest specific for Mercury. Analysed by Cold Vapour Generation Atomic Absorption Spectrometry.





ANALYTICAL REPORT

Dr G. CAMPBELL CAMPBELL, GRAEME and ASSOCIATES PO Box 247 BRIDGETOWN, W.A. 6255 AUSTRALIA

JOB INFORMATION

JOB CODE	:	143.0/1107130
No. of SAMPLES	:	8
No. of ELEMENTS	:	14
CLIENT O/N	:	GCA1112 (Job 1 of 1)
SAMPLE SUBMISSION No.	:	
PROJECT	:	Flinders, PIOP
STATE	:	Ex-Pulp
DATE RECEIVED	:	24/05/2011
DATE COMPLETED	:	13/06/2011
DATE PRINTED	:	13/06/2011
PRIMARY LABORATORY	:	Genalysis Main Laboratory

MAIN OFFICE AND LABORATORY

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LEGEND

Х	= Less than Detection Limit
N/R	= Sample Not Received
*	= Result Checked
()	= Result still to come
I/S	= Insufficient Sample for Analysis
E6	= Result X 1,000,000
UA	= Unable to Assay
>	= Value beyond Limit of Method
OV	= Value over-range for Package

SAMPLE DETAILS

DISCLAIMER

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SIGNIFICANT FIGURES

It is common practice to report data derived from analytical instrumentation to a maximum of two or three significant figures. Some data reported herein may show more figures than this. The reporting of more than two or three figures in no way implies that the third, fourth and subsequent figures may be real or significant.

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SAMPLE STORAGE DETAILS

GENERAL CONDITIONS

SAMPLE STORAGE OF SOLIDS

Bulk Residues and Pulps will be stored for 60 DAYS without charge. After this time all Bulk Residues and Pulps will be stored at a rate of \$3.30 per cubic metre per day until your written advice regarding collection or disposal is received. Expenses related to the return or disposal of samples will be charged to you at cost. Current disposal cost is charged at \$100.00 per cubic metre.

SAMPLE STORAGE OF SOLUTIONS

Samples received as liquids, waters or solutions will be held for 60 DAYS free of charge then disposed of, unless written advice for return or collection is received.

			AN	ALYS	SIS					
ELEMENTS	AI2O3	CaO	Cr2O3	Fe2O3	K2O	LOI	MgO	MnO	Na2O	P2O5
UNITS	%	%	%	%	%	%	%	%	%	%
DETECTION LIMIT	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.002
DIGEST	FB1/	FB1/	FB1/	FB1/	FB1/		FB1/	FB1/	FB1/	FB1/
ANALYTICAL FINISH	XRF50	XRF50	XRF50	XRF50	XRF50	/TGA	XRF50	XRF50	XRF50	XRF50
SAMPLE NUMBERS										
0001 GCA9666	4.85	0.08	Х	68.91	0.03	2.56	0.10	0.03	0.04	0.097
0002 GCA9670	5.83	0.02	Х	77.13	0.04	2.29	0.07	0.01	0.02	0.104
0003 GCA9691	7.71	0.05	0.01	50.94	0.26	3.49	0.13	0.03	0.06	0.106
0004 GCA9692	5.36	0.03	0.01	52.73	0.04	2.30	0.07	0.02	0.03	0.083
0005 GCA9693	6.08	0.03	Х	76.89	0.03	2.57	0.05	0.01	0.03	0.095
0006 GCA9697	14.16	0.04	Х	54.39	0.01	11.95	0.07	Х	0.01	0.077
0007 GCA9710	4.23	0.06	0.01	59.72	0.08	2.66	0.08	0.03	0.07	0.126
0008 GCA9711	7.16	0.03	Х	75.03	0.08	3.35	0.09	0.02	0.02	0.120
CHECKS										
0001 GCA9666	4.88	0.08	Х	68.77	0.03	2.54	0.10	0.03	0.03	0.095
STANDARDS										
0001 GenFe-7						23.04				
0002 SY-4	20.63	8.01	Х	6.19	1.66		0.52	0.11	7.17	0.129
BLANKS										
0001 Control Blank	Х	Х	Х	Х	Х	0.03	Х	Х	Х	Х

			AN/	ALYSI
ELEMENTS	SO3	SiO2	TiO2	Total
UNITS	%	%	%	%
DETECTION LIMIT	0.002	0.01	0.01	0.01
DIGEST	FB1/	FB1/	FB1/	FB1/
ANALYTICAL FINISH	XRF50	XRF50	XRF50	XRF50
SAMPLE NUMBERS				
0001 GCA9666	0.030	23.04	0.40	100.20
0002 GCA9670	0.038	13.97	0.50	100.03
0003 GCA9691	0.022	36.07	0.67	99.61
0004 GCA9692	0.024	38.41	0.48	99.61
0005 GCA9693	0.033	13.15	0.57	99.57
0006 GCA9697	0.015	18.33	1.09	100.21
0007 GCA9710	0.041	32.82	0.31	100.24
0008 GCA9711	0.034	12.95	0.98	99.90
CHECKS				
0001 GCA9666	0.028	22.96	0.39	99.98
STANDARDS				
0001 GenFe-7				
0002 SY-4	0.040	49.56	0.29	99.35
BLANKS				
0001 Control Blank	Х	99.42	Х	99.45

/TGA

METHOD CODE DESCRIPTION

Genalysis Main Laboratory

No digestion or other pre-treatment undertaken. Analysed by Thermal Gravimetric Analyser

FB1/XRF50 Genalysis Main Laboratory

Fused Disk preparation for XRF analysis Analysed by XRF Spectrometry. Clay Minerals Package

Intertek



Dr G Campbell CAMPBELL, GRAEME and ASSOCIATES PTY LTD PO Box 247 BRIDGETOWN WA 6255

JOB INFORMATION

JOB CODE	143.0/1107389
No. of SAMPLES	8
CLIENT O/N	GCA 1112
PROJECT	Flinders PIOP
STATE	Crushings
DATE RECEIVED	24/5/2011
DATE COMPLETED	27/06/2011

LEGEND

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- X = Less than Detection Limit
- N/R = Sample Not Received
 - = Result Checked
 - = Result still to come
- I/S = Insufficient Sample for Analysis
- E6 = Result X 1,000,000
- UA = Unable to Assay
 - = Value beyond Limit of Method

The samples were received as crushings and were indicated to be non calcareous

The digest NH4Cl7 was used as follows for these non calcareous samples:

2g of each of the samples were weighed into a centrifuge tube and pre- washed with 2x 25ml 10 % (v/v) deionised ethylene glycol in 90 % (v/v) ethanol which has been previously deionised by passing through Amberlite resin

After the centrifuge stage there may be finely dispersed material in suspension. If this is the case a few drops of PVA may be necessary. The PVA aqueous solution is 0.05 % (w/v) polyvinyl alcohol. No additions.

Extraction step for Exchangeable cations

After decanting following completion of the 2nd pre-wash, the residue in centrifuge tube is subjected to 2 x 30-minute extractions via end-over-end tumbling at approx. 10 rpm. Each extraction uses 20 ml of 1 M-NH₄Cl buffered at pH 7.0 using ammonia solution 28 % (w/w). At the completion of each extraction, the suspensions are centrifuged and the supernatants decanted and collected into a communal extract. The final communal extract is brought to 50 ml with 4 M-HCl.

Sample analysed for Ca,Mg,K and Na by OES

Reference: Based on procedure 15B2 Australian laboratory handbook of soil and water chemical methods / G.E. Rayment and F.R. Higginson 1992 Inkata Press

GLS Job Code 143.0/1107389

Results of analysis on:

Element		Ca	К	Mg	Na	eCEC	Ca	к	Mg	Na
Method		NH4CI7/OE	NH4CI7/OE	NH4CI7/OE	NH4CI7/OE		exch	exch	exch	exch
										ESP
Units		cmol(+)/kg	cmol(+)/kg	cmol(+)/kg	cmol(+)/kg		%	%	%	%
GCA9666		0.99	0.18	0.86	0.66	2.69	36.6	6.8	32.1	24.4
GCA9666	check	1.12	0.19	1.06	0.75	3.12	35.9	6.1	34.0	24.0
GCA9670		0.23	0.00	1.29	0.77	2.29	10.1	0.0	56.5	33.5
GCA9691		1.00	0.13	1.55	0.79	3.46	28.8	3.6	44.7	22.9
GCA9692		0.80	0.00	0.80	0.37	1.97	40.4	0.0	40.6	19.0
GCA9693		0.27	0.00	0.44	0.83	1.53	17.3	0.0	28.5	54.2
GCA9697		1.32	0.00	1.46	0.57	3.35	39.4	0.0	43.5	17.1
GCA9710		0.60	0.17	0.53	1.72	3.03	19.7	5.7	17.7	56.9
GCA9711		0.64	0.00	1.37	0.32	2.33	27.3	0.0	58.9	13.8
ASPAC-33		42.00	1.47	32.16	2.06	77.69	54.1	1.9	41.4	2.6

Ann Evers

27/06/2011



Intertek

Dr G Campbell CAMPBELL, GRAEME and ASSOCIATES PTY LTD PO Box 247 BRIDGETOWN WA 6255

JOB INFORMATION

JOB CODE	143/1108765
No. of SAMPLES	26
CLIENT O/N	GCA 1112
PROJECT	Flinders PIOP
STATE	Water extracts
DATE RECEIVED	16/06/2011
DATE COMPLETED	18/07/2011

LEGEND

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- X = Less than Detection Limit
- N/R = Sample Not Received
 - = Result Checked
- () = Result still to come
- I/S = Insufficient Sample for Analysis
- E6 = Result X 1,000,000
- UA = Unable to Assay
 - = Value beyond Limit of Method

A series water extracts were received. GCA9665 and GCA9669 were received as turbid extracts, these samples were centrifuged and filtered (0.45um) a split was then taken and dosed with HNO3 The pH, EC and Cl of the "raw" samples was measured Genalysis method codes ENV-W001, ENV-W002, ENV_W013 and the alkalinity measured using APHA method code 2320B

APHA code refers to "Standard methods for the examination of water and wastewater", 21st Edition 2005

The HNO3 dosed filtered solution was analysed for the requested element suite (including S) by ICPMS and /or ICPOES: Genalysis method codes (ICP_W003, ICP_W004)

The charge balance was calculated and found to be within +/- 10% only for samples pH>4.5

Results of analysis on:

Element		CI	EC	pН	HCO3
Method		/COL	/MTR	/MTR	/VOL
Detection		2	10	0.1	1
Units		mg/l	uS/cm	NONE	mgHCO3/L
Sample Name					
Control Blank		Х			
GCA9665 Raw		5	202	8.4	106
GCA9665 Raw	check	5	204	8.4	105
GCA9669 Raw		3	46	7.4	21
GCA9673 Raw		2	21	6.7	8
GCA9680 Raw		2	28	6.9	8
GCA9681 Raw		2	35	6.9	11
GCA9696 Raw		2	31	6.8	10
GCA9699 Raw		2	23	6.7	7
GCA9702 Raw		2	4050	2.5	Х
GCA9708 Raw		2	2304	4.9	4
GCA9714 Raw		2	1016	7.5	73
GCA9719 Raw		2	4100	2.3	Х
GCA9723 Raw		3	1580	2.6	Х

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GLS Job Code 143.0/1108765

Element		Ag	AI	As	В	Ва	Bi	Ca	Cd	Co
Method		/MS	/OE	/MS	/OE	/MS	/MS	/OE	/MS	/MS
Detection		0.01	0.01	0.1	0.01	0.05	0.005	0.01	0.02	0.1
Units		ug/l	mg/l	ug/l	mg/l	ug/l	ug/l	mg/l	ug/l	ug/l
Sample Name										
Control Blank		0.01	0.02	Х	0.01	Х	Х	Х	Х	Х
GCA9665 HNO3		0.01	0.08	1.8	0.11	96.49	0.005	12.18	Х	Х
GCA9669 HNO3		0.01	0.29	0.5	0.09	45.17	Х	0.05	Х	Х
GCA9673 HNO3		0.02	0.02	0.2	0.03	2.51	Х	0.47	Х	0.1
GCA9680 HNO3		Х	0.04	0.2	0.01	2.14	Х	0.84	Х	Х
GCA9681 HNO3		0.02	0.01	0.2	0.01	4.19	Х	1.63	Х	Х
GCA9696 HNO3		Х	Х	0.1	0.02	3.45	Х	1.34	Х	Х
GCA9699 HNO3		Х	0.04	0.2	0.03	2.23	Х	0.53	Х	Х
GCA9702 HNO3		0.02	152.4	48.6	Х	3.42	Х	109.91	4.84	980.1
GCA9708 HNO3		Х	1.2	1.2	Х	26.81	Х	98.56	8.59	307.8
GCA9708 HNO3	check	Х	1.14	0.9	Х	26.56	Х	98.2	8.21	305.2
GCA9714 HNO3		0.02	Х	0.8	Х	28.03	0.008	102.04	0.12	9.7
GCA9719 HNO3		0.03	190.3	104.4	Х	12.01	0.005	15.02	2.61	701.3
GCA9723 HNO3		Х	56.9	7.8	Х	22.66	Х	7.12	1.1	415.2
WET Blank HNO3		0.02	0.02	0.2	Х	0.49	Х	0.02	Х	0.1
WET-DW HNO3		Х	0.03	0.2	Х	0.14	Х	Х	Х	Х
Alcoa16-MS		5.35		28.5		6.63	4.794		5.28	541.5
Alcoa10-OES			1.88		1.11			48.5		
Element		Cr	Cu	Fo Sol	Ha	K	Ma	Mp	Ma	No
Element				re-50	III MS	n /0E	IVIG			
Detection		/UE	70E	70E	/1015	/0E	70E	70E	/1/15	/UE
Detection		0.01	0.01	0.01	0.1	0.1	0.01	0.01	0.05	0.1
Onits Somple Nome		mg/i	mg/i	mg/i	ug/i	mg/i	mg/i	mg/i	ug/i	mg/i
Control Plank		v	v	v	v	0.2	v	v	v	v
				∧	A V	0.2	2.46		1.00	27.0
				0.1	A V	0.0	2.40 V		0.14	27.0
		∧ 0.01		0.23	A V	1.2	∧ 0.59		0.14	10.3
		0.01			× ×	1.4	0.56	∧ ∨		1.0
		×			× ×	1.7	1 5 4	×	0.08	1.0
		× ×			× ×	1.0	1.04	∧ ∨	0.07	1.0
					A V	1.2	1.10		0.14	1.7
		1.0	1 5 4	A 640.92	∧ 	1.3	0.92	7 40	0.10	1.4
		1.Z	1.54 V	040.02	0.5 V	1.3	272.60	7.40	1.24	0.5
	abaak			9.94	× ×	29.0	272.09	91.11	1.34	1.7
	CHECK	× ×		9.90 V	× ×	29.0	66.14	90.04	1.4	1.7
		^ 0.66	2.02	A 5 4 9 4 0	× ×	21.3	44.2	0.23	1.1	1.5
		0.00	0.71	10.7		10.0	44.3 20.16	27.24	0.56	0.7
		0.1Z	0.71	0.05		0.1	30.10 V	21.31 V	0.00 V	0.9
				0.05		0.1				0.1
		~	~	0.03	∧ 25	0.1	~	~	۸ 5.07	0.1
		0.40	0.05	2	2.0	2.0	EG 75	0.5	5.97	227 5
AICOATU-UES	1	0.49	0.25			J.Ö	50.75	0.5	1	231.5

Element		Ni	Р	Pb	S	Sb	Se	Si	Sn	Sr
Method		/OE	/OE	/MS	/OE	/MS	/MS	/OE	/MS	/MS
Detection		0.01	0.1	0.5	0.1	0.01	0.5	0.05	0.1	0.02
Units		mg/l	mg/l	ug/l	mg/l	ug/l	ug/l	mg/l	ug/l	ug/l
Sample Name										
Control Blank		Х	Х	Х	Х	Х	Х	Х	Х	Х
GCA9665 HNO3		Х	Х	Х	2.1	0.2	0.5	15.55	0.1	124.27
GCA9669 HNO3		Х	Х	Х	0.6	0.04	Х	19.01	0.3	0.63
GCA9673 HNO3		Х	Х	7.8	Х	0.05	Х	10.18	0.2	6.69
GCA9680 HNO3		Х	Х	3.7	0.3	0.02	Х	5.76	0.1	5.92
GCA9681 HNO3		0.01	Х	2.7	0.5	0.02	Х	6.64	0.1	8.81
GCA9696 HNO3		Х	Х	1.5	0.3	0.02	Х	6.2	0.1	6.35
GCA9699 HNO3		Х	Х	1.5	0.4	0.02	Х	7.31	0.1	4.5
GCA9702 HNO3		2.18	3.5	261.3	1033.2	0.53	4	9.21	0.2	19.07
GCA9708 HNO3		0.68	Х	23.4	525.6	0.03	8.1	5.41	0.1	95.91
GCA9708 HNO3	check	0.72	Х	23	510.4	0.03	7.9	5.5	0.1	95.03
GCA9714 HNO3		0.02	Х	0.8	167.1	0.51	9.1	4.4	0.2	71.44
GCA9719 HNO3		1.31	0.6	67.3	937.4	0.61	Х	11.45	0.2	14.2
GCA9723 HNO3		0.48	Х	39.2	223.2	0.08	Х	21.32	0.1	22.98
WET Blank HNO3		Х	Х	9.2	0.2	0.01	Х	Х	Х	0.08
WET-DW HNO3		Х	Х	Х	0.1	Х	Х	Х	Х	Х
Alcoa16-MS				6.6		5.53	27		5.8	583.24
Alcoa10-OES		0.53	0.9		19.8			26.94		

Element		Th	TI	U	V	Zn
Method		/MS	/MS	/MS	/OE	/OE
Detection		0.005	0.01	0.005	0.01	0.01
Units		ug/l	ug/l	ug/l	mg/l	mg/l
Sample Name						
Control Blank		Х	Х	Х	Х	Х
GCA9665 HNO3		Х	Х	0.341	Х	Х
GCA9669 HNO3		Х	Х	0.018	Х	Х
GCA9673 HNO3		Х	Х	Х	Х	Х
GCA9680 HNO3		Х	Х	Х	Х	Х
GCA9681 HNO3		Х	Х	Х	Х	Х
GCA9696 HNO3		Х	Х	Х	Х	Х
GCA9699 HNO3		Х	Х	Х	Х	Х
GCA9702 HNO3		17.255	0.12	6.783	0.37	0.79
GCA9708 HNO3		0.026	0.54	0.25	Х	0.15
GCA9708 HNO3	check	0.027	0.53	0.245	Х	0.15
GCA9714 HNO3		Х	0.26	0.125	Х	Х
GCA9719 HNO3		74.645	0.08	24.85	0.09	1.5
GCA9723 HNO3		6.53	2.18	5.316	Х	0.45
WET Blank HNO3		Х	Х	Х	Х	Х
WET-DW HNO3		Х	Х	Х	Х	Х
Alcoa16-MS		5.259	5.02	5.53		
Alcoa10-OES					0.49	0.46

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NATA Signatory: Ann Evers

Ann Evers

Date: 18/07//2011



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Note:

The laboratory-reports, and column-worksheets, in the following pages correspond to the kinetic-testing programme carried out on the six (6) samples of **composite-waste-regoliths** (viz. GCA9728 to GCA9733) from the **Delta-Pit**.



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GRAEME CAMPBELL AND ASSOCIATES

14-9-2011

PO BOX 247,

BRIDGETOWN

WA

OUR REFERENCE 23011

YOUR REFERENCE: 1112 (FLINDERS PIOP)

XRD/PLM ANALYSIS OF SIX ROCK PULPS.

R & D TOWNEND

MINERAL	GCA9728	GCA9729	GCA9730
HEMATITE	MAJOR	MAJOR	DOMINANT
GOETHITE	MINOR	MINOR	MINOR
MAGHEMITE	ACCESSORY	ACCESSORY	ACCESSORY
QUARTZ	MAJOR	MINOR	ACCESSORY
KAOLINITE	ACCESSORY	ACCESSORY	ACCESSORY
MICA		TRACE	

MINERAL	GCA9731	GCA9732	GCA9733
HEMATITE	DOMINANT	MINOR	MINOR
GOETHITE	MAJOR	MAJOR	DOMINANT
MAGHEMITE	ACCESSORY	ACCESSORY	
QUARTZ	ACCESSORY	ACCESSORY	ACCESSORY
KAOLINITE	ACCESSORY	ACCESSORY	TRACE

Roger Townend and Associates





Dr G Campbell CAMPBELL, GRAEME and ASSOCIATES PO Box 247 BRIDGETOWN WA 6255

JOB INFORMATION

JOB CODE	143.0/1107089
No. of SAMPLES	6
CLIENT O/N	GCA 1112
PROJECT	PIOP Flinders mine
STATE	Ex pulp
DATE RECEIVED	24/05/2011
DATE COMPLETED	14/06/2011

LEGEND

>

- X = Less than Detection Limit
- N/R = Sample Not Received
 - = Result Checked
- () = Result still to come
- I/S = Insufficient Sample for Analysis
- E6 = Result X 1,000,000
- UA = Unable to Assay
 - = Value beyond Limit of Method

The samples were received as pulp (-75µm nominal) and crushings (-2mm nominal) 'splits' ex job 1106867

Results of analysis on:

Element		S	S-SO4	С	TOC+C	C-CO3
Method		/CSA	S72/GR	/CSA	C71/CSA	/CALC
Detection		0.01	0.01	0.01	0.01	0.01
Units		%	%	%	%	%
Sample Name						
Control Blank		Х	0.01	0.01	Х	Х
GCA9728		0.03	Х	0.08	0.08	0
GCA9728	check	0.03	Х	0.08	0.09	-0.01
GCA9729		0.03	Х	0.11	0.08	0.03
GCA9730		0.04	Х	0.13	0.08	0.05
GCA9731		0.03	Х	0.19	0.1	0.09
GCA9732		0.02	Х	0.1	0.08	0.02
GCA9733		0.03	Х	0.31	0.13	0.18
SY-4		0.02		1.06		
TOC-1					1.44	
SO4-STD A			0.55			
SO4-STD B			1.23			

- 1. Total-S and Total-C were determined on the pulps
- Total-C and Total-S was determined using an induction furnace according to Genalysis method number MPL_W043. The samples are ignited in oxygen ~1700C and the CO2 and SO2 measured by infrared detectors
- **3.** S-SO4 was determined on the pulps by precipitation of BaSO4 according to Genalysis method number ENV_W039, after digestion with Na2CO3
- TOC+C (acid insoluble carbon compounds and elemental carbon) by a C&S analyser after removal of carbonates and soluble organic carbon using hot hydrochloric acid according to Genalysis method number MPL_W046.

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Results of analysis on:

sample		Fizz	volume	HCI	NaOH	Colour	pН	ANC	ANC
name		Rate	ml	М	М	Change	Drop	soln pH	(kgH2SO4/t)
GCA9728		0	8	0.558	0.188	Ν	Х	1.4	6
GCA9728	check	0	8	0.558	0.188	Ν	Х	1.3	5
GCA9729		0	8	0.558	0.188	Ν	Х	1.5	3
GCA9730		0	8	0.558	0.188	Ν	Х	1.3	2
GCA9731		0	8	0.558	0.188	Ν	Х	1.4	1
GCA9732		0	8	0.558	0.188	Ν	Х	1.4	5
GCA9733		0	8	0.558	0.188	Ν	Х	1.3	4

Notes:

- 1. ANC was determined on 2g of the crushings -. Acid concentrations are as stated.
- 2. Colour change: Y indicates the appearance of a green colouration as the pH=7 endpoint was approached. N indicates no colour change. Two drops of 30 % hydrogen peroxide are added to each sample as the endpoint is approached to oxidise any ferrous iron.
- 3. pH drop : Result reported when the pH drops to a value below 4 on addition of peroxide
- 4. This "Bulk-ANC" static-testing procedure is based on AMIRA (2002), according to Genalysis method number ENV_W035

Element		Ag	Al	As	В	Ba	Bi	Ca	Cd	Со	Cr
Method		4A/MS	FP1/OE	4A/MS	FP1/OE	4A/MS	4A/MS	FP1/OE	4A/MS	4A/MS	FP1/OE
Detection		0.01	0.01	0.5	50	0.1	0.01	0.1	0.02	0.1	50
Units		ppm	%	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm
Duplicates											
Sample Name											
Control Blank		0.01	Х	Х	Х	Х	0.02	Х	Х	Х	Х
GCA9728		0.09	2.78	9.7	Х	43.3	0.16	Х	0.05	3.7	Х
GCA9728	check	0.08	2.92	9.6	Х	43.9	0.14	Х	0.02	3.7	Х
GCA9729		0.1	3.05	11.9	Х	35.8	0.18	Х	Х	2	Х
GCA9730		0.12	2.81	15.6	Х	12.6	0.2	Х	0.02	2	Х
GCA9731		0.12	1.33	12.8	Х	11	0.22	Х	0.03	1.7	Х
GCA9732		0.09	3.41	24.1	Х	34.1	0.18	Х	0.12	3.5	Х
GCA9733		0.09	1.17	18.7	Х	6.2	0.2	Х	0.04	1.8	Х
AMIS0076		3.89		554.5		93.9	2.4		0.83	121.2	
STSD-2											
MPL-4			6.44		333			0.8			1649
HgSTD-4											
OREAS 97.01											
Control Blank			Х		Х			Х			Х
Control Blank											
Control Blank											
Acid Blank				Х		Х	Х		Х	Х	
Acid Blank			Х		Х			Х			Х
Control Blank											

Acid Blank

Element		Cu	F	Fe	Hg	K	Mg	Mn	Мо	Na	Ni
Method		4A/OE	FC7/SIE	FP1/OE	HG1/CV	FP1/OE	FP1/OE	4A/OE	4A/MS	4A/OE	4A/OE
Detection		1	50	0.01	0.01	0.05	0.01	1	0.1	20	1
Units		ppm	ppm	%	ppm	%	%	ppm	ppm	ppm	ppm
Duplicates											
Sample Name											
Control Blank		Х	54	0.03	Х	Х	Х	Х	Х	Х	Х
GCA9728		15	134	46.84	Х	Х	0.1	167	1.1	311	5
GCA9728	check	14	203	48.24	Х	0.19	0.11	162	1.1	281	3
GCA9729		7	179	51.62	Х	0.14	0.12	200	1.6	273	5
GCA9730		4	89	58.88	Х	0.06	0.09	116	2.7	102	2
GCA9731		2	72	63.48	0.02	Х	0.08	324	2.9	52	Х
GCA9732		9	179	49.81	0.66	0.08	0.14	165	2.3	63	19
GCA9733		12	82	60.28	0.1	0.08	0.08	115	2.4	22	3
AMIS0076		90						368	8.5	921	193
STSD-2			1062								
MPL-4				2.19		1.57	0.87				
HgSTD-4					0.34						
OREAS 97.01											
Control Blank				0.02			Х				
Control Blank					Х						
Control Blank											
Acid Blank		Х						Х	Х	Х	Х
Acid Blank				Х		Х	Х				
	-				-						
Element		Р	Pb	S	Sb	Se	Si	Sn	Sr	Th	TI
Method		4A/OE	4A/MS	4A/OE	4A/MS	SE1/MS	FP1/OE	4A/MS	4A/MS	4A/MS	4A/MS
Detection		50	0.5	50	0.05	0.01	0.1	0.1	0.05	0.01	0.02
Units		ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm
Duplicates											
Sample Name											
Control Blank		Х	Х	Х	Х	Х	Х	Х	Х	Х	0.07
GCA9728		411	8.1	158	1.22	0.8	11.4	0.9	4.52	5.25	0.09
GCA9728	check	378	7.2	170	1.13	0.37	11.8	0.8	4.63	5.06	0.05
GCA9729		449	8.3	176	1.24	0.72	8.7	1.2	8.42	4.79	0.13
GCA9730		567	7.8	105	1.7	0.37	3.3	1.7	3.83	3.83	0.06
GCA9731		711	5.9	142	1.88	0.35	1.7	1.9	2.88	2.35	0.05
GCA9732		896	11.8	59	2.21	0.19	6.5	1.7	7.44	3.92	0.11
GCA9733		1251	5	235	1.65	1.01	1.4	1.6	2.05	1.9	0.02
AMIS0076		170	670.4	22498	51.64			1.9	31.93	148.8	0.27
STSD-2											
MPL-4							32.3				
HgSTD-4											
OREAS 97.01						0.68					
Control Blank							Х				
Control Blank											
Control Blank						Х					
Acid Blank		Х	Х	Х	Х			Х	Х	0.02	0.03

Х

GLS Job Code 143.0/1107089

Element		U	V	Zn
Method		4A/MS	4A/OE	4A/OE
Detection		0.01	1	1
Units		ppm	ppm	ppm
Duplicates				
Sample Name				
Control Blank		Х	Х	Х
GCA9728		0.79	93	6
GCA9728	check	0.8	98	5
GCA9729		1.17	83	7
GCA9730		0.8	109	1
GCA9731		0.52	96	1
GCA9732		2.01	110	6
GCA9733		0.73	84	3
AMIS0076		1561.64	24	454
STSD-2				
MPL-4				
HgSTD-4				
OREAS 97.01				
Control Blank				
Control Blank				
Control Blank				
Acid Blank		0.04	Х	Х
Acid Blank				
Control Blank				

The results have been determined according to Genalysis methods codes: Digestions: MPL_W001 (4A/), 4 acid digest using HF MPL_W005 (SE1/) precipitation of Se from an aqua regia digest MPL_W011 (FP1/), peroxide fusion followed by HCl digest of melt ENV_W012 (FC7/SIE) Alkaline fusion in a nickel crucible Specific Ion Electrode using FC7/ digest solution MPL_W008 (HG1/) Low temperature Perchloric acid digest specific for Mercury. Analytical Finishes: ICP_W004 (/OE), ICP_W005 (/MS) and AAS_W004 (/CV). The results included the assay of blanks and international reference standards STSD-2 AMIS0076 Genalysis in-house standards MPL-4 HgSTD 4and OREAS 97.01 The results are expressed as parts per million by mass in the dried and prepared material.

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NATA Signatory: Ann Evers

Ann Evers

Date: 14/06/2011



This document is issued in accordance with

NATA accreditation requirements.

Laboratory Report pH-(1:2) & EC-(1:2) TESTWORK

SAMPLE NO.	SAMPLE WEIGHT (g)	SAMPLE + DEIONW WEIGHT (g)	pH-(1:2)	EC-(1:2) (μS/cm)
GCA9728	30.0	60.0	6.3	120
GCA9729	30.0	60.0	6.5	65
GCA9730	30.0	60.0	6.4	51
GCA9731	30.0	60.0	6.5	30
GCA9732	30.0	60.0	6.4	41
GCA9733	30.0	60.0	6.4	39
GCA9733-1	30.0	60.0	6.4	41

Note: EC = Electrical-Conductivity. Testwork performed on the as-supplied 'pulp' samples (nominal -75 μ m). pH-(1:2) and EC-(1:2) values correspond to pH and EC values of suspensions with a solid:solution ratio of *c*. 1:2 (w/w) pri-(1.2) and EC-(1.2) values correspond to pri and EC values of suspensions with a solution ratio prepared using deionised-water. Drift in pH-glass-electrode less than 0.1 pH unit between commencement, and completion, of testwork. Drift in EC-electrode less than 5 μ S/cm between commencement, and completion, of testwork. Testwork performed in a constant-temperature room (viz. 21 +/- 2-3 °C).

Dr GD Campbell 17th May 2011

Laboratory Report

NET-ACID-GENERATION (NAG) TESTWORK

Sample	Sample Weight	Comments	pH of Test Mixture	A	Test Mixture fter Boiling Step	Titre [0.1 M-	NAG (kg H ₂ SO ₄ /
Number	(g)		Before Boiling Step	pН	EC (µS/cm)	NaOH] (mL)	tonne)
GCA9728	3.0	Reaction peaked overnight	5.9	6.2	40	0.10	< 0.5
GCA9729	3.0	Reaction peaked overnight	5.8	6.1	37	0.20	<0.5
GCA9730	3.0	Reaction peaked overnight	5.5	5.7	24	0.20	<0.5
GCA9731	3.0	Reaction peaked overnight	5.3	5.5	18	0.20	<0.5
GCA9732	3.0	Reaction peaked overnight	5.8	6.2	22	0.10	<0.5
GCA9733	3.0	Reaction peaked overnight	5.3	5.5	16	0.20	<0.5
GCA9733-1	3.0	Reaction peaked overnight	5.3	5.5	16	0.20	< 0.5
BLANK4	3.0	Reaction peaked overnight	5.7	7.2	74	_	< 0.5

Notes: Test conditions based on those described by Miller *et al.* (1997), and AMIRA (2002) for the 'Static-NAG-Test' in its "Single-Additon-Mode". The pH of the 15 % (v/v) H₂O₂ solution was adjusted to 4.5 using 0.1 M-NaOH prior to commencing the NAG Tests. Following an overnight-reaction period, the test-mixtures were boiled for *c.* 2 hours. Then, after allowing the test-mixtures to cool, *c.* 1.0 mL of 0.016 M-CuSO₄ solution was added, and the test-mixtures again boiled for *c.* 2 hours. The addition of Cu(II) catalyses the decomposition of any residual, unreacted-H₂O₂ in the test-mixtures (McElnea and Ahern 2004; O'Shay *et al.* 1990). K-Feldspar was employed for the Blank.

Dr GD Campbell 12th June 2011

Graeme Campbell & Associates Pty Ltd Testing-Laboratory, Unit B, 15 Rose St. Bridgetown, WA 6255

KINETIC-TESTING WORKSHEET (WEATHERING-COLUMNS)

Job No: 1112

Client: Flinders-PIOP

	GCA9728
Column-Packing	
Wt Column-Only (kg)	0.32
Wt Column + Sample (kg)	1.82
Wt Sample (kg)	1.50

Pre-Rinse Cycle (Cycle-0)	GCA9728
Wt DW Added (kg)	1.00
Wt Leach. + Beaker (kg)	0.99
Wt Beaker (kg)	0.26
Wt Leachate (kg)	0.73
pH	6.8
EC (µS/cm)	150

	GCA9728
Weathering-Cycles	
Cycle No.	1
DAY-1 (i.e. Start-of-Day-1) [Monday]	
Lamps-On: Date	6/6/11
Lamps-On: Time	17:00
Wt Deionised-Water Added (kg)	1.00
(Lamps remain off)	
After-Flushing	
Wt Drained-Column(kg)	1.99
Gravimetric-Water-Content (%, w/w)	11.3
Wt Leachate + Beaker (kg)	0.92
Wt Beaker (kg)	0.26
Wt Leachate (kg)	0.66
Leachate-pH	7.0
Leachate-EC (uS/cm)	63

N.B. Approx. 2 weeks to complete draining.

	GCA9728
Weathering-Cycles	
Cycle No.	2
DAY-1 (i.e. Start-of-Day-1) [Monday]	
Lamps-On: Date	27/6/11
Lamps-On: Time	17:00
Wt Deionised-Water Added (kg)	1.00
(Lamps remain off)	
<u>After-Flushing</u>	
After-Flushing Wt Drained-Column(kg)	2.00
After-Flushing Wt Drained-Column(kg) Gravimetric-Water-Content (%, w/w)	2.00 12.0
After-Flushing Wt Drained-Column(kg) Gravimetric-Water-Content (%, w/w) Wt Leachate + Beaker (kg)	2.00 12.0 0.91
After-Flushing Wt Drained-Column(kg) Gravimetric-Water-Content (%, w/w) Wt Leachate + Beaker (kg) Wt Beaker (kg)	2.00 12.0 0.91 0.26
After-Flushing Wt Drained-Column(kg) Gravimetric-Water-Content (%, w/w) Wt Leachate + Beaker (kg) Wt Beaker (kg) Wt Leachate (kg)	2.00 12.0 0.91 0.26 0.65
After-FlushingWt Drained-Column(kg)Gravimetric-Water-Content (%, w/w)Wt Leachate + Beaker (kg)Wt Beaker (kg)Wt Leachate (kg)Leachate-pH	2.00 12.0 0.91 0.26 0.65 6.6

N.B. Approx. 2 weeks to complete draining.

	GCA9728
Weathering-Cycles	
Cycle No.	3
DAY-1 (i.e. Start-of-Day-1) [Monday]	
Lamps-On: Date	18/7/11
Lamps-On: Time	17:00
Wt Deionised-Water Added (kg)	1.00
(Lamps remain off)	
After-Flushing	
Wt Drained-Column(kg)	2.01
Gravimetric-Water-Content (%, w/w)	12.7
Wt Leachate + Beaker (kg)	0.92
Wt Beaker (kg)	0.26
	0.20
Wt Leachate (kg)	0.66
Wt Leachate (kg) Leachate-pH	0.66 7.0

N.B. Approx. 2 weeks to complete draining.

	GCA9728
Weathering-Cycles	
Cycle No.	4
DAY-1 (i.e. Start-of-Day-1) [Monday]	
Lamps-On: Date	8/08/11
Lamps-On: Time	17:00
Wt Deionised-Water Added (kg)	1.00
(Lamps remain off)	
After-Flushing	
After-Flushing Wt Drained-Column(kg)	1.97
After-Flushing Wt Drained-Column(kg) Gravimetric-Water-Content (%, w/w)	1.97 10.0
After-Flushing Wt Drained-Column(kg) Gravimetric-Water-Content (%, w/w) Wt Leachate + Beaker (kg)	1.97 10.0 0.90
After-Flushing Wt Drained-Column(kg) Gravimetric-Water-Content (%, w/w) Wt Leachate + Beaker (kg) Wt Beaker (kg)	1.97 10.0 0.90 0.26
After-Flushing Wt Drained-Column(kg) Gravimetric-Water-Content (%, w/w) Wt Leachate + Beaker (kg) Wt Beaker (kg) Wt Leachate (kg)	1.97 10.0 0.90 0.26 0.64
After-Flushing Wt Drained-Column(kg) Gravimetric-Water-Content (%, w/w) Wt Leachate + Beaker (kg) Wt Beaker (kg) Wt Leachate (kg) Leachate-pH	1.97 10.0 0.90 0.26 0.64 6.8

N.B. Approx. 2 weeks to complete draining.
	GCA9728
Weathering-Cycles	
Cycle No.	5
DAY-1 (i.e. Start-of-Day-1) [Monday]	
Lamps-On: Date	29/08/11
Lamps-On: Time	17:00
Wt Deionised-Water Added (kg)	1.00
(Lamps remain off)	
After-Flushing	
Wt Drained-Column(kg)	1.98
Gravimetric-Water-Content (%, w/w)	10.7
Gravimetric-Water-Content (%, w/w) Wt Leachate + Beaker (kg)	10.7 0.95
Gravimetric-Water-Content (%, w/w) Wt Leachate + Beaker (kg) Wt Beaker (kg)	10.7 0.95 0.26
Gravimetric-Water-Content (%, w/w) Wt Leachate + Beaker (kg) Wt Beaker (kg) Wt Leachate (kg)	10.7 0.95 0.26 0.69
Gravimetric-Water-Content (%, w/w) Wt Leachate + Beaker (kg) Wt Beaker (kg) Wt Leachate (kg) Leachate-pH	10.7 0.95 0.26 0.69 6.6

N.B. Approx. 2 weeks to complete draining.

KINETIC-TESTING WORKSHEET (WEATHERING-COLUMNS)

Job No: 1112

Client: Flinders-PIOP

	GCA9729
Column-Packing	
Wt Column-Only (kg)	0.32
Wt Column + Sample (kg)	1.82
Wt Sample (kg)	1.50

Pre-Rinse Cycle (Cycle-0)	GCA9729
Wt DW Added (kg)	1.00
Wt Leach. + Beaker (kg)	0.92
Wt Beaker (kg)	0.26
Wt Leachate (kg)	0.66
pH	6.2
EC (µS/cm)	250

N.B. No drainage obtained after approx. 5 weeks. Therefore column abandoned.

KINETIC-TESTING WORKSHEET (WEATHERING-COLUMNS)

Job No: 1112

Client: Flinders-PIOP

	GCA9730
Column-Packing	
Wt Column-Only (kg)	0.32
Wt Column + Sample (kg)	1.82
Wt Sample (kg)	1.50

Pre-Rinse Cycle (Cycle-0)	GCA9730
Wt DW Added (kg)	1.00
Wt Leach. + Beaker (kg)	1.00
Wt Beaker (kg)	0.26
Wt Leachate (kg)	0.74
pH	6.2
EC (µS/cm)	100

	GCA9730
Weathering-Cycles	
Cycle No.	1
DAY-1 (i.e. Start-of-Day-1) [Monday]	
Lamps-On: Date	6/6/11
Lamps-On: Time	17:00
Wt Deionised-Water Added (kg)	1.00
(Lamps remain off)	
After-Flushing	
Wt Drained-Column(kg)	1.99
Gravimetric-Water-Content (%, w/w)	11.3
Wt Leachate + Beaker (kg)	0.81
Wt Beaker (kg)	0.26
Wt Leachate (kg)	0.55
Leachate-pH	6.5
Leachate-EC (µS/cm)	63

N.B. Approx. 3 weeks for drainage to be completed for Cycle-1.

After completing the drying-phase for Cycle-2 and flushing, less than 100 mL of leachate was obtained in 8 weeks. This column was therefore abandoned.

KINETIC-TESTING WORKSHEET (WEATHERING-COLUMNS)

Job No: 1112

Client: Flinders-PIOP

	GCA9731
Column-Packing	
Wt Column-Only (kg)	0.32
Wt Column + Sample (kg)	1.82
Wt Sample (kg)	1.50

Pre-Rinse Cycle (Cycle-0)	GCA9731
Wt DW Added (kg)	1.00
Wt Leach. + Beaker (kg)	1.07
Wt Beaker (kg)	0.26
Wt Leachate (kg)	0.81
pH	5.7
EC (µS/cm)	79

	GCA9731	GCA9731	GCA9731
Weathering-Cycles			
Cycle No.	1	2	3
DAY-1 [Monday]			
Lamps-On: Date	6/6/11	13/6/11	20/6/11
Lamps-On: Time	17:00	17:00	17:00
DAY-2 [Tuesday]			
Time	09:00	09:00	09:00
Wt Column (kg)	1.86	1.93	1.94
Gravimetric-Water Content (%, w/w)	2.7	7.3	8.0
DAY-3 [Wednesday]			
Time	09.00	09.00	09.00
Wt Column (kg)	1.84	1.88	1.88
Gravimetric-Water Content (%, w/w)	1.3	4.0	4.0
DAY-4 [Thursday]			
Time	09:00	09:00	09:00
Wt Column (kg)	1.84	1.85	1.85
Gravimetric-Water Content (%, w/w)	1.3	2.0	2.0
DAY-5 [Friday]			
Time	09:00	09:00	09:00
Wt Column (kg)	1.83	1.84	1.84
Gravimetric-Water Content (%, w/w)	0.7	1.3	1.3
Wt Deionised-Water Added (kg)	1.00	1.00	1.00
(Lamps remain off)			
DAY-7 (end-of-Day-7) [Sunday]			
Wt Column(kg)	1.99	2.00	2.01
Gravimetric-Water Content (%, w/w)	11.3	12.0	12.7
Wt Beaker (kg)	0.26	0.26	0.26
Wt Leachate + Beaker (kg)	1.06	1.07	1.06
Wt Leachate (kg)	0.80	0.81	0.80
Leachate-pH	5.9	5.7	5.6
Leachate-EC (µS/cm)	25	18	12

	GCA9731	GCA9731	GCA9731
Weathering-Cycles			
Cycle No.	4	5	6
DAY-1 [Monday]			
Lamps-On: Date	27/6/11	4/7/11	11/7/11
Lamps-On: Time	17:00	17:00	17:00
DAY-2 [Tuesday]			
Time	09:00	09:00	09:00
Wt Column (kg)	1.94	1.95	1.94
Gravimetric-Water Content (%, w/w)	8.0	8.7	8.0
DAY-3 [Wednesday]			
Time	09.00	09.00	09.00
Wt Column (kg)	1.88	1.90	1.87
Gravimetric-Water Content (%, w/w)	4.0	5.3	3.3
DAY-4 [Thursday]			
Time	09:00	09:00	09:00
Wt Column (kg)	1.85	1.86	1.85
Gravimetric-Water Content (%, w/w)	2.0	2.7	2.0
DAY-5 [Friday]			
Time	09:00	09:00	09:00
Wt Column (kg)	1.84	1.84	1.83
Gravimetric-Water Content (%, w/w)	1.3	1.3	0.7
Wt Deionised-Water Added (kg)	1.00	1.00	1.00
(Lamps remain off)			
DAY-7 (end-of-Day-7) [Sunday]			
Wt Column(kg)	2.01	2.01	2.01
Gravimetric-Water Content (%, w/w)	12.7	12.7	12.7
Wt Beaker (kg)	0.26	0.26	0.26
Wt Leachate + Beaker (kg)	1.06	1.06	1.06
Wt Leachate (kg)	0.80	0.80	0.80
Leachate-pH	6.0	5.4	5.6
Leachate-EC (µS/cm)	16	8	9

KINETIC-TESTING WORKSHEET (WEATHERING-COLUMNS)

Job No: 1112

Client: Flinders-PIOP

	GCA9732
Column-Packing	
Wt Column-Only (kg)	0.32
Wt Column + Sample (kg)	1.82
Wt Sample (kg)	1.50

Pre-Rinse Cycle (Cycle-0)	GCA9732
Wt DW Added (kg)	1.00
Wt Leach. + Beaker (kg)	0.92
Wt Beaker (kg)	0.26
Wt Leachate (kg)	0.66
pH	6.5
EC (µS/cm)	210

	GCA9732	GCA9732	GCA9732
Weathering-Cycles			
Cycle No.	1	2	3
DAY-1 [Monday]			
Lamps-On: Date	6/6/11	13/6/11	4/7/11
Lamps-On: Time	17:00	17:00	17:00
DAY-2 [Tuesday]			
Time	09:00	09:00	09:00
Wt Column (kg)	2.02	2.04	2.03
Gravimetric-Water Content (%, w/w)	13.3	14.7	14.0
DAY-3 [Wednesday]			
Time	09.00	09.00	09.00
Wt Column (kg)	2.00	1.98	1.98
Gravimetric-Water Content (%, w/w)	12.0	10.7	10.7
DAY-4 [Thursday]			
Time	09:00 09:00		09:00
Wt Column (kg)	1.97	1.93	1.94
Gravimetric-Water Content (%, w/w)	10.0	7.3	8.0
DAY-5 [Friday]			
Time	09:00	09:00	09:00
Wt Column (kg)	1.94	1.90	1.90
Gravimetric-Water Content (%, w/w)	8.0	5.3	5.3
Wt Deionised-Water Added (kg)	1.00	1.00	1.00
(Lamps remain off)			
DAY-7 (end-of-Day-7) [Sunday]			
Wt Column(kg)	2.10	2.10	2.11
Gravimetric-Water Content (%, w/w)	18.7	18.7	19.3
Wt Beaker (kg)	0.26	0.26	0.26
Wt Leachate + Beaker (kg)	1.05	1.03	1.02
Wt Leachate (kg)	0.79	0.77	0.76
Leachate-pH	6.3	6.0	6.0
Leachate-EC (µS/cm)	26	21	15

	GCA9732	GCA9732	GCA9732
Weathering-Cycles			
Cycle No.	4	5	6
DAY-1 [Monday]			
Lamps-On: Date	11/7/11	18/7/11	25/7/11
Lamps-On: Time	17:00	17:00	17:00
DAY-2 [Tuesday]			
Time	09:00	09:00	09:00
Wt Column (kg)	2.06	2.06	2.10
Gravimetric-Water Content (%, w/w)	16.0	16.0	18.7
DAY-3 [Wednesday]			
Time	09.00	09.00	09.00
Wt Column (kg)	2.02	2.01	2.07
Gravimetric-Water Content (%, w/w)	13.3	12.7	16.7
DAY-4 [Thursday]			
Time	09:00 09:00		09:00
Wt Column (kg)	1.97	1.96	2.03
Gravimetric-Water Content (%, w/w)	10.0	9.3	14.0
DAY-5 [Friday]			
Time	09:00	09:00	09:00
Wt Column (kg)	1.93	1.92	1.98
Gravimetric-Water Content (%, w/w)	7.3	6.7	10.7
Wt Deionised-Water Added (kg)	1.00	1.00	1.00
(Lamps remain off)			
DAY-7 (end-of-Day-7) [Sunday]			
Wt Column(kg)	2.11	2.12	2.11
Gravimetric-Water Content (%, w/w)	19.3	20.0	19.3
Wt Beaker (kg)	0.26	0.26	0.26
Wt Leachate + Beaker (kg)	1.04	1.03	1.09
Wt Leachate (kg)	0.78	0.77	0.83
Leachate-pH	6.1	6.2	6.3
Leachate-EC (µS/cm)	14	12	11

KINETIC-TESTING WORKSHEET (WEATHERING-COLUMNS)

Job No: 1112

Client: Flinders-PIOP

	GCA9733
Column-Packing	
Wt Column-Only (kg)	0.32
Wt Column + Sample (kg)	1.82
Wt Sample (kg)	1.50

<u>Pre-Rinse Cycle (Cycle-0)</u>	GCA9733
Wt DW Added (kg)	1.00
Wt Leach. + Beaker (kg)	1.03
Wt Beaker (kg)	0.26
Wt Leachate (kg)	0.77
pH	6.2
EC (µS/cm)	130

	GCA9733	GCA9733	GCA9733
Weathering-Cycles			
Cycle No.	1	2	3
DAY-1 [Monday]			
Lamps-On: Date	6/6/11	13/6/11	20/6/11
Lamps-On: Time	17:00	17:00	17:00
DAY-2 [Tuesday]			
Time	09:00	09:00	09:00
Wt Column (kg)	1.93	1.97	1.99
Gravimetric-Water Content (%, w/w)	7.3	10.0	11.3
DAY-3 [Wednesday]			
Time	09.00	09.00	09.00
Wt Column (kg)	1.90	1.91	1.93
Gravimetric-Water Content (%, w/w)	5.3	6.0	7.3
DAY-4 [Thursday]			
Time	09:00	09:00	09:00
Wt Column (kg)	1.88	1.87	1.88
Gravimetric-Water Content (%, w/w)	4.0	3.3	4.0
DAY-5 [Friday]			
Time	09:00	09:00	09:00
Wt Column (kg)	1.86	1.86	1.86
Gravimetric-Water Content (%, w/w)	2.7	2.7	2.7
Wt Deionised-Water Added (kg)	1.00	1.00	1.00
(Lamps remain off)			
DAY-7 (end-of-Day-7) [Sunday]			
Wt Column(kg)	2.04	2.03	2.05
Gravimetric-Water Content (%, w/w)	14.7	14.0	15.3
Wt Beaker (kg)	0.26	0.26	0.26
Wt Leachate + Beaker (kg)	1.05	1.07	1.05
Wt Leachate (kg)	0.79	0.81	0.79
Leachate-pH	6.1	6.1	5.9
Leachate-EC (µS/cm)	32	35	24

	GCA9733	GCA9733	GCA9733
Weathering-Cycles			
Cycle No.	4	5	6
DAY-1 [Monday]			
Lamps-On: Date	27/6/11	4/7/11	11/7/11
Lamps-On: Time	17:00	17:00	17:00
DAY-2 [Tuesday]			
Time	09:00	09:00	09:00
Wt Column (kg)	1.99	2.02	1.99
Gravimetric-Water Content (%, w/w)	11.3	13.3	11.3
DAY-3 [Wednesday]			
Time	09.00	09.00	09.00
Wt Column (kg)	1.94	1.98	1.91
Gravimetric-Water Content (%, w/w)	8.0	10.7	6.0
DAY-4 [Thursday]			
Time	09:00	09:00	09:00
Wt Column (kg)	1.89	1.94	1.87
Gravimetric-Water Content (%, w/w)	4.7	8.0	3.3
DAY-5 [Friday]			
Time	09:00	09:00	09:00
Wt Column (kg)	1.87	1.90	1.85
Gravimetric-Water Content (%, w/w)	3.3	5.3	2.0
Wt Deionised-Water Added (kg)	1.00	1.00	1.00
(Lamps remain off)			
DAY-7 (end-of-Day-7) [Sunday]			
Wt Column(kg)	2.06	2.05	2.06
Gravimetric-Water Content (%, w/w)	16.0	15.3	16.0
Wt Beaker (kg)	0.26	0.26	0.26
Wt Leachate + Beaker (kg)	1.04	1.08	1.02
Wt Leachate (kg)	0.78	0.82	0.76
Leachate-pH	6.1	5.9	5.6
Leachate-EC (µS/cm)	17	18	15



Intertek

Dr G Campbell CAMPBELL, GRAEME and ASSOCIATES PTY LTD PO Box 247 BRIDGETOWN WA 6255

JOB INFORMATION

JOB CODE	143/1107725
No. of SAMPLES	11
CLIENT O/N	GCA 1112
PROJECT	Flinders PIOP
STATE	Column leachates
DATE RECEIVED	3/06/2011
DATE COMPLETED	30/06/2011

LEGEND

- X = Less than Detection Limit
- N/R = Sample Not Received
- = Result Checked
- () = Result still to come
- I/S = Insufficient Sample for Analysis
- E6 = Result X 1,000,000
- UA = Unable to Assay
- > = Value beyond Limit of Method

A set of leachates were received some of which (GCA9729-0, GCA9728-0 Raw and GCA9730-0 Raw) were turbid. These samples were centrifuged and filtered (0.45um filter) a split was then taken and dosed with HNO3

GCA9729-0 and GCA9728-0 were still coloured even after filtering through 0.1um filters and were not analysed for HCO3

The pH, EC and Cl of the "raw" sample was measured Genalysis method codes ENV-W001, ENV-W002, ENV_W013 and the alkalinity measured using APHA method code 2320B

APHA code refers to "Standard methods for the examination of water and wastewater", 21st Edition 2005

The HNO3 dosed filtered solution was analysed for the requested element suite (including S) by ICPMS and /or ICPOES: Genalysis method codes (ICP_W003, ICP_W004)

The charge balance was calculated and found to be within +/- 10% for sample GCA9730-0 only suggesting the presence of colloids in the filtered acidified samples

Results of analysis on:

Element		CI	EC	HCO3	pН
Method		/COL	/MTR	/VOL	/MTR
Detection		2	10	1	0.1
Units		mg/l	uS/cm	mgHCO3/L	NONE
Sample Name					
Control Blank					
GCA9728-0 Raw		6	119		7.5
GCA9728-0 Raw	check	6	114		7.6
GCA9729-0 Raw		15	183		7.6
GCA9730-0 Raw		10	91	17	7.3
GCA9731-0 Raw		5	69	14	6.4
GCA9732-0 Raw		11	183	39	6.8
GCA9733-0 Raw		7	109	19	6.7

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GLS Job Code 143.0/1107725

Element	Ag	AI	As	В	Ba	Bi	Са	Cd	Со
Method	/MS	/OE	/MS	/OE	/MS	/MS	/OE	/MS	/MS
Detection	0.01	0.01	0.1	0.01	0.05	0.005	0.01	0.02	0.1
Units	ug/l	mg/l	ug/l	mg/l	ug/l	ug/l	mg/l	ug/l	ug/l
Sample Name									
Control Blank	0.02	Х	Х	Х	0.06	Х	Х	Х	Х
GCA9728-0 HNO3	0.01	0.29	0.7	0.2	15.33	0.006	0.3	Х	0.2
GCA9729-0 HNO3	0.02	0.48	1.4	0.16	16.36	0.005	1.39	Х	0.4
GCA9730-0 HNO3	0.03	0.12	0.9	0.07	7.06	0.008	0.39	Х	Х
GCA9731-0 HNO3	0.01	Х	0.4	0.03	6.42	Х	1.32	0.07	0.2
GCA9732-0 HNO3	Х	0.02	0.8	0.02	23.57	Х	8.63	Х	Х
GCA9733-0 HNO3	0.05	Х	1.3	Х	7.54	0.02	4	Х	1
BLANK-0 HNO3	Х	Х	0.2	Х	0.11	Х	0.02	Х	Х
DW-0 HNO3	0.01	Х	0.1	Х	Х	0.006	Х	Х	0.4
Alcoa16-MS	4.94		25.6		5.99	4.768		4.95	584.5
Alcoa10-OES		1.82		1.12			49.64		
Element	Cr	Cu	Fe-Sol	Ha	к	Ma	Mn	Мо	Na
Method	/0F	/0F	/OF	/MS	/OF	/OF	/0F	/MS	/OF
Detection	0.01	0.01	0.01	0.1	0.1	0.01	0.01	0.05	0.1
Units	ma/l	ma/l	ma/l	ua/l	ma/l	ma/l	ma/l	ua/l	ma/l
Sample Name				- g, ·				4.g, 1	
Control Blank	Х	Х	Х	Х	Х	Х	Х	Х	Х
GCA9728-0 HNO3	X	X	0.23	Х	4.7	0.45	0.01	0.24	20.9
GCA9729-0 HNO3	X	X	0.25	X	4.7	2.25	0.03	0.25	33
GCA9730-0 HNO3	X	X	0.11	Х	2.5	0.31	X	0.07	16
GCA9731-0 HNO3	X	X	X	X	3.3	1.29	X	X	9.7
GCA9732-0 HNO3	Х	Х	Х	1.4	5.5	7.17	Х	0.06	14.4
GCA9733-0 HNO3	X	X	X	Х	5.4	4.23	X	0.1	7
BLANK-0 HNO3	Х	Х	Х	Х	0.2	Х	Х	Х	0.3
DW-0 HNO3	Х	Х	Х	Х	Х	0.02	Х	Х	Х
Alcoa16-MS				2.5				5.78	
Alcoa10-OES	0.49	0.25	1.99		3.9	57.61	0.49		233.3
		1				1	1		
Flement	Ni	Р	Ph	S	Sh	Se	Si	Sn	Sr
Method	/OF	/OF	/MS	/0F	/MS	/MS	/0F	/MS	/MS
Detection	0.01	0.1	0.5	0.1	0.01	0.5	0.05	0.1	0.02
Unite	ma/l	ma/l	U.0/	ma/l	U.0/I	U.0/	ma/l	U.0/I	U.02
Sample Name	iiig/i	iiig/i	ugn	iiig/i	ugn	ug/i	mg/i	ugn	ugn
Control Blank	Y	Y	Y	Y	Y	Y	Y	Y	0.08
	Y	Y	Y	31	20.0	07	12 1/	Y	2.00
GCA9729-0 HNIO3	× ×	× ×	07	6.2	0.00	1.2	21 03	× ×	17.24
GCA0730-0 UNIO2	× ×	× ×	0.7 V	3.1	0.07	1.5	0 11	× ×	2 02
00/01/00/01/000	^	^	^	5.1	0.05	1	3.11	~	2.30

GCA9728-0 HNO3	Х	Х	Х	3.4	0.06	0.7	12.14	Х	2.01
GCA9729-0 HNO3	Х	Х	0.7	6.2	0.07	1.3	21.03	Х	17.24
GCA9730-0 HNO3	Х	Х	Х	3.1	0.03	1	9.11	Х	2.93
GCA9731-0 HNO3	Х	Х	7.5	0.7	0.04	Х	5.43	Х	10.25
GCA9732-0 HNO3	Х	Х	3.5	3.1	0.03	0.7	12.93	Х	45
GCA9733-0 HNO3	Х	Х	1.8	0.7	0.07	0.5	3.6	Х	25.83
BLANK-0 HNO3	Х	Х	3.9	Х	0.01	Х	Х	Х	0.14
DW-0 HNO3	Х	Х	Х	Х	Х	Х	Х	Х	0.37
Alcoa16-MS			5.3		4.94	28.4		5.1	552.78
Alcoa10-OES	0.52	0.9		19.4			24.71		

Element	Th	TI	U	V	Zn
Method	/MS	/MS	/MS	/OE	/OE
Detection	0.005	0.01	0.005	0.01	0.01
Units	ug/l	ug/l	ug/l	mg/l	mg/l
Sample Name					
Control Blank	Х	Х	Х	Х	Х
GCA9728-0 HNO3	Х	Х	0.201	Х	0.02
GCA9729-0 HNO3	0.018	0.01	0.229	Х	0.01
GCA9730-0 HNO3	Х	Х	Х	Х	0.02
GCA9731-0 HNO3	Х	0.01	Х	Х	Х
GCA9732-0 HNO3	Х	0.01	0.013	Х	Х
GCA9733-0 HNO3	0.011	0.03	0.016	Х	Х
BLANK-0 HNO3	Х	Х	Х	Х	0.01
DW-0 HNO3	Х	Х	Х	Х	Х
Alcoa16-MS	5.187	4.73	5.481		
Alcoa10-OES				0.48	0.48

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NATA Signatory: Ann Evers

Ann Evers

Date: 30/06//2011







Dr G Campbell CAMPBELL, GRAEME and ASSOCIATES PTY LTD PO Box 247 BRIDGETOWN WA 6255

JOB INFORMATION

JOB CODE	143/1108764
No. of SAMPLES	7
CLIENT O/N	GCA 1112
PROJECT	Flinders PIOP
STATE	Column leachates
DATE RECEIVED	16/06/2011
DATE COMPLETED	13/07/2011

LEGEND

- X = Less than Detection Limit
- N/R = Sample Not Received
- = Result Checked
- () = Result still to come
- I/S = Insufficient Sample for Analysis
- E6 = Result X 1,000,000
- UA = Unable to Assay
- > = Value beyond Limit of Method

A series of column leachates were received. GCA9732 was received as a turbid column leachate, this sample was centrifuged and filtered (0.45um) a split was then taken and dosed with HNO3 The pH, EC and Cl of the "raw" sample was measured Genalysis method codes ENV-W001, ENV-W002,

ENV_W013 and the alkalinity measured using APHA method code 2320B

APHA code refers to "Standard methods for the examination of water and wastewater", 21st Edition 2005

The HNO3 dosed filtered solution was analysed for the requested element suite (including S) by ICPMS and /or ICPOES: Genalysis method codes (ICP_W003, ICP_W004)

The charge balance was calculated and found to be within +/- 10%

Results of analysis on:

Element		CI	EC	HCO3	рН
Method		/COL	/MTR	/VOL	/MTR
Detection		2	10	1	0.1
Units		mg/l	uS/cm	mgHCO3/L	NONE
Sample Name					
Control Blank		Х			
GCA9731-1 Raw		2	22	6	6.3
GCA9731-1 Raw	check	2	22	6	6.3
GCA9732-1 Raw		2	26	6	6.9
GCA9733-1 Raw		3	31	4	6.3

Element	Ag	AI	As	В	Ва	Bi	Ca	Cd	Co
Method	/MS	/OE	/MS	/OE	/MS	/MS	/OE	/MS	/MS
Detection	0.01	0.01	0.1	0.01	0.05	0.005	0.01	0.02	0.1
Units	ug/l	mg/l	ug/l	mg/l	ug/l	ug/l	mg/l	ug/l	ug/l
Sample Name									
Control Blank	Х	Х	Х	0.01	0.09	Х	Х	Х	Х
GCA9731-1 HNO3	Х	Х	0.3	0.01	1.65	Х	0.26	Х	Х
GCA9732-1 HNO3	Х	0.26	0.1	Х	103.05	Х	0.74	Х	Х
GCA9733-1 HNO3	Х	Х	1.1	Х	2.06	Х	1.06	Х	0.1
Blank-1 HNO3	Х	0.02	Х	Х	0.28	Х	Х	Х	Х
DW-1 HNO3	Х	Х	Х	0.01	Х	Х	Х	Х	Х
Alcoa16-MS	5.29		25.8		6.15	4.904		5.08	504.3
Alcoa10-OES		1.83		1.08			48.68		

Element	Cr	Cu	Fe-Sol	Hg	К	Mg	Mn	Мо	Na
Method	/OE	/OE	/OE	/MS	/OE	/OE	/OE	/MS	/OE
Detection	0.01	0.01	0.01	0.1	0.1	0.01	0.01	0.05	0.1
Units	mg/l	mg/l	mg/l	ug/l	mg/l	mg/l	mg/l	ug/l	mg/l
Sample Name									
Control Blank	Х	Х	Х	Х	Х	Х	Х	Х	Х
GCA9731-1 HNO3	Х	Х	Х	0.6	1.3	0.23	Х	Х	3.2
GCA9732-1 HNO3	Х	Х	0.22	Х	1.1	0.53	Х	0.07	3.1
GCA9733-1 HNO3	Х	Х	Х	Х	1.3	1.3	Х	0.05	1.6
Blank-1 HNO3	Х	Х	Х	Х	Х	Х	Х	Х	0.1
DW-1 HNO3	Х	Х	Х	Х	Х	0.02	Х	Х	Х
Alcoa16-MS				2.5				5.78	
Alcoa10-OES	0.48	0.24	1.95		3.7	56.68	0.48		234.8

Element	Ni	Р	Pb	S	Sb	Se	Si	Sn	Sr
Method	/OE	/OE	/MS	/OE	/MS	/MS	/OE	/MS	/MS
Detection	0.01	0.1	0.5	0.1	0.01	0.5	0.05	0.1	0.02
Units	mg/l	mg/l	ug/l	mg/l	ug/l	ug/l	mg/l	ug/l	ug/l
Sample Name									
Control Blank	Х	Х	Х	Х	Х	Х	Х	Х	0.03
GCA9731-1 HNO3	Х	Х	Х	0.8	0.03	Х	5.18	Х	2.08
GCA9732-1 HNO3	Х	Х	Х	1	0.09	Х	10.7	Х	4.24
GCA9733-1 HNO3	Х	Х	0.8	1.2	0.03	Х	4.44	Х	6.25
Blank-1 HNO3	Х	Х	Х	Х	0.01	Х	0.05	Х	0.07
DW-1 HNO3	Х	Х	Х	Х	Х	Х	Х	Х	Х
Alcoa16-MS			6		5.36	25.8		5.9	600.62
Alcoa10-OES	0.52	0.9		18.9			26.71		

Element	Th	TI	U	V	Zn
Method	/MS	/MS	/MS	/OE	/OE
Detection	0.005	0.01	0.005	0.01	0.01
Units	ug/l	ug/l	ug/l	mg/l	mg/l
Sample Name					
Control Blank	Х	Х	Х	Х	Х
GCA9731-1 HNO3	Х	Х	Х	Х	Х
GCA9732-1 HNO3	Х	Х	0.007	Х	0.01
GCA9733-1 HNO3	Х	Х	Х	Х	Х
Blank-1 HNO3	Х	Х	Х	Х	Х
DW-1 HNO3	Х	Х	Х	Х	Х
Alcoa16-MS	5.179	4.92	5.376		
Alcoa10-OES				0.48	0.45

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NATA Signatory: Ann Evers

Ann Evers

Date: 13/07//2011





Intertek

Dr G Campbell CAMPBELL, GRAEME and ASSOCIATES PTY LTD PO Box 247 BRIDGETOWN WA 6255

JOB INFORMATION

JOB CODE	143/1111216
No. of SAMPLES	32
CLIENT O/N	GCA 1112
PROJECT	Flinders PIOP
STATE	Column leachates
DATE RECEIVED	27/07/2011
DATE COMPLETED	17/08/2011

LEGEND

- X = Less than Detection Limit
- N/R = Sample Not Received
- = Result Checked
- () = Result still to come
- I/S = Insufficient Sample for Analysis
- E6 = Result X 1,000,000
- UA = Unable to Assay
- > = Value beyond Limit of Method

A series of column leachates were received, some were slurries. These samples were centrifuged and filtered (0.45um) a split was then taken and dosed with HNO3

The pH and EC of each "raw" sample was measured Genalysis method codes ENV-W001, ENV-W002 and the alkalinity measured using APHA method code 2320B

APHA code refers to "Standard methods for the examination of water and wastewater", 21st Edition 2005 Due to the brown colour of some of the filtered raw samples the alkalinity was not measured (NA) The HNO3 dosed filtered solution was analysed for the requested element suite (including S) by ICPMS and /or ICPOES: Genalysis method codes (ICP_W003, ICP_W004).The charge balance was calculated as requested but due to the low TDS was not generally found to be within +/- 10%

Results of analysis on:

Element		CI	EC	HCO3	pН
Method		/COL	/MTR	/VOL	/MTR
Detection		2	10	1	0.1
Units		mg/l	uS/cm	mgHCO3/L	NONE
Sample Name					
Control Blank		Х			
GCA9728-1 Raw		Х	50	NA	6.8
GCA9728-1 Raw	check	Х	47	NA	6.8
GCA9728-2 Raw		Х	40	NA	6.8
GCA9730-1 Raw		4	49	7	6.6
GCA9731-2 Raw		Х	28	Х	4.4
GCA9731-3 Raw		Х	10	4	6.1
GCA9731-4 Raw		Х	Х	4	6.4
GCA9731-5 Raw		Х	Х	4	6.3
GCA9731-6 Raw		Х	Х	4	6.3
GCA9732-2 Raw		Х	18	7	6.6
GCA9732-3 Raw		Х	24	8	6.8
GCA9732-4 Raw		Х	13	6	6.5
GCA9733-2 Raw		Х	30	5	6.4
GCA9733-3 Raw		Х	21	4	6.3
GCA9733-4 Raw		Х	16	4	6.3
GCA9733-5 Raw		Х	15	4	6.4
GCA9733-6 Raw		Х	12	4	6.4

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Element		Ag	Al	As	В	Ba	Bi	Ca	Cd
Method		/MS	/OE	/MS	/OE	/MS	/MS	/OE	/MS
Detection		0.01	0.01	0.1	0.01	0.05	0.005	0.01	0.02
Units		ug/l	mg/l	ug/l	mg/l	ug/l	ug/l	mg/l	ug/l
Sample Name									
Control Blank		Х	0.01	Х	0.01	Х	Х	Х	Х
GCA9728-1 HNO3		0.03	0.7	0.4	0.16	9.93	Х	0.4	Х
GCA9728-2 HNO3		Х	0.68	0.5	0.1	8.18	Х	0.29	Х
GCA9730-1 HNO3		Х	0.32	Х	0.07	3.54	Х	0.59	Х
GCA9731-2 HNO3		Х	0.19	0.2	0.04	9	0.007	0.35	Х
GCA9731-3 HNO3		Х	0.25	0.2	0.04	3.59	Х	0.15	Х
GCA9731-3 HNO3	check	0.01	0.24	0.1	0.01	3.65	Х	0.16	Х
GCA9731-4 HNO3		Х	0.18	Х	0.03	2.07	Х	0.11	Х
GCA9731-5 HNO3		Х	0.2	Х	0.04	12.87	Х	0.1	Х
GCA9731-6 HNO3		Х	0.24	Х	0.03	6.44	Х	0.12	Х
GCA9732-2 HNO3		Х	0.2	Х	0.03	6.11	Х	0.45	Х
GCA9732-3 HNO3		Х	0.26	Х	Х	4.19	Х	0.67	Х
GCA9732-4 HNO3		0.01	0.36	Х	Х	10.19	Х	0.65	Х
GCA9733-2 HNO3		Х	0.09	0.4	0.02	1.52	Х	1.01	Х
GCA9733-3 HNO3		Х	0.03	0.2	0.06	1.95	Х	0.74	Х
GCA9733-4 HNO3		Х	0.04	Х	Х	0.83	Х	0.58	Х
GCA9733-5 HNO3		0.06	0.22	0.1	0.04	10.99	Х	0.61	Х
GCA9733-6 HNO3		Х	0.2	Х	0.03	17.09	Х	0.52	Х
Alcoa17-MS		5.21		28.1		5.43	4.748		5.15
Alcoa10-OES			1.85		1.14			50.15	

Element		Со	Cr	Cu	Fe-Sol	Hg	K	Mg	Mn
Method		/MS	/OE	/OE	/OE	/MS	/OE	/OE	/OE
Detection		0.1	0.01	0.01	0.01	0.1	0.1	0.01	0.01
Units		ug/l	mg/l	mg/l	mg/l	ug/l	mg/l	mg/l	mg/l
Sample Name									
Control Blank		Х	Х	Х	Х	Х	Х	Х	Х
GCA9728-1 HNO3		0.3	Х	Х	0.31	0.3	2.5	0.75	Х
GCA9728-2 HNO3		0.2	Х	Х	0.24	Х	2.1	0.69	Х
GCA9730-1 HNO3		Х	Х	Х	0.18	Х	1.6	0.67	Х
GCA9731-2 HNO3		Х	Х	Х	0.21	0.3	1	0.25	Х
GCA9731-3 HNO3		Х	Х	Х	0.23	0.3	0.8	0.16	Х
GCA9731-3 HNO3	check	0.1	Х	0.01	0.2	0.1	0.9	0.17	Х
GCA9731-4 HNO3		Х	Х	Х	0.16	0.2	0.6	0.12	Х
GCA9731-5 HNO3		Х	Х	Х	0.18	0.2	0.5	0.12	Х
GCA9731-6 HNO3		Х	Х	Х	0.24	0.2	0.8	0.1	Х
GCA9732-2 HNO3		Х	Х	Х	0.25	0.2	1	0.42	Х
GCA9732-3 HNO3		Х	Х	Х	0.25	0.2	1.4	0.6	Х
GCA9732-4 HNO3		0.1	Х	Х	0.25	0.2	0.9	0.5	Х
GCA9733-2 HNO3		Х	Х	Х	0.04	0.2	1.3	1.29	Х
GCA9733-3 HNO3		Х	Х	Х	0.03	0.1	1.1	0.85	Х
GCA9733-4 HNO3		Х	Х	Х	0.04	0.2	0.8	0.71	Х
GCA9733-5 HNO3		Х	Х	Х	0.21	0.3	0.9	0.82	Х
GCA9733-6 HNO3		Х	Х	Х	0.15	0.2	0.6	0.64	Х
Alcoa17-MS		531.3				5.4			
Alcoa10-OES			0.5	0.25	2		3.9	59.25	0.49

Element		Мо	Na	Ni	Р	Pb	S	Sb	Se
Method		/MS	/OE	/OE	/OE	/MS	/OE	/MS	/MS
Detection		0.05	0.1	0.01	0.1	0.5	0.1	0.01	0.5
Units		ug/l	mg/l	mg/l	mg/l	ug/l	mg/l	ug/l	ug/l
Sample Name									
Control Blank		Х	Х	Х	Х	Х	Х	Х	Х
GCA9728-1 HNO3		0.27	10.1	Х	Х	2	0.6	0.06	Х
GCA9728-2 HNO3		0.12	7.9	Х	Х	1.3	0.3	0.04	Х
GCA9730-1 HNO3		Х	8.7	0.02	Х	0.9	1.9	Х	0.7
GCA9731-2 HNO3		Х	2	Х	Х	1.1	0.9	0.08	Х
GCA9731-3 HNO3		Х	1.3	0.01	Х	Х	0.3	0.03	Х
GCA9731-3 HNO3	check	Х	1.2	Х	Х	Х	0.7	0.03	Х
GCA9731-4 HNO3		Х	1.1	Х	Х	Х	0.4	0.04	Х
GCA9731-5 HNO3		Х	0.8	Х	Х	Х	Х	Х	Х
GCA9731-6 HNO3		Х	0.8	Х	Х	Х	0.1	Х	Х
GCA9732-2 HNO3		Х	2.1	0.01	Х	Х	0.4	0.05	Х
GCA9732-3 HNO3		Х	2.3	Х	Х	1	0.6	0.01	Х
GCA9732-4 HNO3		Х	1.5	Х	Х	Х	0.2	0.01	Х
GCA9733-2 HNO3		Х	1.2	Х	Х	Х	1.8	0.01	0.5
GCA9733-3 HNO3		Х	0.7	Х	Х	2.4	1.2	0.02	Х
GCA9733-4 HNO3		Х	0.5	Х	Х	0.9	0.8	Х	Х
GCA9733-5 HNO3		Х	0.6	Х	Х	0.7	0.8	Х	Х
GCA9733-6 HNO3		Х	0.5	Х	Х	Х	0.6	Х	Х
Alcoa17-MS		5.54				4.9		5.22	27.7
Alcoa10-OES			241.2	0.55	1		21.2		

Element		Si	Sn	Sr	Th	TI	U	V	Zn
Method		/OE	/MS	/MS	/MS	/MS	/MS	/OE	/OE
Detection		0.05	0.1	0.02	0.005	0.01	0.005	0.01	0.01
Units		mg/l	ug/l	ug/l	ug/l	ug/l	ug/l	mg/l	mg/l
Sample Name									
Control Blank		Х		0.02	Х	Х	Х	Х	Х
GCA9728-1 HNO3		15.65	0.1	2.77	0.009	Х	0.283	Х	Х
GCA9728-2 HNO3		15.41	Х	2.17	0.009	Х	0.201	Х	Х
GCA9730-1 HNO3		13.99	Х	5.91	Х	Х	0.025	Х	Х
GCA9731-2 HNO3		8.37	0.1	2.26	Х	Х	Х	Х	Х
GCA9731-3 HNO3		7.75	Х	1.42	Х	Х	0.007	Х	Х
GCA9731-3 HNO3	check	7.77	Х	1.41	Х	Х	0.008	Х	Х
GCA9731-4 HNO3		5.59	Х	0.82	Х	Х	Х	Х	Х
GCA9731-5 HNO3		4.84	Х	0.85	Х	Х	Х	Х	Х
GCA9731-6 HNO3		5.58	Х	0.98	Х	Х	Х	Х	Х
GCA9732-2 HNO3		11.94	Х	2.4	Х	Х	Х	Х	Х
GCA9732-3 HNO3		13.87	Х	3.63	Х	Х	0.016	Х	Х
GCA9732-4 HNO3		9.34	Х	3.38	Х	Х	0.034	Х	0.02
GCA9733-2 HNO3		7.8	Х	6.56	Х	Х	Х	Х	0.02
GCA9733-3 HNO3		7.59	Х	4.65	Х	Х	Х	Х	0.02
GCA9733-4 HNO3		5	Х	3.15	Х	Х	0.012	Х	0.01
GCA9733-5 HNO3		6.54	Х	3.44	Х	Х	Х	Х	Х
GCA9733-6 HNO3		6.1	Х	3.17	Х	Х	Х	Х	Х
Alcoa17-MS			5.2	536.44	5.381	4.52	4.887		
Alcoa10-OES		27.35						0.48	0.52

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NATA Signatory: Ann Evers

Ann Evers

Date: 17/08//2011







Dr G Campbell CAMPBELL, GRAEME and ASSOCIATES PTY LTD PO Box 247 BRIDGETOWN WA 6255

JOB INFORMATION

JOB CODE	143/1111961
No. of SAMPLES	4
CLIENT O/N	GCA 1112
PROJECT	Flinders PIOP
STATE	Column leachates
DATE RECEIVED	10/08/2011
DATE COMPLETED	31/08/2011

LEGEND

- X = Less than Detection Limit
- N/R = Sample Not Received
- = Result Checked
- () = Result still to come
- I/S = Insufficient Sample for Analysis
- E6 = Result X 1,000,000
- UA = Unable to Assay
- > = Value beyond Limit of Method

A series of column leachates were received, some were slurries. These samples were centrifuged and filtered (0.45um) a split was then taken and dosed with HNO3.

The pH, EC and Cl of each "raw" sample was measured using Genalysis method codes: ENV-W001, ENV-W002, ENV_W013 and the alkalinity measured using APHA method code 2320B *APHA code refers to "Standard methods for the examination of water and wastewater"*, 21st Edition 2005

The HNO3 dosed filtered solution was analysed for the requested element suite (including S) by ICPMS and /or ICPOES: Genalysis method codes (ICP_W003, ICP_W004). The charge balance was calculated as requested and found to be within +/- 10%

Element		CI	EC	HCO3	pН
Method		/COL	/MTR	/VOL	/MTR
Detection		2	10	1	0.1
Units		mg/l	uS/cm	mgHCO3/L	NONE
Sample Name					
Control Blank		Х			
GCA9732-5 Raw		2	12	6	6.7
GCA9732-5 Raw	check	2	12	6	6.7
GCA9732-6 Raw		Х	11	5	6.6
N191		98			

Results of analysis on:

Element	Ag	AI	As	В	Ва	Bi	Ca	Cd
Method	/MS	/OE	/MS	/OE	/MS	/MS	/OE	/MS
Detection	0.01	0.01	0.1	0.01	0.05	0.005	0.01	0.02
Units	ug/l	mg/l	ug/l	mg/l	ug/l	ug/l	mg/l	ug/l
Sample Name								
Control Blank	Х	Х	х	Х	х	х	Х	х
GCA9732-5 HNO3	0.78	0.27	х	0.06	78.82	х	0.32	х
GCA9732-6 HNO3	0.18	0.21	Х	0.05	23.36	Х	0.24	х
Alcoa17-MS	5.06		27.2		5.99	4.634		5.53
Alcoa11-OES		2.04		0.96			50.52	
Element	Co	Cr	Cu	Fe-Sol	Hg	К	Mg	Mn
Method	/MS	/OE	/OE	/OE	/MS	/OE	/OE	/OE
Detection		0.04	0.04	0.04	0.4	0.4	0.04	0.04

Method	/1010	/UE	/UE	/OE	/1013	/UE	/UE	/UE
Detection	0.1	0.01	0.01	0.01	0.1	0.1	0.01	0.01
Units	ug/l	mg/l	mg/l	mg/l	ug/l	mg/l	mg/l	mg/l
Sample Name								
Control Blank	0.1	Х	Х	Х	Х	Х	Х	Х
GCA9732-5 HNO3	Х	Х	Х	0.29	0.1	0.8	0.31	Х
GCA9732-6 HNO3	Х	Х	Х	0.23	Х	1	0.24	Х
Alcoa17-MS	559.1				5.6			
Alcoa11-OES		0.52	0.51	2.09		3.8	49.86	0.51

Element	Мо	Na	Ni	Р	Pb	S	Sb	Se
Method	/MS	/OE	/OE	/OE	/MS	/OE	/MS	/MS
Detection	0.05	0.1	0.01	0.1	0.5	0.1	0.01	0.5
Units	ug/l	mg/l	mg/l	mg/l	ug/l	mg/l	ug/l	ug/l
Sample Name								
Control Blank	Х	0.3	0.01	Х	Х	Х	Х	х
GCA9732-5 HNO3	0.08	1.5	х	х	0.9	х	0.02	х
GCA9732-6 HNO3	0.12	1.3	0.02	х	х	0.2	0.03	х
Alcoa17-MS	5.58				5.5		5.68	28
Alcoa11-OES		243.9	0.51	0.9		16.5		

Element	Si	Sn	Sr	Th	TI	U	V	Zn
Method	/OE	/MS	/MS	/MS	/MS	/MS	/OE	/OE
Detection	0.05	0.1	0.02	0.005	0.01	0.005	0.01	0.01
Units	mg/l	ug/l	ug/l	ug/l	ug/l	ug/l	mg/l	mg/l
Sample Name								
Control Blank	Х	Х	Х	Х	Х	Х	Х	Х
GCA9732-5 HNO3	10.17	х	2.01	Х	х	0.009	х	х
GCA9732-6 HNO3	10.77	х	1.61	Х	х	0.009	Х	х
Alcoa17-MS		5.5	549.69	5.25	5.05	5.114		
Alcoa11-OES	17.82						0.53	0.49

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NATA Signatory: Ann Evers

Ann Evers

Date: 31/08//2011







Dr G Campbell CAMPBELL, GRAEME and ASSOCIATES PTY LTD PO Box 247 BRIDGETOWN WA 6255

JOB INFORMATION

JOB CODE	143/1113002
No. of SAMPLES	1
CLIENT O/N	GCA 1112
PROJECT	Flinders PIOP
STATE	Column leachate/slurry
DATE RECEIVED	23/08/2011
DATE COMPLETED	23/09/2011

LEGEND

- X = Less than Detection Limit
- N/R = Sample Not Received
- = Result Checked
- () = Result still to come
- I/S = Insufficient Sample for Analysis
- E6 = Result X 1,000,000
- UA = Unable to Assay
- > = Value beyond Limit of Method

A column leachate was received as slurry. The sample was centrifuged and filtered (0.45um) a split was then taken and dosed with HNO3

The pH, EC and Cl of the %aw+samples was measured Genalysis method codes ENV-W001, ENV-W002 and ENV_W013

Due to the brown colour of the filtered raw samples the alkalinity was not measured

The HNO3 dosed filtered solution was analysed for the requested element suite by ICPMS and /or ICPOES: Genalysis method codes (ICP_W003, ICP_W004)

Results of analysis on:

Element		Cl	EC	рΗ
Method		/COL	/MTR	/MTR
Detection		2	10	0.1
Units		mg/l	uS/cm	NONE
Sample Name				
Control Blank		Х		
GCA9728-3 Raw		Х	37	7.3
GCA9728-3 Raw	check	Х	38	7.3
N191		97		

GLS Job Code 143.0/1113002

Element	Ag	Al	As	В	Ва	Bi	Ca	Cd
Method	/MS	/OE	/MS	/OE	/MS	/MS	/OE	/MS
Detection	0.01	0.01	0.1	0.01	0.05	0.005	0.01	0.02
Units	ug/l	mg/l	ug/l	mg/l	ug/l	ug/l	mg/l	ug/l
Sample Name		-	-		-	-		
Control Blank	Х	Х	0.1	Х	0.07	Х	Х	Х
GCA9728-3 HNO3	Х	0.49	0.6	0.1	7.19	Х	0.26	0.1
Alcoa11-OES		1.94		0.99			48.91	
AlcoaHi3-OES		47.5		19.74			951.67	
Alcoa-High4-MS	20.52		107.2		20.99	20.446		21.52
Element	Со	Cr	Cu	Fe-Sol	Hg	K	Mg	Mn
Method	/MS	/OE	/OE	/OE	/MS	/OE	/OE	/OE
Detection	0.1	0.01	0.01	0.01	0.1	0.1	0.01	0.01
Units	ug/l	mg/l	mg/l	mg/l	ug/l	mg/l	mg/l	mg/l
Sample Name								
Control Blank	0.2	Х	Х	Х	Х	0.3	Х	Х
GCA9728-3 HNO3	Х	Х	Х	0.23	Х	2.3	0.51	Х
Alcoa11-OES		0.5	0.52	2.03		3.8	48.67	0.49
AlcoaHi3-OES		19.61	2.61	93.86		476.8	201.92	19.27
Alcoa-High4-MS	984.1				21.2			
Element	Мо	Na	Ni	Р	Pb	S	Sb	Se
Method	/MS	/OE	/OE	/OE	/MS	/OE	/MS	/MS
Detection	0.05	0.1	0.01	0.1	0.5	0.1	0.01	0.5
Units	ug/l	mg/l	mg/l	mg/l	ug/l	mg/l	ug/l	ug/l
Sample Name								
Control Blank	Х	Х	Х	Х	Х	Х	Х	Х
GCA9728-3 HNO3	0.52	8.5	0.02	Х	2.2	0.2	0.07	Х
Alcoa11-OES		245.4	0.5	0.9		16.7		
AlcoaHi3-OES		1958.7	19.68	47.6		261.4		
Alcoa-High4-MS	20.89				21		22.64	104.9
Element	Si	Sn	Sr	Th	TI	U	V	Zn
Method	/OE	/MS	/MS	/MS	/MS	/MS	/OE	/OE
Detection	0.05	0.1	0.02	0.005	0.01	0.005	0.01	0.01
Units	mg/l	ug/l	ug/l	ug/l	ug/l	ug/l	mg/l	mg/l
Sample Name								
Control Blank	Х	Х	Х	Х	Х	Х	Х	Х
GCA9728-3 HNO3	14.74	Х	1.97	0.029	Х	0.206	Х	0.31
Alcoa11-OES	17.98						0.52	0.5
AlcoaHi3-OES	100.87						20.16	19.97
Alcoa-High4-MS		22.1	1041.81	22.237	20.58	22.874		

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NATA Signatory: Ann Evers

Ann Evers

Date: 23/09//2011







Dr G Campbell CAMPBELL, GRAEME and ASSOCIATES PTY LTD PO Box 247 BRIDGETOWN WA 6255

JOB INFORMATION

JOB CODE	143/1114205
No. of SAMPLES	1
CLIENT O/N	GCA 1112
PROJECT	Flinders PIOP
STATE	Column leachate/slurry
DATE RECEIVED	16/09/2011
DATE COMPLETED	3/10/2011

LEGEND

- X = Less than Detection Limit
- N/R = Sample Not Received
- = Result Checked
- () = Result still to come
- I/S = Insufficient Sample for Analysis
- E6 = Result X 1,000,000
- UA = Unable to Assay
- > = Value beyond Limit of Method

The column leachates were received as slurries. The samples were centrifuged and filtered (0.45um) a split was then taken and dosed with HNO3

The pH, EC and Cl of the %aw+samples was measured Genalysis method codes ENV-W001, ENV-W002 and ENV_W013

Due to the brown colour of the filtered raw samples the alkalinity was not measured

The HNO3 dosed filtered solution was analysed for the requested element suite by ICPMS and /or ICPOES: Genalysis method codes (ICP_W003, ICP_W004)

Results of analysis on:

Element		Cl	EC	рН
Method		/COL	/MTR	/MTR
Detection		2	10	0.1
Units		mg/l	uS/cm	NONE
Sample Name				
Control Blank				
GCA9728-4 Raw		Х	36	7.2
GCA9728-4 Raw	check	Х	36	7.2
GCA9728-5 Raw		Х	30	7.2
N191		97		

GLS Job Code 143.0/1114205

Element	Ag	Al	As	В	Ва	Bi	Ca	Cd	Со
Method	/MS	/OE	/MS	/OE	/MS	/MS	/OE	/MS	/MS
Detection	0.01	0.01	0.1	0.01	0.05	0.005	0.01	0.02	0.1
Units	ug/l	mg/l	ug/l	mg/l	ug/l	ug/l	mg/l	ug/l	ug/l
Sample Name									
Control Blank	Х	0.03	Х	Х	Х	Х	Х	Х	Х
GCA9728-4 HNO3	Х	0.49	0.7	0.12	9.02	Х	0.28	Х	0.2
GCA9728-5 HNO3	0.17	0.28	1.7	0.1	5.46	0.162	0.21	0.18	8.6
Alcoa17-MS	5.19		25		6.11	4.554		5.59	540.1
Alcoa11-OES		1.98		1.03			52.27		
Alcoa-High4-MS	20.62		102.3		20.47	18.514		20.8	1073.1
AlcoaHi3-OES		50.25		19.81			998.93		
		1	1	r	1	1	1	-	1
Element	Cr	Cu	Fe	Hg	К	Mg	Mn	Mo	Na
Method	/OE	/OE	/OE	/MS	/OE	/OE	/OE	/MS	/OE
Detection	0.01	0.01	0.01	0.1	0.1	0.01	0.01	0.05	0.1
Units	mg/l	mg/l	mg/l	ug/l	mg/l	mg/l	mg/l	ug/l	mg/l
Sample Name									
Control Blank	Х	Х	Х	0.1	Х	0.01	Х	Х	Х
GCA9728-4 HNO3	Х	Х	0.08	0.2	1.9	0.46	Х	0.41	8.1
GCA9728-5 HNO3	Х	0.01	0.05	0.5	1.7	0.36	Х	0.52	8
Alcoa17-MS				5.4				5.48	
Alcoa11-OES	0.54	0.55	2		4.2	52.06	0.55		261.1
Alcoa-High4-MS				20.5				20.78	
AlcoaHi3-OES	20.53	2.76	101.54		505.9	213.49	20.61		2054.8
Element	Ni	Р	Pb	S	Sb	Se	Si	Sn	SO4
Method	/OE	/OE	/MS	/OE	/MS	/MS	/OE	/MS	/CALC
Detection	0.01	0.1	0.5	0.1	0.01	0.5	0.05	0.1	0.3
Units	mg/l	mg/l	ug/l	mg/l	ug/l	ug/l	mg/l	ug/l	mg/l
Sample Name									
Control Blank	Х	Х	Х	Х	Х	Х	Х	Х	Х
GCA9728-4 HNO3	Х	Х	0.9	0.2	0.05	Х	14.67	Х	0.5
GCA9728-5 HNO3	Х	Х	1.1	0.2	0.22	1.3	11.87	0.2	0.5
Alcoa17-MS			5.3	_	5.55	27.9		5.7	
Alcoa11-OES	0.51	0.9		17.9			17.76		53.5
Alcoa-High4-MS			20	_	21.47	107.1		21.5	
AlcoaHi3-OES	20.6	44.9		258.7			93.27		775.1

Element	Sr	Th	TI	U	V	Zn
Method	/MS	/MS	/MS	/MS	/OE	/OE
Detection	0.02	0.005	0.01	0.005	0.01	0.01
Units	ug/l	ug/l	ug/l	ug/l	mg/l	mg/l
Sample Name						
Control Blank	Х	Х	Х	Х	Х	0.01
GCA9728-4 HNO3	1.63	0.009	Х	0.167	Х	0.02
GCA9728-5 HNO3	9.33	0.173	0.17	0.399	Х	Х
Alcoa17-MS	518.05	5.218	4.72	5.161		
Alcoa11-OES					0.57	0.53
Alcoa-High4-MS	1037.91	20.445	19.2	20.697		
AlcoaHi3-OES					21.14	20.52

NATA ENDORSED DOCUMENT

Company Accreditation Number 3244

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NATA Signatory: Ann Evers

Ann Evers

Date: 3/10//2011



Note:

The laboratory-reports, and column-worksheets, in the following pages correspond to the kinetic-testing programme carried out on the three (3) samples of **composite-waste-bedrocks** (viz. GCA9682/83, GCA9685/86, and GCA9688/90) from the **Delta-Pit**.



Roger Townend and Associates Consulting Mineralogists

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GRAEME CAMPBELL AND ASSOC

23-10-2011

PO BOX 247,

BRIDGE TOWN

WA

OUR REFERENCE 23061

XRD/PLM/SEM ANALYSES OF THREE WASTE ROCK SAMPLES .

R TOWNEND

RESULTS XRD/PLM/SEM

GCA	9682	9685`	9688
QUARTZ	DOMINANT	DOMINANT	DOMINANT
STILPNOMELANE	MINOR	MINOR	MINOR
K FELDSPAR	MINOR	MINOR	,MINOR
CHLORITE	ACCESSORY	ACCESSORY	ACCESSORY
SIDERITE	ACCESSORY	ACCESSORY	ACCESSORY
PYRITE	ACCESSORY	ACCESSORY	ACCESSORY

SIDERITE ANALYSES WT% MgO CaO MnO FeO

9682	5	1	1.5	51.3
9685	<1	1.2	3.8	54
9688	4	0.9	0.6	55.1

Roger Townend and Hissociates





Dr G Campbell CAMPBELL, GRAEME and ASSOCIATES PTY LTD PO Box 247 BRIDGETOWN WA 6255

JOB INFORMATION

JOB CODE	143/1111022
No. of SAMPLES	3
CLIENT O/N	GCA 1112
PROJECT	Flinders -PIOP
STATE	Mine Waste
DATE RECEIVED	26/07/2011
DATE COMPLETED	16/08/2011

LEGEND

>

- X = Less than Detection Limit
- N/R = Sample Not Received
- = Result Checked
- () = Result still to come
- I/S = Insufficient Sample for Analysis
- E6 = Result X 1,000,000
- UA = Unable to Assay
 - = Value beyond Limit of Method

The samples were received as mine wastes. The samples were dried 80C crushed to a nominal -2mm. A split was taken and fine pulverised to a nominal -75um

Results of analysis on:

Element		S	S-SO4	С	TOC+C	C-CO3
Method		/CSA	S72/GR	/CSA	C71/CSA	/CALC
Detection		0.01	0.01	0.01	0.01	0.01
Units		%	%	%	%	%
Sample Name						
Control Blank		Х	Х	Х	Х	
GCA9682/83		1.88	0.3	2.55	0.75	1.8
GCA9682/83	check	1.9	0.3	2.55	0.72	1.83
GCA9685/86		2.18	0.22	3.78	0.63	3.14
GCA9688/90		1.27	0.08	2.28	0.34	1.94
MA-3a		0.98		2.64		
MA-1b		1.17		2.46		
CD-1		3.13		0.2		
SO4-S STD A			0.57			
SO4-S STD B			1.3			

Notes

- 1. Total-S and Total-C were determined on the pulps
- Total-C and Total-S was determined using an induction furnace according to Genalysis method number MPL_W043. The samples are ignited in oxygen ~1700C and the CO2 and SO2 measured by infrared detectors
- S-SO4 was determined on the pulps by precipitation of BaSO4 according to Genalysis method number ENV_W039, after digestion with Na2CO3
- TOC+C (acid insoluble carbon compounds and elemental carbon) by a C&S analyser after removal of carbonates and soluble organic carbon using hot hydrochloric acid according to Genalysis method number MPL_W046.

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GLS Job Code 143.0/1111022

Results of analysis on:

sample		Fizz	volume	HCI	NaOH	Colour	pН	ANC	ANC
name		Rate	ml	М	М	Change	Drop	soln pH	(kgH2SO4/t)
GCA9682/83		0	20	0.539	0.512	Ν	2.8	1.4	35
GCA9682/83	check	0	20	0.539	0.512	N	2.8	1.4	34
GCA9685/86		0	20	0.539	0.512	Ν	2.7	1.7	65
GCA9688/90		0	20	0.539	0.512	N	2.9	1.4	64

Notes:

- 1. ANC was determined on 2g of the crushings -. Acid concentrations are as stated.
- 2. Colour change: Y indicates the appearance of a green colouration as the pH=7 endpoint was approached. N indicates no colour change. Two drops of 30 % hydrogen peroxide are added to each sample as the endpoint is approached to oxidise any ferrous iron.
- 3. pH drop : Result reported when the pH drops to a value below 4 on addition of peroxide
- 4. This "Bulk-ANC" static-testing procedure is based on AMIRA (2002), according to Genalysis method number ENV_W035

NATA ENDORSED DOCUMENT

Company Accreditation Number 3244

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NATA Signatory: Ann Evers

Ann Evers

Date: 16/08/2011


Laboratory Report pH-(1:2) & EC-(1:2) TESTWORK

SAMPLE NO.	SAMPLE WEIGHT (g)	SAMPLE + DEIONW WEIGHT (g)	рН-(1:2)	EC-(1:2) (μS/cm)
GCA9682/83	30.0	60.0	3.7	1,400
GCA9685/86	30.0	60.0	4.8	1,500
GCA9688/90	30.0	60.0	5.9	1,100
GCA9688/90-1	30.0	60.0	5.9	1,100

Note: EC = Electrical-Conductivity. Testwork performed on the as-supplied 'pulp' samples (nominal -75 μm). pH-(1:2) and EC-(1:2) values correspond to pH and EC values of suspensions with a solid:solution ratio of *c*. 1:2 (w/w) prepared using deionised-water. Drift in pH-glass-electrode less than 0.1 pH unit between commencement, and completion, of testwork.

Drift in EC-electrode less than 5 μ S/cm between commencement, and completion, of testwork. Testwork performed in a constant-temperature room (viz. 21 +/- 2-3 °C).

Dr GD Campbell 17th August 2011

Laboratory Report

NET-ACID-GENERATION (NAG) TESTWORK

Sample	Sample Weight	Comments	pH of Test Mixture	A	Test Mixture fter Boiling Step	Titre [0.1 M-	NAG (kg H ₂ SO ₄ /
Number	(g)		Before Boiling Step	рН	EC (µS/cm)	NaOH] (mL)	tonne)
GCA9682/83	3.0	Reaction peaked overnight	2.4	3.1	940	11.10	19
GCA9685/86	3.0	Reaction peaked overnight	2.5	4.2	890	10.60	18
GCA9688/90	3.0	Reaction peaked overnight	2.7	3.6	500	5.80	9.5
GCA9688/90-1	3.0	Reaction peaked overnight	2.7	3.5	640	5.80	9.5
BLANK1	3.0	Reaction peaked overnight	5.8	7.1	46	-	< 0.5

Notes: Test conditions based on those described by Miller *et al.* (1997), and AMIRA (2002) for the 'Static-NAG-Test' in its "Single-Additon-Mode". The pH of the 15 % (v/v) H_2O_2 solution was adjusted to 4.5 using 0.1 M-NaOH prior to commencing the NAG Tests. Following an overnight-reaction period, the test-mixtures were boiled for *c.* 2 hours. Then, after allowing the test-mixtures to cool, *c.* 1.0 mL of 0.016 M-CuSO₄ solution was added, and the test-mixtures again boiled for *c.* 2 hours. The addition of Cu(II) catalyses the decomposition of any residual, unreacted- H_2O_2 in the test-mixtures (McElnea and Ahern 2004; O'Shay *et al.* 1990). K-Feldspar was employed for the Blank.

Dr GD Campbell 12th August 2011





ANALYTICAL REPORT

Dr G. CAMPBELL CAMPBELL, GRAEME and ASSOCIATES PO Box 247 BRIDGETOWN, W.A. 6255 AUSTRALIA

JOB INFORMATION

JOB CODE	:	143.0/1111024
No. of SAMPLES	:	3
No. of ELEMENTS	:	32
CLIENT O/N	:	GCA1112 (Job 2 of 2)
SAMPLE SUBMISSION No.	:	
PROJECT	:	Flinders-PIOP
STATE	:	Ex-Pulp
DATE RECEIVED	:	26/07/2011
DATE COMPLETED	:	18/08/2011
DATE PRINTED	:	16/09/2011
PRIMARY LABORATORY	:	Genalysis Main Laboratory

MAIN OFFICE AND LABORATORY

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LEGEND

Х	= Less than Detection Limit
N/R	= Sample Not Received
*	= Result Checked
()	= Result still to come
I/S	= Insufficient Sample for Analysis
E6	= Result X 1,000,000
UA	= Unable to Assay
>	= Value beyond Limit of Method
OV	= Value over-range for Package

SAMPLE DETAILS

DISCLAIMER

Genalysis Laboratory Services Pty Ltd wishes to make the following disclaimer pertaining to the accompanying analytical results.

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SIGNIFICANT FIGURES

It is common practice to report data derived from analytical instrumentation to a maximum of two or three significant figures. Some data reported herein may show more figures than this. The reporting of more than two or three figures in no way implies that the third, fourth and subsequent figures may be real or significant.

Genalysis Laboratory Services Pty Ltd accepts no responsibility whatsoever for any interpretation by any party of any data where more than two or three significant figures have been reported.

SAMPLE STORAGE DETAILS

GENERAL CONDITIONS

SAMPLE STORAGE OF SOLIDS

Bulk Residues and Pulps will be stored for 60 DAYS without charge. After this time all Bulk Residues and Pulps will be stored at a rate of \$3.30 per cubic metre per day until your written advice regarding collection or disposal is received. Expenses related to the return or disposal of samples will be charged to you at cost. Current disposal cost is charged at \$100.00 per cubic metre.

SAMPLE STORAGE OF SOLUTIONS

Samples received as liquids, waters or solutions will be held for 60 DAYS free of charge then disposed of, unless written advice for return or collection is received.

ANALYSIS										
ELEMENTS	Ag	AI	As	В	Ba	Bi	Ca	Cd	Co	Cr
UNITS	ppm	%	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm
DETECTION LIMIT	0.1	0.01	0.5	50	0.1	0.01	0.1	0.02	0.1	50
DIGEST	4A/	FP1/	4A/	FP1/	4A/	4A/	FP1/	4A/	4A/	FP1/
ANALYTICAL FINISH	MS	OE	MS	OE	MS	MS	OE	MS	MS	OE
SAMPLE NUMBERS										
0001 GCA9682/83	0.2	4.66	43.9	115	246.8	0.38	0.3	0.20	18.3	68
0002 GCA9685/86	0.2	3.98	39.7	111	227.0	0.31	0.5	0.21	23.5	169
0003 GCA9688/90	0.1	3.31	46.6	112	228.6	0.51	0.4	0.41	13.1	X
CHECKS										
0001 GCA9682/83	0.3	4.81	44.3	69	256.0	0.39	0.3	0.26	18.4	207
STANDARDS										
0001 CRM No. 782-1		0.03		71			18.5			Х
0002 HgSTD-4										
0003 OREAS 45P	0.3		11.6		302.7	0.20		0.10	120.7	
0004 OREAS 97.01										
0005 STSD-2										
BLANKS										
0001 Control Blank	0.1	Х	Х	73	Х	0.07	Х	Х	Х	Х
0002 Control Blank	Х		Х		Х	Х		Х	Х	
0003 Control Blank		Х		Х			Х			68
0004 Control Blank										
0005 Control Blank										
0006 Acid Blank	Х		Х		Х	Х		Х	Х	
0007 Acid Blank		Х		Х			Х			Х

			ANA	LYS	IS					
ELEMENTS	Cu	F	Fe	Hg	К	Mg	Mn	Мо	Na	Ni
UNITS	ppm	ppm	%	ppm	%	%	ppm	ppm	ppm	ppm
DETECTION LIMIT	1	50	0.01	0.01	0.05	0.01	1	0.1	20	1
DIGEST	4A/	FC7/	FP1/	HG1/	FP1/	FP1/	4A/	4A/	4A/	4A/
ANALYTICAL FINISH	OE	SIE	OE	CV	OE	OE	OE	MS	OE	OE
SAMPLE NUMBERS										
0001 GCA9682/83	44	329	14.52	0.17	5.71	0.66	3446	2.8	124	34
0002 GCA9685/86	50	581	20.04	0.17	5.38	1.12	6892	2.7	93	43
0003 GCA9688/90	26	357	19.22	0.23	4.46	1.02	1937	3.4	146	26
CHECKS										
0001 GCA9682/83	47	420	14.70	0.25	5.81	0.69	3428	2.7	102	37
STANDARDS										
0001 CRM No. 782-1			0.32		0.13	11.18				
0002 HgSTD-4				0.34						
0003 OREAS 45P	700						1234	2.1	838	348
0004 OREAS 97.01										
0005 STSD-2		1023								
BLANKS										
0001 Control Blank	2	Х	0.01	Х	0.05	Х	1	Х	Х	Х
0002 Control Blank	2						Х	Х	Х	Х
0003 Control Blank			0.01		Х	Х				
0004 Control Blank				Х						
0005 Control Blank										
0006 Acid Blank	2						1	Х	Х	Х
0007 Acid Blank			Х		Х	Х				

			ANA	LYS	IS					
ELEMENTS	Р	Pb	S	Sb	Se	Sn	Sr	Th	TI	U
UNITS	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
DETECTION LIMIT	50	0.5	50	0.05	0.01	0.1	0.05	0.01	0.02	0.01
DIGEST	4A/	4A/	4A/	4A/	SE1/	4A/	4A/	4A/	4A/	4A/
ANALYTICAL FINISH	OE	MS	OE	MS	MS	MS	MS	MS	MS	MS
SAMPLE NUMBERS										
0001 GCA9682/83	314	18.1	1.85%	3.29	1.29	1.4	13.07	8.07	0.70	2.77
0002 GCA9685/86	821	15.8	2.07%	3.56	1.08	1.4	8.21	6.39	0.75	2.41
0003 GCA9688/90	550	21.9	1.21%	2.59	0.62	1.8	8.94	8.32	1.97	2.59
CHECKS										
0001 GCA9682/83	316	18.4	1.81%	3.33	1.41	1.5	13.07	8.25	0.73	2.81
STANDARDS										
0001 CRM No. 782-1										
0002 HgSTD-4										
0003 OREAS 45P	379	20.0	303	0.84		2.8	33.28	9.26	0.23	2.16
0004 OREAS 97.01					0.63					
0005 STSD-2										
BLANKS										
0001 Control Blank	Х	Х	Х	Х	Х	Х	Х	Х	Х	Х
0002 Control Blank	Х	Х	Х	Х		Х	Х	Х	Х	Х
0003 Control Blank										
0004 Control Blank										
0005 Control Blank					0.01					
0006 Acid Blank	Х	Х	Х	Х		Х	Х	Х	Х	Х
0007 Acid Blank										

ANALYSIS

ELEMENTS	V	Zn
UNITS	ppm	ppm
DETECTION LIMIT	1	1
DIGEST	4A/	4A/
ANALYTICAL FINISH	OE	OE
SAMPLE NUMBERS		
0001 GCA9682/83	73	68
0002 GCA9685/86	69	127
0003 GCA9688/90	31	117
CHECKS		
0001 GCA9682/83	75	69
STANDARDS		
0001 CRM No. 782-1		
0002 HgSTD-4		
0003 OREAS 45P	250	126
0004 OREAS 97.01		
0005 STSD-2		
BLANKS		
0001 Control Blank	Х	Х
0002 Control Blank	х	х
0003 Control Blank		
0004 Control Blank		
0005 Control Blank		
0006 Acid Blank	Х	Х
0007 Acid Blank		

METHOD CODE DESCRIPTION

4A/MS

Genalysis Main Laboratory

Multi-acid digest including Hydrofluoric, Nitric, Perchloric and Hydrochloric acids in Teflon Tubes. Analysed by Inductively Coupled Plasma Mass Spectrometry.

4A/OE

Genalysis Main Laboratory

Multi-acid digest including Hydrofluoric, Nitric, Perchloric and Hydrochloric acids in Teflon Tubes. Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.

FC7/SIE Genalysis Main Laboratory

Alkaline fusion (Nickel crucible) specific for Fluorine. Analysed by Specific Ion Electrode.

FP1/OE Genalysis Main Laboratory

Sodium peroxide fusion (Nickel crucibles) and Hydrochloric acid to dissolve the melt. Analysed by Inductively Coupled PI

HG1/CV Genalysis Main Laboratory

Low temperature Perchloric acid digest specific for Mercury. Analysed by Cold Vapour Generation Atomic Absorption Spectrometry.

SE1/MS

Genalysis Main Laboratory

Aqua-Regia digest followed by Precipitation and Concentration. Specific for Selenium. Analysed by Inductively Coupled PI

Graeme Campbell & Associates Pty Ltd Testing-Laboratory, Unit B, 15 Rose St. Bridgetown, WA 6255

KINETIC-TESTING WORKSHEET (WEATHERING-COLUMNS)

Job No: 1112_____

Client: Flinders-PIOP

	GCA9682/83	GCA9685/86	GCA9688/90
Column-Packing			
Wt Column-Only (kg)	0.32	0.32	0.32
Wt Column + Sample (kg)	1.82	1.82	1.82
Wt Sample (kg)	1.50	1.50	1.50

Pre-Rinse Cycle (Cycle-0)	GCA9682/83	GCA9685/86	GCA9688/90
Wt DW Added (kg)	3.00	6.00	4.38
Wt Leach. + Beaker (kg)	3.49	6.37	1.24
Wt Beaker (kg)	1.24	1.24	0.26
Wt Leachate (kg)	2.25	5.13	0.98
pH	3.1	4.4	7.9
EC (µS/cm)	4,500	2,400	2,000

	GCA9682/83	GCA9685/86	GCA9688/90
Weathering-Cycles			
Cycle No.	1	1	1
DAY-1 (i.e. Start-of-Day-1) [Monday]			
Lamps-On: Date	27/6/11	27/6/11	27/6/11
Lamps-On: Time	17:00	17:00	17:00
DAY-2 [Tuesday]			
Time	09:00	09:00	09:00
Wt Column (kg)	2.05	2.01	2.01
Gravimetric-Water-Content (%, w/w)	15.3	12.7	12.7
DAY-3 [Wednesday]			
Time	09:00	09:00	09:00
Wt Drying-Column (kg)	1.99	1.95	1.96
Gravimetric-Water-Content (%, w/w)	11.3	8.7	9.3
DAY-4 [Thursday]			
Time	09:00	09:00	09:00
Wt Drying-Column (kg)	1.92	1.89	1.91
Gravimetric-Water-Content (%, w/w)	6.7	4.7	6.0
DAY-5 [Friday]			
Time	09:00	09:00	09:00
Wt Drying-Column (kg)	1.88	1.86	1.88
Gravimetric-Water-Content (%, w/w)	4.0	2.7	4.0
Wt Deionised-Water Added (kg)	1.00	1.00	1.00
(Lamps remain off)			
DAY-7 (i.e. End-of-Day-7)			
Wt Drained-Column(kg)	2.13	2.08	2.10
Gravimetric-Water-Content (%, w/w)	20.7	17.3	18.7
Wt Leachate + Beaker (kg)	0.98	1.00	1.00
Wt Beaker (kg)	0.26	0.26	0.26
Wt Leachate (kg)	0.72	0.74	0.74
Leachate-pH	5.7	6.3	6.4
Leachate-EC (µS/cm)	1,900	1,300	840

	GCA9682/83	GCA9685/86	GCA9688/90
Weathering-Cycles			
Cycle No.	2	2	2
DAY-1 (i.e. Start-of-Day-1) [Monday]			
Lamps-On: Date	4/7/11	4/7/11	4/7/11
Lamps-On: Time	17:00	17:00	17:00
DAY-2 [Tuesday]			
Time	09:00	09:00	09:00
Wt Column (kg)	2.07	2.02	2.05
Gravimetric-Water-Content (%, w/w)	16.7	13.3	15.3
DAY-3 [Wednesday]			
Time	09:00	09:00	09:00
Wt Drying-Column (kg)	2.02	1.95	1.99
Gravimetric-Water-Content (%, w/w)	13.3	8.7	11.3
DAY-4 [Thursday]			
Time	09:00	09:00	09:00
Wt Drying-Column (kg)	1.96	1.89	1.93
Gravimetric-Water-Content (%, w/w)	9.3	4.7	7.3
DAY-5 [Friday]			
Time	09:00	09:00	09:00
Wt Drying-Column (kg)	1.90	1.85	1.88
Gravimetric-Water-Content (%, w/w)	5.3	2.0	4.0
Wt Deionised-Water Added (kg)	1.00	1.00	1.00
(Lamps remain off)			
DAY-7 (i.e. End-of-Day-7)			
Wt Drained-Column(kg)	2.13	2.08	2.10
Gravimetric-Water-Content (%, w/w)	20.7	17.3	18.7
Wt Leachate + Beaker (kg)	0.99	0.99	1.00
Wt Beaker (kg)	0.26	0.26	0.26
Wt Leachate (kg)	0.73	0.73	0.74
Leachate-pH	5.8	6.3	6.3
Leachate-EC (µS/cm)	1,500	1,300	800

	GCA9682/83	GCA9685/86	GCA9688/90
Weathering-Cycles			
Cycle No.	3	3	3
DAY-1 (i.e. Start-of-Day-1) [Monday]			
Lamps-On: Date	11/7/11	11/7/11	11/7/11
Lamps-On: Time	17:00	17:00	17:00
DAY-2 [Tuesday]			
Time	09:00	09:00	09:00
Wt Column (kg)	2.07	2.01	2.05
Gravimetric-Water-Content (%, w/w)	16.7	12.7	15.3
DAY-3 [Wednesday]			
Time	09:00	09:00	09:00
Wt Drying-Column (kg)	2.00	1.94	1.99
Gravimetric-Water-Content (%, w/w)	12.0	8.0	11.3
DAY-4 [Thursday]			
Time	09:00	09:00	09:00
Wt Drying-Column (kg)	1.94	1.87	1.94
Gravimetric-Water-Content (%, w/w)	8.0	3.3	8.0
DAY-5 [Friday]			
Time	09:00	09:00	09:00
Wt Drying-Column (kg)	1.88	1.84	1.88
Gravimetric-Water-Content (%, w/w)	4.0	1.3	4.0
Wt Deionised-Water Added (kg)	1.00	1.00	1.00
(Lamps remain off)			
DAY-7 (i.e. End-of-Day-7)			
Wt Drained-Column(kg)	2.12	2.07	2.09
Gravimetric-Water-Content (%, w/w)	20.0	16.7	18.0
Wt Leachate + Beaker (kg)	0.99	1.01	0.98
Wt Beaker (kg)	0.26	0.26	0.26
Wt Leachate (kg)	0.73	0.75	0.72
Leachate-pH	5.7	6.2	6.4
Leachate-EC (µS/cm)	1,400	1,400	900

	GCA9682/83	GCA9685/86	GCA9688/90
Weathering-Cycles			
Cycle No.	4	4	4
DAY-1 (i.e. Start-of-Day-1) [Monday]			
Lamps-On: Date	18/7/11	18/7/11	18/7/11
Lamps-On: Time	17:00	17:00	17:00
DAY-2 [Tuesday]			
Time	09:00	09:00	09:00
Wt Column (kg)	2.06	2.02	2.03
Gravimetric-Water-Content (%, w/w)	16.0	13.3	14.0
DAY-3 [Wednesday]			
Time	09:00	09:00	09:00
Wt Drying-Column (kg)	1.98	1.97	1.98
Gravimetric-Water-Content (%, w/w)	10.7	10.0	10.7
DAY-4 [Thursday]			
Time	09:00	09:00	09:00
Wt Drying-Column (kg)	1.92	1.92	1.93
Gravimetric-Water-Content (%, w/w)	6.7	6.7	7.3
DAY-5 [Friday]			
Time	09:00	09:00	09:00
Wt Drying-Column (kg)	1.87	1.87	1.88
Gravimetric-Water-Content (%, w/w)	3.3	3.3	4.0
Wt Deionised-Water Added (kg)	1.00	1.00	1.00
(Lamps remain off)			
DAY-7 (i.e. End-of-Day-7)			
Wt Drained-Column(kg)	2.13	2.07	2.09
Gravimetric-Water-Content (%, w/w)	20.7	16.7	18.0
Wt Leachate + Beaker (kg)	0.97	1.02	1.01
Wt Beaker (kg)	0.26	0.26	0.26
Wt Leachate (kg)	0.71	0.76	0.75
Leachate-pH	5.7	6.2	6.6
Leachate-EC (µS/cm)	880	770	580

	GCA9682/83	GCA9685/86	GCA9688/90
Weathering-Cycles			
Cycle No.	5	5	5
DAY-1 (i.e. Start-of-Day-1) [Monday]			
Lamps-On: Date	25/7/11	25/7/11	25/7/11
Lamps-On: Time	17:00	17:00	17:00
DAY-2 [Tuesday]			
Time	09:00	09:00	09:00
Wt Column (kg)	2.08 2.02		2.03
Gravimetric-Water-Content (%, w/w)	17.3	13.3	14.0
DAY-3 [Wednesday]			
Time	09:00	09:00	09:00
Wt Drying-Column (kg)	2.03	1.96	1.96
Gravimetric-Water-Content (%, w/w)	14.0	9.3	9.3
DAY-4 [Thursday]			
Time	09:00	09:00	09:00
Wt Drying-Column (kg)	1.97	1.90	1.88
Gravimetric-Water-Content (%, w/w)	10.0	5.3	4.0
DAY-5 [Friday]			
Time	09:00	09:00	09:00
Wt Drying-Column (kg)	1.91	1.85	1.85
Gravimetric-Water-Content (%, w/w)	6.0	2.0	2.0
Wt Deionised-Water Added (kg)	1.00	1.00	1.00
(Lamps remain off)			
DAY-7 (i.e. End-of-Day-7)			
Wt Drained-Column(kg)	2.13	2.06	2.09
Gravimetric-Water-Content (%, w/w)	20.7	16.0	18.0
Wt Leachate + Beaker (kg)	1.01	1.01	0.99
Wt Beaker (kg)	0.26	0.26	0.26
Wt Leachate (kg)	0.75	0.75	0.73
Leachate-pH	5.7	6.0	6.2
Leachate-EC (µS/cm)	920	880	750

	GCA9682/83	GCA9685/86	GCA9688/90
Weathering-Cycles			
Cycle No.	6	6	6
DAY-1 (i.e. Start-of-Day-1) [Monday]			
Lamps-On: Date	1/08/11	1/08/11	1/08/11
Lamps-On: Time	17:00	17:00	17:00
DAY-2 [Tuesday]			
Time	09:00	09:00	09:00
Wt Column (kg)	2.04	2.00	2.00
Gravimetric-Water-Content (%, w/w)	14.7	12.0	12.0
DAY-3 [Wednesday]			
Time	09:00	09:00	09:00
Wt Drying-Column (kg)	1.96	1.93	1.91
Gravimetric-Water-Content (%, w/w)	9.3	7.3	6.0
DAY-4 [Thursday]			
Time	09:00	09:00	09:00
Wt Drying-Column (kg)	1.89	1.88	1.87
Gravimetric-Water-Content (%, w/w)	4.7	4.0	3.3
DAY-5 [Friday]			
Time	09:00	09:00	09:00
Wt Drying-Column (kg)	1.83	1.83	1.84
Gravimetric-Water-Content (%, w/w)	0.7	0.7	1.3
Wt Deionised-Water Added (kg)	1.00	1.00	1.00
(Lamps remain off)			
DAY-7 (i.e. End-of-Day-7)			
Wt Drained-Column(kg)	2.11	2.05	2.08
Gravimetric-Water-Content (%, w/w)	19.3	15.3	17.3
Wt Leachate + Beaker (kg)	0.95	1.00	0.97
Wt Beaker (kg)	0.26	0.26	0.26
Wt Leachate (kg)	0.69	0.74	0.71
Leachate-pH	5.5	5.9	6.2
Leachate-EC (µS/cm)	990	900	700





Dr G Campbell CAMPBELL, GRAEME and ASSOCIATES PTY LTD PO Box 247 BRIDGETOWN WA 6255

JOB INFORMATION

JOB CODE	143/1112030
No. of SAMPLES	36
CLIENT O/N	GCA 1112
PROJECT	Flinders PIOP
STATE	Column leachates
DATE RECEIVED	10/08/2011
DATE COMPLETED	31/08/2011

A series of column leachates were received.

LEGEND

- X = Less than Detection Limit
- N/R = Sample Not Received
- = Result Checked
- () = Result still to come
- I/S = Insufficient Sample for Analysis
- E6 = Result X 1,000,000
- UA = Unable to Assay
- > = Value beyond Limit of Method

The pH, EC and Cl of each "raw" sample was measured using Genalysis method codes: ENV-W001, ENV-W002, and ENV_W013

The acidity of requested samples was measured by titration to pH=8.3(Acidy) using sodium hydroxide and expressed as mgH2SO4/L. APHA method code 2310B

APHA code refers to "Standard methods for the examination of water and wastewater", 21st Edition 2005

The HNO3 dosed filtered solution was analysed for the requested element suite (including S) by ICPMS and /or ICPOES: Genalysis method codes (ICP_W003, ICP_W004).

Results of analysis on:

Element		Acidy	CI	EC	pН
Method		/VOL	/COL	/MTR	/MTR
Detection		1	2	10	0.1
Units		mgH2SO4/L	mg/l	uS/cm	NONE
Sample Name					
Control Blank			Х		
9682/83-0 Raw		427	6	3160	3.0
9682/83-0 Raw	check	418	7	3160	3.0
9682/83-1 Raw		14	35	1282	6.4
9682/83-2 Raw		13	44	945	6.3
9682/83-3 Raw		9	64	961	5.1
9682/83-4 Raw		8	66	883	4.7
9682/83-5 Raw		7	48	906	5.0
9685/86-0 Raw		31	5	1658	4.6
9685/86-1 Raw		5	64	852	5.6
9685/86-2 Raw		8	83	882	4.3
9685/86-3 Raw		11	93	936	4.2
9685/86-4 Raw		10	35	780	6.4
9685/86-5 Raw		6	26	860	6.0
9688/90-0 Raw		9	8	1349	7.9
9688/90-1 Raw		8	42	603	7.4
9688/90-2 Raw		9	20	565	7.7
9688/90-3 Raw		7	8	610	7.4
9688/90-4 Raw		8	Х	606	7.4
9688/90-5 Raw		6	2	748	7.4
N191			96		

Element		AI	As	Ca	Cu	Fe-Sol	K
Method		/OE	/MS	/OE	/OE	/OE	/OE
Detection		0.01	0.1	0.01	0.01	0.01	0.1
Units		mg/l	ug/l	mg/l	mg/l	mg/l	mg/l
Sample Name							
Control Blank		Х	Х	Х	Х	Х	Х
9682/83-0 HNO3		21.77	4.2	157.3	0.33	99.54	71.7
9682/83-1 HNO3		0.11	0.9	47.58	Х	0.46	18.9
9682/83-2 HNO3		0.03	0.5	34.35	Х	0.1	13.8
9682/83-2 HNO3	check	0.03	0.6	35.11	Х	0.09	14.2
9682/83-3 HNO3		0.11	0.9	32.88	Х	0.11	14.4
9682/83-4 HNO3		0.08	1	30.45	Х	0.05	13.5
9682/83-5 HNO3		0.01	1.1	30.26	Х	0.02	13.1
9685/86-0 HNO3		2.89	0.9	99.94	0.06	1.82	58.4
9685/86-1 HNO3		0.08	0.5	38.83	Х	Х	5.2
9685/86-2 HNO3		0.02	0.5	37.11	Х	0.04	4.8
9685/86-3 HNO3		0.06	0.6	41.39	Х	Х	5.9
9685/86-4 HNO3		0.02	0.5	36.57	Х	Х	6.3
9685/86-5 HNO3		0.06	0.3	38.96	Х	Х	6.9
9688/90-0 HNO3		0.01	1.2	84.77	Х	0.03	95.9
9688/90-1 HNO3		Х	0.7	41.97	Х	Х	13.6
9688/90-2 HNO3		0.02	0.5	38.87	Х	Х	13.6
9688/90-3 HNO3		0.02	0.8	43.1	Х	Х	17.2
9688/90-4 HNO3		Х	0.7	42.52	Х	0.01	19
9688/90-5 HNO3		X	0.6	52.45	Х	Х	26.7
Alcoa17-MS			26				
Alcoa11-OES		1.94		47.27	0.51	2.02	3.7

Element		Mg	Mn	Na	S	Si	Zn
Method		/OE	/OE	/OE	/OE	/OE	/OE
Detection		0.01	0.01	0.1	0.1	0.05	0.01
Units		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Sample Name							
Control Blank		Х	Х	Х	0.2	Х	Х
9682/83-0 HNO3		264.13	146.96	2.3	742.8	14.62	1.33
9682/83-1 HNO3		131.82	56.69	1.1	267	2.39	0.05
9682/83-2 HNO3		91.16	38.32	0.7	200.6	1.9	0.03
9682/83-2 HNO3	check	92.76	39.11	0.7	192.6	1.93	0.03
9682/83-3 HNO3		90.39	33.72	0.6	200.1	2.1	0.02
9682/83-4 HNO3		83.56	31.37	0.5	188.8	1.93	0.02
9682/83-5 HNO3		84.18	31.18	0.4	177.5	1.97	0.02
9685/86-0 HNO3		135.11	77.61	1.2	349.6	4.15	0.54
9685/86-1 HNO3		83.36	16.89	0.3	182.5	0.44	0.02
9685/86-2 HNO3		84.37	16.7	0.3	180.7	0.43	0.02
9685/86-3 HNO3		90.43	17.99	0.4	225.8	0.46	0.03
9685/86-4 HNO3		69.36	21.81	0.4	159	0.46	0.02
9685/86-5 HNO3		78.87	25.82	0.4	171.3	0.46	0.02
9688/90-0 HNO3		95.4	10.54	4.2	222.4	6.38	0.09
9688/90-1 HNO3		42.63	1.87	0.8	114.9	2.84	0.06
9688/90-2 HNO3		38.92	2.34	0.7	95.9	2.83	0.02
9688/90-3 HNO3		40.29	3.29	1	100.2	3.22	0.01
9688/90-4 HNO3		37.88	4.07	1.1	92.7	3.14	0.02
9688/90-5 HNO3		45.75	6.5	1.4	117.1	3.58	0.02
Alcoa17-MS							
Alcoa11-OES		47.05	0.54	232.3	17.4	18.57	0.5

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NATA Signatory: Ann Evers

Ann Evers

Date: 31/08//2011



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Dr G Campbell CAMPBELL, GRAEME and ASSOCIATES PTY LTD PO Box 247 BRIDGETOWN WA 6255

JOB INFORMATION

JOB CODE	143/1113001
No. of SAMPLES	6
CLIENT O/N	GCA 1112
PROJECT	Flinders PIOP
STATE	Column leachates
DATE RECEIVED	31/08/2011
DATE COMPLETED	23/09/2011

LEGEND

- X = Less than Detection Limit
- N/R = Sample Not Received
- * = Result Checked
- () = Result still to come
- I/S = Insufficient Sample for Analysis
- E6 = Result X 1,000,000
- UA = Unable to Assay
- > = Value beyond Limit of Method

A series of column leachates were received

The pH, EC and Cl of the %aw+samples was measured Genalysis method codes ENV-W001, ENV-W002 and ENV_W013. The acidity to pH 8.3 was also measured using APHA method code 2310B APHA code refers to "Standard methods for the examination of water and wastewater", 21st Edition 2005

The HNO3 dosed filtered solution was analysed for the requested element suite by ICPMS and /or ICPOES: Genalysis method codes (ICP_W003, ICP_W004)

Results of analysis on:

Element		Acidy	CI	EC	pН
Method		NOL	/COL	/MTR	/MTR
Detection		1	2	10	0.1
Units		mgH2SO4/L	mg/l	uS/cm	NONE
Sample Name					
Control Blank			Х		
9682/83-6 Raw		6	3	1011	4.9
9682/83-6 Raw	check	6	2	1009	5.2
9685/86-6 Raw		9	Х	914	7.1
9688/90-6 Raw		5	Х	700	7.7
N191			97		

Element	Al	As	Ca	Cu	Fe-Sol	K
Method	/OE	/MS	/OE	/OE	/OE	/OE
Detection	0.01	0.1	0.01	0.01	0.01	0.1
Units	mg/l	ug/l	mg/l	mg/l	mg/l	mg/l
Sample Name						
Control Blank	Х	Х	Х	Х	Х	Х
9682/83-6 HNO3	Х	0.8	32.68	Х	0.02	13.2
9685/86-6 HNO3	Х	0.4	43.2	Х	Х	8.1
9688/90-6 HNO3	Х	0.5	48.81	Х	Х	28.8
Alcoa11-OES	1.94	255.4	48.86	0.52	2.03	3.9
AlcoaHi3-OES	47.17		974.62	2.61	93.61	473.4
Element	Mg	Mn	Na	S	Si	Zn
Method	/OE	/OE	/OE	/OE	/OE	/OE
Detection	0.01	0.01	0.1	0.1	0.05	0.01
Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Sample Name						
Control Blank	Х	Х	Х	Х	Х	Х
9682/83-6 HNO3	96.51	30.78	0.4	192.2	1.74	0.01
9685/86-6 HNO3	75.84	37.8	0.3	163.3	0.38	0.02
9688/90-6 HNO3	41	8.26	1.3	108.8	3.52	0.02
Alcoa11-OES	47.78	0.49	241.6	16.5	18.61	0.5
AlcoaHi3-OES	196.15	19.27	1993	259.2	105.65	20.05

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NATA Signatory: Ann Evers

Ann Evers

Date: 23/09//2011



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FLINDERS MINES LIMITED GEOCHEMICAL CHARACTERISATION OF MINE WASTE AND TAILINGS IMPLICATIONS FOR MINE WASTE MANAGEMENT

APPENDIX B

GRAEME CAMPBELL & ASSOCIATES PTY LTD Specialists in Mine-Waste Geochemistry, & Soil-Moisture-Retention Testing

P.O. Box 247, Bridgetown, Western Australia 6255 Phone: (61 8) 9761 2829 Fax: (61 8) 9761 2830 E-mail: <u>gca@wn.com.au</u>

1112/2

COMPANY:	Flinders Mines Limited				
ATTENTION:	Mick Anstey				
FROM:	Graeme Carr	npbell			
SUBJECT:	Flinders Pilbara Iron-Ore Project (FPIOP): Geochemica Characterisation of Process-Tailings-Solids Sample an Management Implications				
NO. PAGES (including this p	bage):	60	DATE:	15th November 2011	

Mick,

The testwork results obtained in this study are presented in Tables 1-4.

Details of the tailings-solids sample submitted for testing are presented in Attachment I.

Details of the testwork methods are presented in Attachment II, and classification criteria in terms of Acid-Formation Potential (AFP) are summarised in Attachment III. Copies of the laboratory reports are presented in Attachment IV.

1.0 TESTWORK OUTCOMES

The tailings-solids sample contained "negligible-sulphides" and "minute/trace-carbonates" (viz. Sulphide-S value of 0.01 %, and CO₃-C value of 0.07 %), and is classified as <u>Non-Acid Forming (NAF)</u> [Table 1].

Although the tailings-solids sample was variously enriched in As, Sb, Se, and Ag (Table 2), the degree of enrichment was not marked.

The sample was dominated by hematite with sub-ordinate kaolinite, goethite, and quartz (Table 3).

The stability of the sorbed forms of minor-elements in the tailings-solids sample is shown by the very-low concentrations in the leachates generated over six (6) weekly-weathering-cycles (Table 4). The occurrence of "ultra-fines" (e.g. Fe/Al-sesquioxides of "near-nano" dimensions [viz. colloidal]) that passed through the 0.45- μ m-membrane during vacuum-filtration means that the recorded minor-element concentrations are variously biased "on-the-high-side", due to contributions from particulates. The recorded minor-element concentrations were typically close to, or below, the respective detection-limits within the range 0.1-10 μ g/L.

2.0 CONCLUSIONS

Based on the testwork results obtain in this study, it is concluded that the processtailings to be produced during the FPIOP should be geochemically benign. In essence, due to the strongly-weathered and -leached status of the ores *in situ*, the process-tailings have "nonething-to-give", hydrogeochemically, as they are subjected to slow 'residualweathering' under the episodic, pulsed rainfall-regime of the Pilbara.

3.0 CLOSURE

I trust the above is useful to you.

Regards,

Dr GD Campbell Director

encl. Tables 1-4. Attachments I to IV. TABLES

Graeme Campbell & Associates Pty Ltd

Table 1: Acid-Base-Analysis and Net-Acid-Generation Results

GCA- SAMPLE NO.	TOTAL-S (%)	SO ₄ -S (%)	SULPHIDE- S (%)	TOTAL-C (%)	CO ₃ -C (%)	Bulk-ANC NAPP NAG kg H2SO4/tonne		NAG-pH	AFP CATEGORY	
GCA9766	0.01 (0.02)	0.01 (0.01)	0.01	0.17 (0.16)	0.07 (0.07)	5 (4)	nc	<0.5 (<0.5)	5.5 (5.6)	NAF

Notes:

 \overrightarrow{ANC} = Acid-Neutralisation-Capacity; NAPP = Net-Acid-Producing-Potential; AFP = Acid-Formation-Potential; NAG = Net-Acid Generation; nc = not calculated; NAF = Non-Acid-Forming. All results expressed on a dry-weight basis, except for NAG-pH.

Values in parentheses represent duplicates.

Table 2: Multi-Element-Analysis Results

	TOTAL-ELEMENT	AVCRUSTAL	GEOCHEMICAL-
ELEMENT	CONTENT (mg/kg or %)	ABUNDANCE	ABUNDANCE INDEX (GAI)
	GCA9766	(mg/kg or %)	GCA9766
Al	3.3%	8.2%	0
Fe	48.8%	4.1%	3
Na	0.017%	2.3%	0
K	0.11%	2.1%	0
Mg	0.08%	2.3%	0
Са	0.2%	4.1%	0
Ag	2.9	0.07	5
Cu	14	50	0
Zn	23	75	0
Cd	0.06	0.11	0
Pb	19	14	0
Cr	110	100	0
Ni	10	80	0
Co	2.7	20	0
Mn	170	950	0
Hg	0.01	0.05	0
Sn	3.8	2.2	0
Sr	6.9	370	0
Ba	21	500	0
Th	6.7	12	0
U	1.4	2.4	0
Tl	0.06	0.6	0
V	58	160	0
As	16	1.5	3
Bi	0.24	0.048	2
Sb	1.9	0.2	3
Se	1.0	0.05	4
Mo	2.2	1.5	0
В	<50	10	0
Р	440	1,000	0
F	210	950	0

Note: Average-crustal abundance of elements based on Bowen (1979), and the Geochemical-Abundance Index (GAI) is based on Förstner et al. (1993). Refer Attachment II.

Table 3: **Mineralogical Results**

GCA9766								
he ka c gu cai leu	domin min acces trac	nant Ior sory ce						
eCEC	eCEC %-Proportion							
[cmol (p+)/kg]	Na	K	Mg	Ca				
3.6	14	5	40	41				

Notes:

eCEC = effective-Cation-Exchange-Capacity. dominant = greater than 50 %; minor = 10-20 %; accessory = 2-10 %; and, trace = less than 2 %

Table 4:Column-Leachate-Analysis Results

ELEMENT/ PARAMETER	PRE- RINSING- CYCLE	WEEKLY-WEATHERING-CYCLES (GCA9766)							
		1	2	3	4	5	6		
Major-Parameters									
pН	7.4	6.9	7.0	7.0	7.0	7.1	6.9		
EC [µS/cm]	390	69	43	37	33	31	26		
Major-Ions (mg/L)									
Cl	73	5	<2	<2	<2	<2	<2		
HCO ₃	32	-	-	-	-	-	-		
SO_4	34	6	3	2	1	1	1		
Na	55	15	9.4	8.2	7.7	6.7	5.2		
K	3.6	1.3	1.1	0.9	0.8	0.7	0.7		
Mg	7.3	1.8	1.9	1.5	1.2	0.67	0.65		
Ca	9.3	2.5	2.6	2.0	1.6	1.1	0.99		
Fe	0.38	1.6 2.7	1.4	1.2	0.82	0.39	0.34		
Si	16	21	18	18	18	18	16		
Leachate Wt (kg)	0.65	0.69	0.73	0.71	0.76	0.76	0.70		

<u>Notes</u>: EC = Electrical-Conductivity. A hyphen for HCO_3 indicates that acidimetric-titration to determine HCO_3 could not be undertaken, since the filtered-(0.45mm-membrane)-leachates were turbid, due to "ultra-fines" of sesquioxides/silicates (likely of near-colloidal dimensions).

ELEMENT/ PARAMETER	PRE- RINSING- CYCLE	WEEKLY-WEATHERING-CYCLES (GCA9766)						
		1	2	3	4	5	6	
Minor-Ions (µg/L)								
Cu	<10	30	20	10	20	20	10	
Ni	<10	<10	<10	<10	<10	<10	<10	
Zn	<10	40	40	40	20	<10	10	
Со	0.2	0.6	0.5	0.4	0.3	0.2	0.2	
Cd	0.03	0.24	0.09	0.06	0.06	0.03	0.02	
Pb	1.5	6.6	6.6	5.2	4.2	4.0	4.2	
Cr	<10	<10	<10	<10	<10	<10	<10	
Hg	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.2	< 0.1	
As	1.8	0.6	0.4	0.2	0.3	< 0.1	0.5	
Sb	0.10	0.21	0.18	0.20	0.23	0.25	0.22	
Bi	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.006	< 0.005	
Se	6.2	0.5	<0.5	< 0.5	< 0.5	< 0.5	< 0.5	
В	20	220	140	140	120	130	140	
Мо	0.74	3.6	3.3	2.9	2.9	3.4	3.8	
Р	<100	<100	<100	<100	<100	<100	<100	
Ag	0.09	0.18	0.22	0.16	0.19	0.19	0.23	
Ba	75	19	21	18	14	18	13	
Sr	61	20	19	15	12	7.4	7.8	
Tl	< 0.01	0.02	0.01	< 0.01	< 0.01	0.01	< 0.01	
V	<10	<10	<10	<10	<10	<10	<10	
Sn	< 0.1	0.1	0.1	0.1	< 0.1	< 0.1	< 0.1	
U	0.044	0.20	0.19	0.17	0.13	0.076	0.081	
Th	0.012	0.040	0.034	0.030	0.023	0.007	< 0.005	
Mn	20	20	20	10	10	<10	<10	

ATTACHMENT I

SAMPLE DETAILS

Graeme Campbell & Associates Pty Ltd





FLINDERS MINES LIMITED

EcoNomics

Pilbara Iron Ore Project

Tailings Sample Testwork

201012-00322

30-Aug-11

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FLINDERS MINES LIMITED PILBARA IRON ORE PROJECT TAILINGS SAMPLE TESTWORK

SYNOPSIS

This note provides a summary of the tailings sample assay used for the mineralogy analysis performed by Graeme Campbell.

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PROJ	PROJECT 201012-00322 - PILBARA IRON ORE PROJECT									
REV	DESCRIPTION	ORIG	REVIEW	WORLEY- PARSONS APPROVAL	DATE	CLIENT APPROVAL	DATE			
A	Issued for Study	J Patel	M Esvelt	N/A	30-Aug-11	<u>N/A</u>				

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FLINDERS MINES LIMITED PILBARA IRON ORE PROJECT TAILINGS SAMPLE TESTWORK

SUMMARY

WorleyParsons Services Pty Ltd (WorleyParsons) developed a testwork programme, directed sample compilation and managed the testwork to prepare samples for sinter testwork. The programme exclusively focussed on the detrital iron deposit (DID 2, DID 3 and DID 4 composites) and Brockman iron deposit (BIDg and BIDh composites) ores of the Delta deposit from the Blacksmith tenements.

Both DID and BID composites were crushed to -6.3 mm, with the DID 2 and DID 3 composites subjected to a 0.3 mm wet screening step. In addition to this beneficiation step, the sample were grade controlled and blended to ensure that the >58% Fe, <6% SiO₂ and <3.5% for DID and <3.0% for BID AI_2O_3 target grades were met prior to sinter testwork.

The mineralogy report noted that for the reject samples from DID 2 and DID 3, that ~50% of the total mineral mass of the goethite, hematite and magnetite was liberated. However, the remaining iron oxides were locked in silicates (7-18%), iron oxide interface (8-28%) and iron oxide interface with silicates (11-32%). The main host of AI was the kaolinite-Fe oxide interface.

Fe	SiO ₂	Al ₂ O ₃	TiO2	Mn	CaO	P XRF	S XRF
%	%	%	%	%	%	%	%
52.5	13.3	6.7	0.564	0.020	0.075	0.050	0.024

The grade of the tailings sample (from DID 2 and DID 3) is as tabled below:

MgO	K2O	Na ₂ O	CI	LOI 371	LOI 371-650	LOI 650-1000	LOI 1000
%	%	%	ppm	%	%	%	%
0 123	0.044	0.037	106.8	2.2	1 /	0.2	3.0

The silica range was between 11 and 21.6 in the composites and the alumina range was between 5.85 and 10.03%

ATTACHMENT II

TESTWORK METHODS

Graeme Campbell & Associates Pty Ltd

ATTACHMENT II

TESTWORK METHODS

The testwork methods outlined below are proven approaches to 'static-testing' and 'kinetic-testing' within the Australian, and international mining-industries (e.g. Price 2009; Stewart *et al.* 2006; AMIRA 2002; Morin and Hutt 1997).¹ The MEND-document prepared by Price (2009), and *c.* 10-20 years in the making by an experienced practitioner, is an invaluable source of information on testing methods on mine-waste geochemistry. There is also the Global-Acid-Rock-Drainage-Guide (GARD Guide) which is an INAP initiative (go to: www.gardguide.com). However, in terms of comprehensiveness, structure, and clarity, the document by Price (2009) is recommended.

Part of the acid-base-account (ABA) testing, and all of the multi-element analyses, and clay-surface-chemical determinations, are carried out by Genalysis Laboratory Services Pty Ltd [GLS] (Maddington). Specialised ABA-testing, and kinetic-testing, is undertaken by GCA (Bridgetown). Characterisation of rock- and clay-mineralogy is carried out by Roger Townend & Associates (Malaga).

Samples are crushed to 2mm (nominal) in a jaw/rolls-crusher, and pulverised to $75\mu m$ (nominal), for specific tests, as required. These sample-splits are referred to herein as "crushings" and "pulps", respectively.

It should be noted that the testwork methods described below are routinely employed in work programmes undertaken by GCA. However, the testwork methods described are generic, and specific tests may not necessarily be undertaken in a given study.

1.0 ACID-BASE-CHEMISTRY AND SALINITY TESTWORK

Acid-base chemistry and salinity are assessed by determining:

- pH and Electrical-Conductivity (EC) on sample slurries;
- Total-Sulphur (Total-S), and Sulphate-Sulphur (SO₄-S);
- Acid-Neutralisation-Capacity (ANC), and CO₃-C;
- Net-Acid-Producing-Potential (NAPP); and,
- Net-Acid-Generation (NAG).

Relevant details of the testwork methods employed are discussed below. Further details are presented in the laboratory reports.

¹ 'Static'-testing' corresponds to "whole-rock" analyses and tests.

1.1 pH-(1:2) and EC-(1:2) Tests

Measurements of pH and EC are performed on slurries prepared using deionised-water, and a solid:water ratio of c. 1:2 (w/w). The slurries are allowed to age for c. 24 hours, prior to measuring pH and EC.² These tests are performed on the crushings.

<u>pH-(1:2)</u> and <u>EC-(1:2)</u> values provide a measure of the inherent acidity/alkalinity and salinity.³

1.2 Total-S and SO₄-S

<u>Total-S</u> is determined by Leco combustion (@ 1300 °C) with detection of evolved $SO_{2(g)}$ by infra-red spectroscopy. <u>SO₄-S</u> is determined by the Na₂CO₃-Extraction Method (Berigari and Al-Any 1994; Lenahan and Murray-Smith 1986).⁴ The difference between Total-S and SO₄-S indicates the <u>Sulphide-S</u> (strictly Non-Sulphate-S) value. The Total-S and SO₄-S tests are performed on pulps.

1.3 Acid-Consuming Properties

1.3.1 ANC

ANC is determined by a procedure based on that of Sobek *et al.* (1978) which is the "standard" ANC-testing method (AMIRA 2002; Morin and Hutt 1997).

Samples (as crushings) are reacted with dilute HCl for *c*. 2 hours at 80-90 °C, followed by back-titration with NaOH to a pH=7 end-point to determine the amount of acid consumed.⁵ The simmering step for *c*. 2 hours differs from the Sobek *et al.* procedure wherein test-mixtures are heated to near boiling until reaction is deemed to be complete, followed by boiling for one minute. In terms of the dissolution of carbonate- and primary-silicate-minerals, this variation to the Sobek *et al.* method is inconsequential.

The Sobek *et al.* (1978) procedure subjects samples to both strongly-acidic conditions (e.g. pH of 1-2), and a near-boiling temperature. Provided excess acid is added, the dissolution of carbonate-minerals is near-quantitative, and traces of primary-silicates

 $^{^2\,}$ The slurries are stirred at the beginning of the testwork, and once again immediately prior to measuring pH and EC.

³ The pH-(1:2) values approximate the "Abrasion-pH" values for identifying minerals in the field (e.g. Stevens and Carron 1948).

⁴ The Na₂CO₃-reagent extracts SO₄ which occurs as soluble sulphates, and calcium sulphates (e.g. gypsum and anhydrite). It also extracts SO₄ sorbed to the surfaces of sesquioxides, clays and primary-silicates. However, SO₄ present as barytes (BaSO₄) is <u>not</u> extracted, and SO₄ associated with jarositic-type and alunitic-type compounds is incompletely extracted.

⁵ A few drops of 30 % (w/w) H_2O_2 are added to the test mixtures as the pH=7 end-point is approached, so that Fe(II) forms released by the acid-attack of ferroan-carbonates (and -silicates) are oxidised to Fe(III) forms (which then hydrolyse to "Fe(OH)₃"). This step ensures that the resulting ANC values are not unduly biased "on-the-high-side", due to the release of Fe(II) during the acid-digestion step (AMIRA 2002), provided that the ferroan-carbonate content is not excessive (e.g. siderite-C values less than 1.5 % [Stewart *et al.* 2006]).
also dissolve. However, at circum-neutral-pH (viz. pH 6-8) relevant to mine-waste and environmental management, the dissolution of primary-silicates is kinetically limiting (e.g. see review-monograph by White and Brantley [1995]).

In the absence of inhibiting alteration-rims, dissolution rates of mafic/felsic-silicates generally equate to H_2SO_4 -consumption rates 'of-the-order' 10^{-11} - 10^{-12} moles/m²/s. Accordingly, for particle-sizes within the sub-mm range, circum-neutral-dissolution rates of primary-silicates correspond to Sulphide-Oxidation Rates (SORs) 'of-the-order' 1-10 mg SO₄/kg/week (= *c*. 0.1-1.0 kg H₂SO₄/tonne/year).⁶ In practice, circum-neutral buffering through the surface-hydrolysis/dissolution of primary-silicates is therefore restricted to <u>both</u> particle-gradings akin to "rock-flour" (viz. sub-mm), <u>and</u> slow rates of sulphide-oxidation (e.g. as exhibited by "trace-sulphides" which are not atypically reactive).⁷

Despite aggressive-digestion conditions, the ANC values determined by the Sobek *et al.* (1978) method allow an informed "screening" of acid-consuming properties, especially when due regard is given to groundmass-mineralogy (Morin and Hutt 1997). Jambor *et al.* (2005, 2002, 2000) list 'Sobek-ANC' values for different types of primary-silicates which assists interpretation of ANC-testwork results.

That the ANC value is <u>not</u> an intrinsic property of a sample of geologic media, but rather the outcome of the particular ANC-testwork method employed, is shown by Morin and Hutt (2009).

 CO_3 -C is the difference between the Total-C and Total-Organic-C (TOC). Total-C is measured by Leco combustion (@ 1300 °C) with detection of evolved $CO_{2(g)}$ by infrared spectroscopy. TOC is determined by Leco combustion on a sub-sample which had been treated with strong HCl to decompose carbonate-minerals. Pulps are used for these determinations.

1.3.3 pH-Buffering Properties

pH-Buffering properties are determined via a Metrohm[®] 736 Titrino auto-titrator, and 0.05 M-H₂SO₄. Auto-titrations comprise regular addition of H_2SO_4 to decrease the pH values of the test-suspensions (prepared using pulps) to 3.0 typically over the course of

⁶ SORs of this magnitude (at circum-neutral-pH) would typically only be recorded for the oxidation of "trace-sulphides" (e.g. Sulphide-S contents less than *c*. 0.5 %) which are not hyper-reactive, and so excludes *inter alia* framboidal-pyrite, and marcasite.

⁷ Primary-particle-sizes within the "rock-flour" range is a given for process-tailings-solids. In the case of mine-wastes, despite its usually small weight-based abundance, this size-fraction is invariably the main seat of geochemical-weathering reactions within waste-dumps, and thereby the main "source-term" for solute generation (e.g. Price and Kwong 1997). Such "rock-flour" occurs in two forms: that obtained via dry-sieving, and that associated with the surfaces of clasts of wide-ranging sizes, and which can only be obtained via wet-sieving.

c. 1 day.⁸ Despite taking up to 1 day to complete, the H_2SO_4 -addition rates employed in the auto-titrations are 'orders-of-magnitude' <u>faster</u> than the sulphide-oxidation rates typically observed under "ambient-weathering" conditions.

1.4 NAPP Calculations

NAPP values are calculated from Total-S, SO₄-S and ANC values, assuming that <u>all</u> of the Sulphide-S occurs in the form of pyrite, and/or pyrrhotite. NAPP values facilitate assessment of Acid-Formation Potential (AFP).

The complete-oxidation of pyrite (and/or marcasite) may be described by:

 $FeS_2 + 15/4 O_2 + 7/2 H_2 O = 2H_2 SO_4 + "Fe(OH)_3"$

The complete-oxidation of pyrrhotite may be described by:

$$"FeS" + 9/2O_2 + 5/2H_2O = H_2SO_4 + "Fe(OH)_3"$$

Since pyrrhotite is non-stoichiometric, expressing it as "FeS" is approximate (Janzen *et al.* 2000). Elemental-S may also be produced during pyrrhotite weathering (Nicholson and Scharer 1994), especially at low-pH. However, Elemental-S is ultimately oxidised to H_2SO_4 .

It may be shown that, if the Sulphide-S (in %S) occurs as pyrite/pyrrhotite, then the amount of acid (in kg H_2SO_4 /tonne) produced through complete-oxidation is given by <u>**30.6 x %S**</u>. That is, the same conversion-factor of 30.6 applies for both pyrite-, and pyrrhotite-oxidation.

<u>Note</u>: The above treatment of oxidation-reaction stoichiometry is restricted to oxidation by 'atmospheric-O₂' which is the dominant oxidant at circum-neutral-pH. A different oxidation-stoichiometry applies under acidic conditions (e.g. pH less than 3-4) where soluble-Fe(III) forms prevail, and then function as the chief oxidant (e.g. Rimstidt and Newcomb 1993).

Mechanistic aspects of pyrite- and pyrrhotite-oxidation were reviewed by Rimstidt and Vaughan (2003), and Belzile *et al.* (2004), respectively.

1.5 NAG Tests

The NAG Test is a direct measure of the potential for acid-production through sulphideoxidation, and also provides an indication of the reactivity of the sulphide-minerals, and the availability of alkalinity-forms (AMIRA 2002; Miller *et al.* 1997, 1994). Since this test is performed on pulps, sulphide-grains are fully liberated, and available for reaction.

⁸ In titrating to a pH=3.0 end-point, any Fe(II) released through acid attack of ferroan-carbonates and -silicates is <u>not</u> quantitatively oxidised to Fe(III), and subsequently hydrolysed/precipitated to "Fe(OH)₃". The equivalent of *c*. 0.5 kg H₂SO₄/tonne is generally required to decrease the pH of the "solution-only" to pH=3.0. <u>No</u> correction is made for this "electrolyte-consumption" of H₂SO₄.

The sample is reacted with H_2O_2 to oxidise sulphide-minerals, and allow the produced acid to react with the acid-neutralising components (chiefly carbonate-minerals). The results from NAG testwork supplement the NAPP-based assessment of AFP (Stewart *et al.* 2006; Shaw 2005; Morin and Hutt 1997).

The NAG-testing methodology used by GCA is the <u>'Static-NAG Test'</u> in its "singleaddition" mode, with NaOH-titration to a pH=7 end-point (AMIRA 2002; Miller *et al.* 1994, 1997). The Start-pH of the 15 % (v/v) H₂O₂ solution (prepared from A.R.-grade H₂O₂) is adjusted to pH=4.5 using 0.1 M-NaOH. The boiling treatment to decompose residual, unreacted-H₂O₂ following overnight reaction is carried out in two stages (viz. boiling for *c*. 2 hours initially, cooling and addition of 1 mL of 0.02 M-CuSO₄, followed by boiling for a further *c*. 2 hours). The addition of Cu(II) catalyses the decomposition of unreacted-H₂O₂, and thereby prevents "positive-blank" values (McElnea and Ahern 2004; O'Shay *et al.* 1990).⁹

Prior to the boiling steps, the pH values of the test-suspensions are measured. Such pH values reflect buffering under ambient conditions without accelerated dissolution of groundmass-minerals through boiling. In the interpretation of NAG-testwork results, it is important to note the pH values prior to the boiling steps, especially for lithotypes characterised by "trace-sulphides" (e.g. Sulphide-S within the sub-% range), and ANC values less than *c*. 10-20 kg H₂SO₄/tonne (e.g. a groundmass devoid of carbonate-minerals). The rates of "peroxide-oxidation" are orders-of-magnitude faster than those of "ambient-oxidation" (viz. SORs recorded in kinetic-testing employing Weathering-Columns). If circum-neutral-pH is to prevail during NAG testwork, then the rate of acid-consumption must be proportionately faster than that for "ambient-oxidation", and is essentially restricted to buffering by reactive-carbonate-minerals (e.g. calcites, dolomites, and ankerites). This aspect must be borne in mind when interpreting NAG-testwork results, especially for samples that contain "trace-sulphides" in a carbonate-deficient groundmass.

2.0 MULTI-ELEMENT ANALYSES

The total content of a wide range of major- and minor-elements are determined through the use of various digestion and analytical techniques. The respective detection-limits are appropriate for environmental investigations.

Element enrichments are identified using the *Geochemical Abundance Index (GAI)*.¹⁰ The GAI quantifies an assay result for a particular element in terms of the average-

⁹ Where samples contain sufficient Cu(II), then Cu(II) forms will be released to solution during reaction with H_2O_2 , especially at low-pH.

¹⁰ The GAI was developed by Förstner *et al* (1993), and is defined as:

 $GAI = \log_2 \left[C_n / (1.5 \times B_n) \right]$

where:

 C_n = measured content of n-th element in the sample.

 B_n = "background" content of the n-th element in the sample.

crustal-abundance of that element.¹¹ The latter corresponds to the typical composition of soils, regoliths and bedrocks derived from <u>unmineralised</u> terrain.

The GAI (based on a log-2 scale) is expressed in 7 integer increments (viz. 0 to 6). A GAI of 0 indicates that the content of the element is less than, or similar to, the average-crustal-abundance; a GAI of 3 corresponds to a 12-fold enrichment above the average-crustal-abundance; and so forth, up to a GAI of 6 which corresponds to a 96-fold, or greater, enrichment above average-crustal-abundances.

3.0 MINERALOGY AND CLAY-SURFACE CHEMISTRY

The semi-quantitative mineralogy, and clay-surface chemistry (generally restricted to waste-regoliths, oxide-ores, and/or soils), are determined using methods routinely used in geology, and soil science.

Indicative abundances of mineral fall into one of the following broad classes, viz.

• major 20-50	%
• minor 10-20	%
 accessory 2-10 % trace less th 	6 an 2 %

Randomly- and preferentially-oriented specimens are prepared, and variously treated with sodium-hexametaphosphate (dispersant), ethylene-glycol, and heating, to quantify non-expansive, and expansive (e.g. smectites), varieties of clay-minerals.

The Effective-Cation-Exchange Capacity (eCEC), and suite of Exchangeable-Cations, are determined by different methods for samples (as crushings) of non-calcareous and calcareous materials (Rengasamy and Churchman 1999). In both cases, soluble-salts are initially removed via pre-washing using a "mixed-organic-solvent" (viz. ethylene-glycol and ethanol). Method 15A2 in Rayment and Higginson (1992) is then employed for non-calcareous samples to determine eCEC, and Exchangeable-Sodium Percentage (ESP). In the case of calcareous samples, a method based on that described by Pierce and Morris (2004) is used, and prevents the dissolution of carbonate-minerals (e.g. calcites and dolomites).¹² After the initial pre-washing step above, extraction is carried out with 1 M-NH₄Cl buffered at pH=8.5 in an ethanolic-aqueous solution. Without such precautions to suppress dissolution of carbonate-minerals, the eCEC is biased "on-the-high-side", and ESP biased "on-the-low-side". Depending on the abundance and nature of the carbonate-minerals, the magnitude of this bias can be marked.

¹¹ The average-crustal-abundances of the elements for the GAI calculations are based on the values listed in Bowen (1979).

¹² The procedure described by Pierce and Morris (2004) is closely related to that originally developed by Tucker (1974).

4.0 SOLUBILITY OF MAJOR/MINOR-ELEMENTS

4.1 Water-Extraction Testwork

Water-Extraction Testwork on the crushings is performed via the bottle-roll technique, and using deionised-water. The test-slurries have a solid:solution ratio of *c*. 1:2 (w/w), and are bottle-rolled for *c*. 1 day before being left to "still-stand" for *c*. 1 day to allow suspended mineral-fines to settle. The resulting supernatants are decanted, vacuum-filtered (0.45μ m-membrane), and preserved, as appropriate, for specific analyses. Where required, centrifuging at *c*. 4,000 G for 30 minutes is undertaken to expedite solid-solution separation for vacuum-filtration. The Water-Extraction Testwork is performed in the GCA-Testing Laboratory.

4.2 Na₂EDTA-Extraction Testwork

Na₂EDTA-Extraction Testwork (at pH=6) is carried out on the crushings, based on the method described by Clayton and Tiller (1979). The test-slurries have a solid:solution ratio of *c*. 1:2 (w/w), and are bottle-rolled for *c*. 7 days. This testwork provides a measure of the "metal-pool" potentially available for uptake by biota (e.g. absorption by plant roots).

5.0 **REFERENCES**

- AMIRA International Ltd, 2002, "ARD Test Handbook", Prepared by Ian Wark Research Institute, and Environmental Geochemistry International Pty Ltd
- Belzile N, Chen Y-W, Cai M-F and Li Y, 2004, "A Review on Pyrrhotite Oxidation", *Journal of Geochemical Exploration*, <u>84</u>:65-76
- Berigari MS and Al-Any FMS, 1994, "Gypsum Determination in Soils by Conversion to Water-Soluble Sodium Sulfate", *Soil Science Society of America Journal*, <u>58</u>:1624-1627
- Bowen HJM, 1979, "Environmental Chemistry of the Elements", Academic Press, New York Clayton PM and Tiller KG, 1979, "A Chemical Method for the Determination of the Heavy Metal
- Content of Soils In Environmental Studies", Division of Soils, Technical Paper No. 41, CSIRO Förstner U, Ahlf W and Calmano W, 1993, "Sediment Quality Objectives and Criteria Development in Germany", *Water Science & Technology*, 28:307-316
- Jambor JL, Dutrizac JE and Chen TT, 2000, "Contribution of Specific Minerals to the Neutralization Potential in Static Tests", pp. 551-565 in "Proceedings from the Fifth International Conference on Acid Rock Drainage", Volume I, Denver
- Jambor JL, Dutrizac JE, Groat LA and Raudsepp M, 2002, "Static Tests of Neutralization Potentials of Silicate and Aluminosilicate Minerals", *Environmental Geology*, <u>43</u>:1-17
- Jambor JL, Dutrizac JE and Raudsepp M, 2005, "Neutralization Potentials of Some Common and Uncommon Rocks, and Some Pitfalls in NP Measurements", in "Challenges in the Prediction of Drainage Chemistry", Proceedings of the 12th Annual British Columbia – MEND ML/ARD Workshop
- Janzen MP, Nicholson RV and Scharer JM, 2000, "Pyrrhotite Reaction Kinetics: Reaction Rates for Oxidation by Oxygen, Ferric Iron, and for Nonoxidative Dissolution", *Geochimica et Cosmochimica Acta*, <u>64</u>:1511-1522
- Jerz JK and Rimstidt JD, 2004, "Pyrite Oxidation in Moist Air", Geochimica et Cosmochimica Acta, <u>68</u>:701-714
- Lenahan WC and Murray-Smith R de L, 1986, "Assay and Analytical Practice in the South African Mining Industry", The South African Institute of Mining and Metallurgy Monograph Series M6, Johannesburg
- McElnea AE and Ahern CR, 2004, "Peroxide pH (pH_{ox}), Titratable Peroxide Acidity (TPA) and Excess Acid Neutralising Capacity (ANC_E) – Method Codes 23B, 23G and 23Q", Chapter 3 in "Acid

Sulfate Soils Laboratory Methods Guidelines", Eds Ahern CR, McElnea AE and Sullivan LA, Department of Natural Resources, Mines and Energy, Indooroopilly, Queensland

- Miller SD, Jeffery JJ and Donohue TA, 1994, "Developments in Predicting and Management of Acid Forming Mine Wastes in Australia and Southeast Asia", pp. 177-184 in "Proceedings of the International Land Reclamation and Mine Drainage Conference and Third International Conference on the Abatement of Acidic Drainage", Pittsburgh
- Miller S, Robertson A and Donohue T, 1997, "Advances in Acid Drainage Prediction Using the Net Acid Generation (NAG) Test", pp. 535-547 in "Proceedings of the Fourth International Conference on Acid Rock Drainage", Vancouver
- Morin KA and Hutt NM, 1997, "Environmental Geochemistry of Minesite Drainage: Practical Theory and Case Studies", MDAG Publishing, Vancouver
- Morin KA and Hutt NM, 2009, "On the Nonesense of Arguing the Superiority of an Analytical Method for Neutralization Potential", Mine Drainage Assessment Group (MDAG), Internet Case Study #32 (go to: www.mdag.com)
- Nicholson RV and Scharer JM, 1994, "Laboratory Studies of Pyrrhotite Oxidation Kinetics", pp. 14-30 in Alpers CN and Blowes DW (eds), "Environmental Geochemistry of Sulfide Oxidation", ACS Symposium Series 550, American Chemical Society, Washington D.C.
- O'Shay T, Hossner LR and Dixon JB, 1990, "A Modified Hydrogen Peroxide Method for Determination of Potential Acidity in Pyritic Overburden", *Journal of Environmental Quality*, <u>19</u>:778-782
 Pierce CG and Morris S, 2004, "Comparison of Extraction Techniques for Measuring Exchangeable
- Pierce CG and Morris S, 2004, "Comparison of Extraction Techniques for Measuring Exchangeable Cations in Calcareous Soils", *Australian Journal of Soil Research*, <u>42</u>:301-311
- Price W, 2009, "Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials", MEND Report 1.20.1
- Price W and Kwong YTJ, 1997, "Waste Rock Weathering, Sampling and Analysis: Observations from the British Columbia Ministry of Employment and Investment Database", pp. 31-45 in "Proceedings of the Fourth International Conference on Acid Rock Drainage", Vancouver
- Rayment GE and Higginson FR, 1992, "Australian Laboratory Handbook of Soil and Water Chemical Methods", Inkata Press, Melbourne
- Rengasamy P and Churchman GJ, 1999, "Cation Exchange Capacity, Exchangeable Cations and Sodicity", Chapter 9, pp. 147-170 in Peverill KI, Sparrow LA, and Reuter DJ (eds), "Soil Analysis: An Interpretation Manual", CSIRO Publishing, Collingwood
- Rimstidt JD and Vaughan DJ, 2003, "Pyrite Oxidation: A State-of-the-Art Assessment of Reaction Mechanism", *Geochimica et Cosmochimica Acta*, 67:873-880
- Shaw S, 2005, "Case Studies and Subsequent Guidelines for the Use of the Static NAG Procedure", Presentation A.4 in "Proceedings of the 12th Annual British Columbia – MEND ML/ARD Workshop on "Challenges in the Prediction of Drainage Chemistry", November 30 to December 1, 2005, Vancouver, British Columbia
- Sobek AA, Schuller WA, Freeman JR and Smith RM, 1978, "Field and Laboratory Methods Applicable to Overburdens and Minesoils", EPA-600/2-78-054
- Stevens RE and Carron MK, 1948, "Simple Field Test for Distinguishing Minerals by Abrasion pH", *American Mineralogist*, <u>33</u>:31-49
- Stewart WA, Miller SD and Smart R, 2006, "Advances in Acid Rock Drainage (ARD) Characterisation of Mine Wastes", pp. 2098-2117 in "Proceedings from the Seventh International Conference on Acid Rock Drainage", St. Louis, Missouri
- Tucker BM, 1974, "Laboratory Procedures for Cation Exchange Measurements on Soils", Division of Soils Technical Paper No. 23, CSIRO, Melbourne
- White AF and Brantley SL (eds.), 1995, "Chemical Weathering Rates of Silicate Minerals", Reviews in Mineralogy, Volume 31, Mineralogical Society of America, Washington, D.C.

KINETIC-TESTING METHODOLOGY EMPLOYED IN THE GCA-TESTING LABORATORY

1.0 GENERAL

The kinetic-testing methodology employed in the GCA-Testing Laboratory is based on "standard" procedures developed by practitioners, academics, and regulators both within Australia, and the northern-hemisphere (chiefly Canada and USA). Such "standard" procedures vary in detail, but essentially entail inundating a rigid, porous sample-bed in a column (or "cell") to elute solutes produced from weathering, followed by dewatering to promote weathering (e.g. sulphide-oxidation) prior to the next flushing-step. The drying-phase often produces a final moisture status that is at, or close to, residual-moistures/suctions.

The GCA-kinetic-testing methodology also reflects research by Dr. Graeme Campbell since the early-1990s, as governed by the diverse demands of projects in terms of both lithotype traits (viz. geochemistry, mineralogy, and physicals), and biophysical setting of the project-site (especially climate).

Where geochemically logical, modifications to the basic procedure (performed for routine kinetic-testing) are made to meet study objectives, and assist management-decision making (c.f. "blind-adherence" to some "standard" protocol which may provide information on reaction dynamics and solubility behaviour that is inconclusive, at best, or worse still, misleading).

2.0 WEATHERING-COLUMNS

• The (short) weathering-columns allow assessment of reaction dynamics under aeration and moisture regimes which are near-optimal for sulphide-oxidation.

The sample-bed-lengths in the columns are typically within the range **5-7 cm**.

• The weathering-columns, and the geometry of the gantry housing the columns and flood-lamps (see Plate 1a), are based on those described in AMIRA (2002).¹

The main departures from AMIRA (2002) are:

- the power, and operation, of the flood-lamps in order to constrain the maximum/minimum-temperatures of the sample-beds during the drying-phase; and,
- the use of weekly-weathering-cycles (i.e. weekly-flushing), and a greater rate of deionised-water addition during flushing.

¹ Six (6) flood-lamps are employed per ten (10) weathering-columns to ensure that the "end-columnpairs" receive the same daily heat-loads as the other "internal-column-pairs" (c.f. the use of 4 flood-lamps per 10 columns, as per AMIRA [2002], where the "end-column-pairs" receive reduced daily heat-loads).

Salient details of the above are discussed below.

2.1 Sample-Bed-Temperature Control

- The gantry housing the weathering-columns is located in a modern, high-ceiling (c. 10 m), workshop-type area fitted with roof-venting-whirlygigs, but without air-conditioning.² Accordingly, ambient-temperatures vary both diurnally, and seasonally, under the (inland) Mediterranean climate of Bridgetown.
- In order to constrain variations in the sample-bed-temperatures, 80W-floodlamps are employed, and turned-on intermittently during the night-time (via automatic-timers) as follows (see Plate 1b):
 - June to September

9 hrs: 17.00-19.00, 22.00-24.00, 2.00-5.00, and, 7.00-9.00

• October to May

6 hrs: 22.00-24.00, 2.00-5.00, and, 8.00-9.00

The above differs from that described in AMIRA (2002) where 150W-floodlamps are turned-on continuously during the daytime for *c*. 8-10 hrs. Although it is implied in AMIRA (2002) that this setup maintains a surface-temperature of *c*. 30-35 °C, this is not the case under the conditions of our laboratory.

GCA-research (unpublished) using columns instrumented with thermistors and soil-moisture sensors, and automatically logged hourly (see Plate 2), has shown that, during the latter stages of drying when residual-moisture contents are attained, the methodology described in AMIRA (2002) results in summer-peak-temperatures (for *c*. 1-2 hrs in mid-afternoon) up to *c*. 70-80 °C in the top *c*. 10 mm on the side of the sample-beds closest to the centre of the flood-lamps (i.e. near-lamp-side).³ However, with the 80W-flood-lamps operated intermittently during the night-time, the near-lamp-side temperature in the top *c*. 10 mm ranges up to *c*. 40 °C only on extreme-summer-days. Since the peak-temperature is in the top *c*. 10 mm on the near-lamp-side, the remainder of the sample-bed has temperatures ranging up to no greater than 30-40 °C.

 $^{^2}$ To routinely operate multiple (e.g. 20-30+) heat-lamps simultaneously to dewater multiple columns, and then to attempt to "air-condition" the working area via refrigerated-air-conditioning, would be, these days, environmentally irresponsible.

³ The temperature extremes are realised as residual-moistures are approached, due to the limited contribution of water to the heat-capacity of the sample-bed/water/air mixture overall. In the 4-weekly-weathering-cycles of the AMIRA (2002) procedure, the sample-beds are only "partially-wetted" in 3 of the 4 weeks (c.f. saturated when flushing), so that residual-moistures occur for quite a number of days during each cycle. The above extreme-summer-peak-temperatures would then prevail for quite a number of days during weathering-cycles that span the summer period.

Likewise, during winter, the operation of the 80W-flood-lamps during the nighttime ensures that the basal-section of the sample-beds on the far-lamp-side have winter-peak-temperatures typically above 10-15 °C during the coldest nights with ambient-temperature-minima near 5 °C.⁴ During the winter-months, the flood-lamps are operated 9 hrs per day (c.f. 6 hrs per day for the rest of year) to ensure that sulphide-oxidation is not limited by restricted evaporative-drying (i.e. relative-saturation of pore-spaces remaining above 80-85 % for too long).⁵

Summarising, operation of weathering-columns in the GCA-Testing Laboratory, as described, has been proved to constrain maximum-sample-bed-temperatures to within 30-40 °C during the latter stages of the drying-phase when residual-moisture are attained, even on extreme-summer days.

In terms of assessing the temperature dependence of sulphide-oxidation rates (SORs), the winter- and summer-peak-SORs broadly correspond to meansample-bed-temperatures of 20 °C, and 30 °C, respectively. Therefore, where SORs have more-or-less stabilised during kinetic-testing (as often observed during circum-neutral-weathering), the difference between the peak-seasonal-SORs, together with the mean-peak-seasonal-temperature difference of 10 °C, allows estimation of the activation-energy (E_a) for sulphide-oxidation specific to the tested-lithotype.⁶ Such lithotype-specific estimates of E_a then serve as useful input to geochemical modelling of sulphide-oxidation rates at field-scale (and so supplement literature-derived E_a values obtained for "pristine" (i.e. sulphidegrain-surfaces purposely "pre-cleaned"), monomineralic specimens of specific sulphide-minerals [e.g. pyrite]).

2.2 Weekly-Weathering-Cycles

٠

• The columns are weighed each day to track the rate, and extent, of dewatering.⁷

Where the attainment of residual-moisture contents is not desired (e.g. for minesites in well-watered settings), an addition of 0.10-0.20 kg of deionised-water is added to "wet" (but not "flush") the sample-beds part way through the dryingphase of each weathering-cycle. The amount and timing of such "remoistening" is sample- and project-specific.

⁴ In terms of the peak-temperatures attained with the AMIRA (2002) procedure during the wintermonths, the instrumented-columns showed that the top c. 10 mm on the near-lamp-side of the samplebeds reached c. 45-50 °C as residual-moistures were approached.

⁵ Pan-evaporation (E_{pan}) rates are routinely determined, and range from 3-5 mm/day over the winterpeak, to 6-8 mm/day over the summer-peak.

 $^{^{6}}$ In practice, it generally means that the kinetic-testing programme would need to run for at least 1-2 years in order to capture the seasonal-extremes of "stable-SORs" for E_a estimation.

 $^{^7\,}$ Due to the "sub-decimetre" thickness of the sample-beds, and the seepage-face-lower-boundary condition, the actual-evaporation rates (E_{actual}) are typically close to the corresponding E_{pan} rates until residual-moisture/suctions are approached.

- The flood-lamps are operated intermittently commencing on Monday, Tuesday, Wednesday, and Thursday evenings/nights (i.e. flood-lamps operated over four nights during each weathering-cycle). The flushing-step is undertaken latemorning on Fridays, and corresponds to a **"flooding-with-ponding"** mode of deionised-water addition. Where required, the top 5-10 mm of the sample-bedsurface is worked-over with a spatula to fill-in/seal-over, any desiccation-cracks developed during the drying-phase, and thereby prevent inefficient leaching from "breakthrough", and "by-pass", during the flushing-step.
 - The AMIRA (2002) procedure involves the wetting of the sample-beds at the end of Week-1, Week-2, and Week-3, and then flushing at the end of Week-4 to produce leachates for analysis (i.e. 4-weekly-flushing regime with weekly-wetting between). The rate of deionised-water addition (viz. 0.10 kg deionised-water per kg solids) in the wetting-step is typically shy of "field-capacity" (enhanced by the seepage-face-lower-boundary condition), so there is generally no drainage.

Weekly-weathering-cycles (i.e. flushing with leachate collection on a weekly basis) are employed in the GCA procedure.

Typically, there is **1.50 kg** (dry-solids-equivalent) of sample in each weatheringcolumn.⁸ 1.00 kg of deionised-water is generally added to each column during the flushing-step, corresponding to 0.66 kg of deionised-water per kg of solids (i.e. 1.00 kg of deionised-water used to flush 1.50 kg of solids). This rate of water addition exceeds the 0.40 kg per kg solids advocated in AMIRA (2002) which occurs every 4-weeks (c.f. 2.7 kg of deionised-water per kg solids over 4weeks herein). Where the Leachate-EC value indicate that flushing of solutes from the columns is limited, then a second 1.00-kg-lot of deionised-water is added, and a "communal-leachate" then generated.⁹

The weekly-flushing regime, and rate of deionised-water addition, employed by GCA is similar to that typically employed in "humidity-cell" testing in Canada, and the USA (Price 2009; Morin and Hutt 1997; ASTM 2007).

- In broad terms, the addition of 1.00 kg of deionised-water to each column corresponds to a storm-depth of c. 45 mm. This provides a useful, approximate basis for cross-correlating lab-weathering and field-weathering dynamics under the episodic, pulsed rainfall-regime of the Australian interior.
- The residence-time of water during the flushing-step is generally ranges up to *c*. 12 hrs, as governed by sample texture.

 $^{^{8}}$ With 1.50 kg of solids in each column there is sufficient free-board, and so expedites flushing with deionised-water.

⁹ EC = Electrical-Conductivity.

• The leachates are collected in beakers beneath the columns, and left to "age" under ambient conditions until the Monday when the next weathering-cycle commences.

All leachates are weighed (for mass-balance calculations), prior to Leachate-pH and Leachate-EC values being determined, followed by vacuum-filtering (0.45- μ m-membrane), and preservation, as appropriate, for the determination of specific analytes.

Prior to commencing the weathering-cycles, the GCA-columns are subjected to a thorough pre-rinsing treatment using deionised-water to elute pre-existing solutes. Pre-rinsing is continued using 1.00-kg lots of deionised-water until the EC value of the "last-incremental-leachate" (e.g. last 100 mL) is less than *c*. 300-500 μ S/cm. This pre-rinsing step facilitates interpretation of the kinetictesting results overall.

3.0 REFERENCES

•

- AMIRA International Ltd, 2002, "ARD Test Handbook", Prepared by Ian Wark Research Institute, and Environmental Geochemistry International Pty Ltd
- ASTM, 2007, "Standard Test Method for Laboratory Weathering of Solid Materials Using a Humidity Cell", ASTM D 5744-07.
- Morin KA and Hutt NM, 1997, "Environmental Geochemistry of Minesite Drainage: Practical Theory and Case Studies", MDAG Publishing, Vancouver
- Price W, 2009, "Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials", MEND Report 1.20.1



Plate 1a: Typical Weathering-Column Assembly

Layout and configuration-geometry as per AMIRA (2002).



Plate 1b: Seasonal and Diurnal Schedule for Operation of 80W-Flood-Lamps.

Required variation to AMIRA (2002) in order to constrain maximum-temperatures of sample-beds to within 30-40 $^{\rm o}C.$



Plate 2: GCA-Research Project: Instrumented-Weathering-Column with -4.75mm Fraction of Trace-Sulphide/Calcareous-Basalt-waste-bedrock Sample.

Circum-neutral Weathering.

Volumetric-Water Content (VWC) of upper-half and lower-half of sample-beds logged hourly using calibrated MP406-sensors.

Temperature of top c. 10 mm, and bottom c. 10 mm, on both the near-lamp-side, and far-lamp-side (as seen in front of columns in photograph), logged hourly using thermistors.

Daily-pan-evaporation rates determined via daily weighing of perspex-container to the left of columns.

ATTACHMENT III

ACID-FORMATION POTENTIAL (AFP):

CALCULATED PARAMETERS AND CLASSIFICATION CRITERIA

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ATTACHMENT III

ACID-FORMATION POTENTIAL (AFP):

CALCULATED PARAMETERS AND CLASSIFICATION CRITERIA

<u>Notes</u>: The geochemically-based parameters, and AFP-classification criteria, indicated below apply equally to samples of mine-wastes (e.g. waste-regoliths and waste-bedrocks), low-grade-ores, and process-tailings-solids. The generic descriptor "test-sample" is employed below.

1.0 CALCULATED PARAMETERS

<u>Maximum-Potential-Acidity (MPA)</u> values (in kg H_2SO_4 /tonne) of test-samples are typically calculated by multiplying the Sulphide-S values (in %) by 30.6. The multiplication-factor of 30.6 reflects both the reaction stoichiometry for the complete-oxidation of pyrite, by O₂ to "Fe(OH)₃" and H₂SO₄, and the different weight-based units of %, and kg H₂SO₄/tonne.

<u>Net-Acid-Producing-Potential (NAPP)</u> values (in kg H_2SO_4 /tonne) are calculated from the corresponding MPA and <u>Acid-Neutralisation-Capacity (ANC)</u> values (i.e. NAPP = MPA - ANC).

2.0 CLASSIFICATION CRITERIA

In terms of AFP, test-samples may be classified into one of the following categories, viz.

- Non-Acid Forming (NAF)
- <u>Potentially-Acid Forming (PAF)</u>

There are **no** unifying, "standard" criteria for classifying the AFP of test-samples (e.g. Price 2009; AMIRA 2002), and reflects the diversity of sulphide- and gangue-mineral assemblages within (un)mineralised-lithotypes of varying weathering- and alteration-status. Rather, criteria for classifying AFP may need to be tailored to deposit-specific geochemistry, mineralogy, and site-specific climate.

The AFP-classification criteria often employed at mining-operations worldwide are:

- <u>NAF</u>: Sulphide-S < 0.3 %. For Sulphide-S \ge 0.3 %, <u>both</u> a negative NAPP value, <u>and</u> an ANC/MPA ratio \ge 2.0
- **<u>PAF</u>**: For Sulphide-S \ge 0.3 %, any positive-NAPP value; negative-NAPP value with an ANC/MPA ratio < 2.0

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In assessing AFP, lithotypes from hard-rock mines with Sulphide-S values less than 0.3 % are unlikely to acidify (e.g. pH less than 4-5) through sulphide-oxidation. This position holds especially where the groundmass hosting the "trace-sulphides" is <u>not</u> simply quartz, soil-clays, and/or sesquioxides (Price *et al.* 1997), and where the sulphide-minerals are <u>not</u> hyper-reactive varieties (e.g. framboidal-pyrite). A "cut-off" of 0.3 % for Sulphide-S also accords with the findings of kinetic-testing, since the late-1980s, by Dr. Graeme Campbell for test-samples of diverse mineralogy in terms of sulphide-weathering dynamics, and solubility behaviour.

The risk posed by PAF-lithotypes during the active-mine-life is governed primarily by the duration of the <u>lag-phase</u> (i.e. the period during which sulphide-oxidation occurs, but acidification does <u>not</u> develop, due to circum-neutral buffering by gangue-phases [chiefly reactive-carbonate-minerals]).¹ Although the duration of the lag-phase for mine-wastes at field-scale cannot be accurately predicted *a priori*, estimates may still be needed to identify threshold exposure-times for the safe handling of PAF-lithotypes. Lag-phase duration may be estimated via kinetic-testing (viz. Weathering-Columns), and consideration of the moisture/aeration/thermal-regimes of exposed (i.e. uncovered) mine-wastes under the site's climatic conditions. In the absence of results from kinetic-testing, experience permits "first-pass" estimates of sulphide-oxidation rates and lag-phase duration to be made from the results of static-testing, and thereby classify PAF-lithotypes into **PAF-[Short-Lag]** and **PAF-[Long-Lag]** sub-categories. Such "first-pass" estimations are necessarily provisional, and subject to revision, in the light of the outcomes of kinetic-testing, and field observations.

3.0 REFERENCES

- AMIRA International Ltd, 2002, "ARD Test Handbook", Prepared by Ian Wark Research Institute, and Environmental Geochemistry International Pty Ltd
- Price W, 2009, "Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials", MEND Report 1.20.1
- Price WA, Morin K and Hutt N, 1997, "Guidelines for the Prediction of Acid Rock Drainage and Metal Leaching for Mines in British Columbia: Part II. Recommended Procedures for Static and Kinetic Testing", pp. 15-30 in "Proceedings of the Fourth International Conference on Acid Rock Drainage", Volume I, Vancouver

 $^{^1}$ SO₄ is still produced by sulphide-oxidation during the lag-phase, and appreciable amounts of solubleforms of certain minor-elements (e.g. Ni and As) may be released at circum-neutral-pH during lag-phase weathering. However, in the latter case, the mine-wastes would need to be sufficiently enriched in Total-Ni and Total-As to begin with.

ATTACHMENT IV

LABORATORY REPORTS

Graeme Campbell & Associates Pty Ltd



Roger Townend and Associates Consulting Mineralogists

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GRAEME CAMPBELL AND ASSOC.

2-11-2011

PO BOX 247,

BRIDGETOWN

WA

OUR REFERENCE 22987

YOUR REFERENCE: 1112/2 (FLINDERS PIOP)

XRD/PLM ANALYSIS OF ONE ROCK PULP.

D TOWNEND

RESULTS XRD/PLM ANALYSES

MINERAL	GCA9766
HEMATITE	DOMINANT
GOETHITE	ACCESSORY
QUARTZ	MINOR
KAOLINITE	MINOR
LEUCOXENE	TRACE
BIOTITE	TRACE
CARBONATE	TRACE

Roger Townend and Hssociates



Intertek

Dr G Campbell CAMPBELL, GRAEME and ASSOCIATES PTY LTD PO Box 247 BRIDGETOWN WA 6255

JOB INFORMATION

JOB CODE	143/1107964
No. of SAMPLES	1
CLIENT O/N	GCA 1112/2
PROJECT	Pilbara Iron-Ore
STATE	Tailings Samples
DATE RECEIVED	8/06/2011
DATE COMPLETED	24/06/2011

LEGEND

- X = Less than Detection Limit
- N/R = Sample Not Received
 - = Result Checked
- () = Result still to come
- I/S = Insufficient Sample for Analysis
- E6 = Result X 1,000,000
- UA = Unable to Assay
- > = Value beyond Limit of Method

The sample was received as tailings solid. The sample was dried at 80C crushed to a nominal -2mm. A split was taken and fine pulverised to a nominal -75um

Results of analysis on:

Element		S	S-SO4	С	TOC+C	C-CO3
Method		/CSA	S72/GR	/CSA	C71/CSA	/CALC
Detection		0.01	0.01	0.01	0.01	0.01
Units		%	%	%	%	%
Sample Name						
Control Blank		Х	Х	0.02	Х	
GCA9766		0.02	0.01	0.24	0.17	0.07
GCA9766	check	0.01	0.01	0.23	0.16	0.07
OREAS 93		0.71		0.12		
MA-1b		1.22		2.48		
TOC-1					1.41	
S_SO4_A			0.56			
S_SO4_B			1.28			

Notes

- 1. Total-S and Total-C were determined on the pulps
- Total-C and Total-S was determined using an induction furnace according to Genalysis method number MPL_W043. The samples are ignited in oxygen ~1700C and the CO2 and SO2 measured by infrared detectors
- 3. S-SO4 was determined on the pulps by precipitation of BaSO4 according to Genalysis method number ENV_W039, after digestion with Na2CO3
- TOC+C (acid insoluble carbon compounds and elemental carbon) by a C&S analyser after removal of carbonates and soluble organic carbon using hot hydrochloric acid according to Genalysis method number MPL_W046.

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Results of analysis on:

sample		Fizz	volume	HCI	NaOH	Colour	pН	ANC	ANC
name		Rate	ml	М	М	Change	Drop	soln pH	(kgH2SO4/t)
GCA9766		0	8	0.558	0.188	N		1.4	5
GCA9766	check	0	8	0.558	0.188	N		1.5	4

Notes:

- 1. ANC was determined on 2g of the crushings -. Acid concentrations are as stated.
- 2. Colour change: Y indicates the appearance of a green colouration as the pH=7 endpoint was approached. N indicates no colour change. Two drops of 30 % hydrogen peroxide are added to each sample as the endpoint is approached to oxidise any ferrous iron.
- 3. pH drop : Result reported when the pH drops to a value below 4 on addition of peroxide
- 4. This "Bulk-ANC" static-testing procedure is based on AMIRA (2002), according to Genalysis method number ENV_W035

NATA ENDORSED DOCUMENT

Company Accreditation Number 3244

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NATA Signatory: Ann Evers

Ann Evers

Date: 24/06/2011



This document is issued in accordance with NATA accreditation requirements.

Laboratory Report

NET-ACID-GENERATION (NAG) TESTWORK

Sample	Sample Weight	Comments	pH of Test Mixture	A	Test Mixture fter Boiling Step	Titre [0.1 M-	NAG (kg H ₂ SO ₄ /
Number	(g)		Before	pН	EC (µS/cm)	NaOH]	tonne)
			Boiling Step			(mL)	
GCA9766	3.0	No apparent reaction	5.2	5.5	29	0.20	<0.5
GCA9766-1	3.0	No apparent reaction	5.2	5.6	28	0.30	<0.5
BLANK1	3.0	Reaction peaked overnight	5.8	7.1	62	_	<0.5

Notes: Test conditions based on those described by Miller *et al.* (1997), and AMIRA (2002) for the 'Static-NAG-Test' in its "Single-Additon-Mode". The pH of the 15 % (v/v) H_2O_2 solution was adjusted to 4.5 using 0.1 M-NaOH prior to commencing the NAG Tests. Following an overnight-reaction period, the test-mixtures were boiled for *c.* 2 hours. Then, after allowing the test-mixtures to cool, *c.* 1.0 mL of 0.016 M-CuSO₄ solution was added, and the test-mixtures again boiled for *c.* 2 hours. The addition of Cu(II) catalyses the decomposition of any residual, unreacted- H_2O_2 in the test-mixtures (McElnea and Ahern 2004; O'Shay *et al.* 1990). K-Feldspar was employed for the Blank.

Dr GD Campbell 12th September 2011





ANALYTICAL REPORT

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JOB INFORMATION

JOB CODE	:	143.0/1108180
No. of SAMPLES	:	1
No. of ELEMENTS	:	33
CLIENT O/N	:	GCA1112/2 (Job 1 of 1)
SAMPLE SUBMISSION No.	:	
PROJECT	:	Pilbara Iron-Ore Project
STATE	:	Ex-Pulp
DATE RECEIVED	:	14/06/2011
DATE COMPLETED	:	27/06/2011
DATE PRINTED	:	27/06/2011
PRIMARY LABORATORY	:	Genalysis Main Laboratory

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LEGEND

Х	= Less than Detection Limit
N/R	= Sample Not Received
*	= Result Checked
()	= Result still to come
I/S	= Insufficient Sample for Analysis
E6	= Result X 1,000,000
UA	= Unable to Assay
>	= Value beyond Limit of Method
OV	= Value over-range for Package

SAMPLE DETAILS

DISCLAIMER

Genalysis Laboratory Services Pty Ltd wishes to make the following disclaimer pertaining to the accompanying analytical results.

Genalysis Laboratory Services Pty Ltd disclaims any liability, legal or otherwise, for any inferences implied from this report relating to either the origin of, or the sampling technique employed in the collection of, the submitted samples.

SIGNIFICANT FIGURES

It is common practice to report data derived from analytical instrumentation to a maximum of two or three significant figures. Some data reported herein may show more figures than this. The reporting of more than two or three figures in no way implies that the third, fourth and subsequent figures may be real or significant.

Genalysis Laboratory Services Pty Ltd accepts no responsibility whatsoever for any interpretation by any party of any data where more than two or three significant figures have been reported.

SAMPLE STORAGE DETAILS

GENERAL CONDITIONS

SAMPLE STORAGE OF SOLIDS

Bulk Residues and Pulps will be stored for 60 DAYS without charge. After this time all Bulk Residues and Pulps will be stored at a rate of \$3.30 per cubic metre per day until your written advice regarding collection or disposal is received. Expenses related to the return or disposal of samples will be charged to you at cost. Current disposal cost is charged at \$100.00 per cubic metre.

SAMPLE STORAGE OF SOLUTIONS

Samples received as liquids, waters or solutions will be held for 60 DAYS free of charge then disposed of, unless written advice for return or collection is received.

NOTES

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Company Accreditation Number 3244

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The analysis results reported herein have been obtained using the following methods and conditions:

The samples as listed were received as being 'Tailing-Solids' which had been dried and pulverised in a zirconia bowl as per Genalysis job number 143_0_1107964.

The results have been determined according to Genalysis methods codes : Digestions : MPL_W001 (4A/), MPL_W005 (SE1/), ENV_W012 (FC7/SIE), MPL_W011 (FP1/), MPL_W008 (HG1/). Analytical Finishes: ICP_W004 (/OE), ICP_W005 (/MS), and AAS_W004 (/CV).

The results included the assay of blanks and international reference standards STSD-2, AMIS0076 and AMIS0085 and Genalysis in-house standards HgSTD-4 and OREAS 97.01

The results are expressed as parts per million or percent by mass in the dried and prepared material.

NATA Signatory: A Evers Chief CHemist

Date: 27/06/2011 This document is issued in accordance with NATA's accreditation requirements.

ANALYSIS										
ELEMENTS	Ag	AI	As	В	Ва	Bi	Ca	Cd	Co	Cr
UNITS	ppm	%	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm
DETECTION LIMIT	0.01	0.01	0.5	50	0.1	0.01	0.1	0.02	0.1	50
DIGEST	4A/	FP1/	4A/	FP1/	4A/	4A/	FP1/	4A/	4A/	FP1/
ANALYTICAL FINISH	MS	OE	MS	OE	MS	MS	OE	MS	MS	OE
SAMPLE NUMBERS										
0001 GCA9766	2.88	3.21	15.8	Х	20.4	0.24	0.2	0.06	2.7	104
CHECKS										
0001 GCA9766	2.85	3.24	14.9	Х	19.4	0.22	0.2	0.04	2.7	96
STANDARDS										
0001 AMIS0076		1.50		Х			0.3			1004
0002 AMIS0085	0.38		68.7		357.1	0.46		0.18	24.6	
0003 HgSTD-4										
0004 OREAS 97.01										
0005 STSD-2										
BLANKS										
0001 Control Blank	0.05	Х	Х	Х	0.3	Х	0.1	Х	Х	Х
0002 Control Blank		Х		Х			0.1			Х
0003 Control Blank										
0004 Acid Blank	Х		Х		Х	Х		Х	Х	
0005 Acid Blank		Х		Х			Х			Х
0006 Acid Blank										

			ANA	ALYS	IS					
ELEMENTS	Cu	F	Fe	Hg	к	Mg	Mn	Мо	Na	Ni
UNITS	ppm	ppm	%	ppm	%	%	ppm	ppm	ppm	ppm
DETECTION LIMIT	1	50	0.01	0.01	0.05	0.01	1	0.1	20	1
DIGEST	4A/	FC7/	FP1/	HG1/	FP1/	FP1/	4A/	4A/	4A/	4A/
ANALYTICAL FINISH	OE	SIE	OE	CV	OE	OE	OE	MS	OE	OE
SAMPLE NUMBERS										
0001 GCA9766	14	163	48.62	0.01	0.08	0.08	165	2.2	167	9
CHECKS										
0001 GCA9766	13	208	48.74	0.01	0.11	0.08	170	2.2	170	10
STANDARDS										
0001 AMIS0076			3.50		0.36	0.30				
0002 AMIS0085	430						498	3.9	1.27%	66
0003 HgSTD-4				0.38						
0004 OREAS 97.01										
0005 STSD-2		1004								
BLANKS										
0001 Control Blank	2	Х	0.02	Х	Х	Х	1	Х	Х	1
0002 Control Blank			0.02		Х	Х				
0003 Control Blank				Х						
0004 Acid Blank	Х						Х	Х	Х	Х
0005 Acid Blank			Х		Х	Х				
0006 Acid Blank				Х						

ANALYSIS										
ELEMENTS	Р	Pb	S	Sb	Se	Si	Sn	Sr	Th	TI
UNITS	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm
DETECTION LIMIT	50	0.5	50	0.05	0.01	0.1	0.1	0.05	0.01	0.02
DIGEST	4A/	4A/	4A/	4A/	SE1/	FP1/	4A/	4A/	4A/	4A/
ANALYTICAL FINISH	OE	MS	OE	MS	MS	OE	MS	MS	MS	MS
SAMPLE NUMBERS										
0001 GCA9766	430	18.3	214	1.82	1.00	5.7	3.5	6.84	6.64	0.06
CHECKS										
0001 GCA9766	437	16.8	211	1.72	0.83	5.7	3.8	6.86	6.46	0.05
STANDARDS										
0001 AMIS0076						35.8				
0002 AMIS0085	314	128.9	3483	10.54			3.2	105.62	54.26	1.10
0003 HgSTD-4										
0004 OREAS 97.01					0.71					
0005 STSD-2										
BLANKS										
0001 Control Blank	Х	Х	Х	Х	Х	Х	0.1	Х	Х	Х
0002 Control Blank						Х				
0003 Control Blank										
0004 Acid Blank	Х	Х	Х	Х			Х	Х	0.01	Х
0005 Acid Blank						Х				
0006 Acid Blank										

Page	7	of	8
Pa	ari	t 4,	/4

			ANA	LYS	IS	IS
ELEMENTS	U	V	Zn			
UNITS	ppm	ppm	ppm			
DETECTION LIMIT	0.01	1	1			
DIGEST	4A/	4A/	4A/			
ANALYTICAL FINISH	MS	OE	OE			
SAMPLE NUMBERS						
0001 GCA9766	1.36	58	23			
CHECKS						
0001 GCA9766	1.35	57	22			
STANDARDS						
0001 AMIS0076						
0002 AMIS0085	273.25	30	94			
0003 HgSTD-4						
0004 OREAS 97.01						
0005 STSD-2						
BLANKS						
0001 Control Blank	Х	Х	2			
0002 Control Blank						
0003 Control Blank						
0004 Acid Blank	Х	Х	Х			
0005 Acid Blank						
0006 Acid Blank						

METHOD CODE DESCRIPTION

4A/MS

Genalysis Main Laboratory

Multi-acid digest including Hydrofluoric, Nitric, Perchloric and Hydrochloric acids in Teflon Tubes. Analysed by Inductively Coupled Plasma Mass Spectrometry.

4A/OE

Genalysis Main Laboratory

Multi-acid digest including Hydrofluoric, Nitric, Perchloric and Hydrochloric acids in Teflon Tubes. Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.

FC7/SIE Genalysis Main Laboratory

Alkaline fusion (Nickel crucible) specific for Fluorine. Analysed by Specific Ion Electrode.

FP1/OE Genalysis Main Laboratory

Sodium peroxide fusion (Nickel crucibles) and Hydrochloric acid to dissolve the melt. Analysed by Inductively Coupled PI

HG1/CV Genalysis Main Laboratory

Low temperature Perchloric acid digest specific for Mercury. Analysed by Cold Vapour Generation Atomic Absorption Spectrometry.

SE1/MS

Genalysis Main Laboratory

Aqua-Regia digest followed by Precipitation and Concentration. Specific for Selenium. Analysed by Inductively Coupled PI





ANALYTICAL REPORT

Dr G. CAMPBELL CAMPBELL, GRAEME and ASSOCIATES PO Box 247 BRIDGETOWN, W.A. 6255 AUSTRALIA

JOB INFORMATION

JOB CODE	÷	143.0/1108182
No. of SAMPLES	:	1
No. of ELEMENTS	:	14
CLIENT O/N	:	GCA1112/2 (Job 1 of 1)
SAMPLE SUBMISSION No.	:	
PROJECT	:	Pilbara Iron-Ore Project
STATE	:	Ex-Pulp
DATE RECEIVED	:	14/06/2011
DATE COMPLETED	:	06/07/2011
DATE PRINTED	:	21/07/2011
PRIMARY LABORATORY	:	Genalysis Main Laboratory

MAIN OFFICE AND LABORATORY

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LEGEND

Х	= Less than Detection Limit
N/R	= Sample Not Received
*	= Result Checked
()	= Result still to come
I/S	= Insufficient Sample for Analysis
E6	= Result X 1,000,000
UA	= Unable to Assay
>	= Value beyond Limit of Method
OV	= Value over-range for Package

SAMPLE DETAILS

DISCLAIMER

Genalysis Laboratory Services Pty Ltd wishes to make the following disclaimer pertaining to the accompanying analytical results.

Genalysis Laboratory Services Pty Ltd disclaims any liability, legal or otherwise, for any inferences implied from this report relating to either the origin of, or the sampling technique employed in the collection of, the submitted samples.

SIGNIFICANT FIGURES

It is common practice to report data derived from analytical instrumentation to a maximum of two or three significant figures. Some data reported herein may show more figures than this. The reporting of more than two or three figures in no way implies that the third, fourth and subsequent figures may be real or significant.

Genalysis Laboratory Services Pty Ltd accepts no responsibility whatsoever for any interpretation by any party of any data where more than two or three significant figures have been reported.

SAMPLE STORAGE DETAILS

GENERAL CONDITIONS

SAMPLE STORAGE OF SOLIDS

Bulk Residues and Pulps will be stored for 60 DAYS without charge. After this time all Bulk Residues and Pulps will be stored at a rate of \$3.30 per cubic metre per day until your written advice regarding collection or disposal is received. Expenses related to the return or disposal of samples will be charged to you at cost. Current disposal cost is charged at \$100.00 per cubic metre.

SAMPLE STORAGE OF SOLUTIONS

Samples received as liquids, waters or solutions will be held for 60 DAYS free of charge then disposed of, unless written advice for return or collection is received.

			AN/	ALYS	IS					
ELEMENTS	AI2O3	CaO	Cr2O3	Fe2O3	K2O	LOI	MgO	MnO	Na2O	P2O5
UNITS	%	%	%	%	%	%	%	%	%	%
DETECTION LIMIT	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.002
DIGEST	FB1/	FB1/	FB1/	FB1/	FB1/		FB1/	FB1/	FB1/	FB1/
ANALYTICAL FINISH	XRF50	XRF50	XRF50	XRF50	XRF50	/TGA	XRF50	XRF50	XRF50	XRF50
SAMPLE NUMBERS										
0001 GCA9766	6.76	0.07	Х	75.07	0.04	3.85	0.11	0.02	0.03	0.112
CHECKS										
0001 GCA9766	6.80	0.06	Х	74.98	0.04	3.86	0.12	0.02	0.03	0.111
STANDARDS										
0001 SY-4	20.66	7.93	Х	6.20	1.66		0.52	0.11	7.24	0.125
BLANKS										
0001 Control Blank	Х	Х	Х	Х	Х	0.07	Х	Х	Х	Х

			AN/	ALYS
ELEMENTS	SO3	SiO2	TiO2	Total
UNITS	%	%	%	%
DETECTION LIMIT	0.002	0.01	0.01	0.01
DIGEST	FB1/	FB1/	FB1/	FB1/
ANALYTICAL FINISH	XRF50	XRF50	XRF50	XRF50
SAMPLE NUMBERS				
0001 GCA9766	0.059	13.34	0.56	100.02
CHECKS				
0001 GCA9766	0.057	13.21	0.56	99.85
STANDARDS				
0001 SY-4	0.044	49.93	0.29	
BLANKS				
0001 Control Blank	Х	99.51	Х	

METHOD CODE DESCRIPTION

Genalysis Main Laboratory

No digestion or other pre-treatment undertaken. Analysed by Thermal Gravimetric Analyser

FB1/XRF50 Genalysis Main Laboratory

/TGA

Fused Disk preparation for XRF analysis Analysed by XRF Spectrometry. Clay Minerals Package

Intertek



Dr G Campbell CAMPBELL, GRAEME and ASSOCIATES PTY LTD PO Box 247 BRIDGETOWN WA 6255

JOB INFORMATION

JOB CODE	143.0/1108181
No. of SAMPLES	1
CLIENT O/N	GCA 1112/2
PROJECT	Pilbara Iron–Ore Project
STATE	Tailings Solid
DATE RECEIVED	8/06/2011
DATE COMPLETED	7/07/2011

LEGEND

()

>

- X = Less than Detection Limit
- N/R = Sample Not Received
 - = Result Checked
 - = Result still to come
- I/S = Insufficient Sample for Analysis
- E6 = Result X 1,000,000
- UA = Unable to Assay
 - = Value beyond Limit of Method

The sample was received as a dry tailings solid and was indicated to be non calcareous i.e C-CO3<0.1%

The digest NH4Cl7 was used as follows for these non calcareous samples:

2g of each of the samples were weighed into a centrifuge tube and pre- washed with 2x 25ml 10 % (v/v) deionised ethylene glycol in 90 % (v/v) ethanol which has been previously deionised by passing through Amberlite resin

After the centrifuge stage there may be finely dispersed material in suspension. If this is the case a few drops of PVA may be necessary. The PVA aqueous solution is 0.05 % (w/v) polyvinyl alcohol. Addition made.

Extraction step for Exchangeable cations

After decanting following completion of the 2nd pre-wash, the residue in centrifuge tube is subjected to 2 x 30-minute extractions via end-over-end tumbling at approx. 10 rpm. Each extraction uses 20 ml of 1 M-NH₄Cl buffered at pH 7.0 using ammonia solution 28 % (w/w). At the completion of each extraction, the suspensions are centrifuged and the supernatants decanted and collected into a communal extract. The final communal extract is brought to 50 ml with 4 M-HCl.

Sample analysed for Ca,Mg,K and Na by OES

Reference: Based on procedure 15B2 Australian laboratory handbook of soil and water chemical methods / G.E. Rayment and F.R. Higginson 1992 Inkata Press
GLS Job Code 143.0/1108181

Results of analysis on:

Element		Ca	К	Mg	Na	eCEC	Са	K	Mg	Na
Method		NH4CI7/OE	NH4CI7/OE	NH4CI7/OE	NH4CI7/OE		exch	exch	exch	exch
										ESP
Units		cmol(+)/kg	cmol(+)/kg	cmol(+)/kg	cmol(+)/kg		%	%	%	%
GCA9766		1.40	0.11	1.29	0.46	3.26	42.9	3.4	39.6	14.1
GCA9766	check	1.49	0.16	1.43	0.48	3.56	41.8	4.5	40.1	13.5
ASPAC-33		42.31	1.54	35.18	1.84	80.86	52.3	1.9	43.5	2.3

Ann Evers

7/07/2011

Graeme Campbell & Associates Pty Ltd Testing-Laboratory, Unit B, 15 Rose St. Bridgetown, WA 6255

KINETIC-TESTING WORKSHEET (WEATHERING-COLUMNS)

Job No: 1112/2

Client: Flinders-PIOP

	GCA9766
Column-Packing	
Wt Column-Only (kg)	0.32
Wt Column + Sample (kg)	1.82
Wt Sample (kg)	1.50

	GCA9766	GCA9766	GCA9766
Weathering-Cycles			
Cycle No.	1	2	3
DAY-1 (i.e. Start-of-Day-1) [Monday]			
Lamps-On: Date	20/6/11	27/6/11	4/7/11
Lamps-On: Time	17:00	17:00	17:00
DAY-2 [Tuesday]			
Time	09:00	09:00	09:00
Wt Column (kg)	2.03	2.10	2.13
Gravimetric-Water-Content (%, w/w)	14.0	18.7	20.7
DAY-3 [Wednesday]			
Time	09:00	09:00	09:00
Wt Drying-Column (kg)	1.98	2.04	2.06
Gravimetric-Water-Content (%, w/w)	10.7	14.7	16.0
DAY-4 [Thursday]			
Time	09:00	09:00	09:00
Wt Drying-Column (kg)	1.93	1.98	2.00
Gravimetric-Water-Content (%, w/w)	7.3 10.7		12.0
DAY-5 [Friday]			
Time	09:00	09:00	09:00
Wt Drying-Column (kg)	1.89	1.94	1.93
Gravimetric-Water-Content (%, w/w)	4.7	8.0	7.3
Wt Deionised-Water Added (kg)	1.00	1.00	1.00
(Lamps remain off)			
DAY-7 (i.e. End-of-Day-7)			
Wt Drained-Column(kg)	2.17	2.19	2.19
Gravimetric-Water-Content (%, w/w)	23.3	24.7	24.7
Wt Leachate + Beaker (kg)	0.95	0.99	0.97
Wt Beaker (kg)	0.26	0.26	0.26
Wt Leachate (kg)	0.69	0.73	0.71
Leachate-pH	6.9	6.5	6.8
Leachate-EC (µS/cm)	86	63	38

	GCA9766	GCA9766	GCA9766
Weathering-Cycles			
Cycle No.	4	5	6
DAY-1 (i.e. Start-of-Day-1) [Monday]			
Lamps-On: Date	11/7/11	18/7/11	25/7/11
Lamps-On: Time	17:00	17:00	17:00
DAY-2 [Tuesday]			
Time	09:00	09:00	09:00
Wt Column (kg)	2.14	2.12	2.12
Gravimetric-Water-Content (%, w/w)	21.3	20.0	20.0
DAY-3 [Wednesday]			
Time	09:00	09:00	09:00
Wt Drying-Column (kg)	2.08	2.07	2.05
Gravimetric-Water-Content (%, w/w)	17.3	16.7	15.3
DAY-4 [Thursday]			
Time	09:00	09:00	09:00
Wt Drying-Column (kg)	2.02	2.01	1.98
Gravimetric-Water-Content (%, w/w)	13.3	12.7	10.7
DAY-5 [Friday]			
Time	09:00	09:00	09:00
Wt Drying-Column (kg)	1.96	1.96	1.91
Gravimetric-Water-Content (%, w/w)	9.3	9.3	6.0
Wt Deionised-Water Added (kg)	1.00	1.00	1.00
(Lamps remain off)			
DAY-7 (i.e. End-of-Day-7)			
Wt Drained-Column(kg)	2.17	2.18	2.18
Gravimetric-Water-Content (%, w/w)	23.3	24.0	24.0
Wt Leachate + Beaker (kg)	1.02	1.02	0.96
Wt Beaker (kg)	0.26	0.26	0.26
Wt Leachate (kg)	0.76	0.76	0.70
Leachate-pH	6.7	6.4	6.4
Leachate-EC (µS/cm)	42	19	23



Intertek

Dr G Campbell CAMPBELL, GRAEME and ASSOCIATES PTY LTD PO Box 247 BRIDGETOWN WA 6255

JOB INFORMATION

JOB CODE	143/1107963
No. of SAMPLES	1
CLIENT O/N	GCA 1112/2
PROJECT	Flinders PIOP
STATE	Column leachates
DATE RECEIVED	8/06/2011
DATE COMPLETED	30/06/2011

LEGEND

- X = Less than Detection Limit
- N/R = Sample Not Received
 - = Result Checked
- () = Result still to come
- I/S = Insufficient Sample for Analysis
- E6 = Result X 1,000,000
- UA = Unable to Assay
- > = Value beyond Limit of Method

A turbid column leachate was received. The sample was centrifuged and filtered a split was then taken and dosed with HNO3

The pH, EC and Cl of the "raw" sample was measured Genalysis method codes ENV-W001, ENV-W002, ENV_W013 and the alkalinity measured using APHA method code 2320B

APHA code refers to "Standard methods for the examination of water and wastewater", 21st Edition 2005

The HNO3 dosed filtered solution was analysed for the requested element suite (including S) by ICPMS and /or ICPOES: Genalysis method codes (ICP_W003, ICP_W004)

The charge balance was calculated and found to be within +/- 10%

Results of analysis on:

Element		Cl	EC	HCO3	pН
Method		/COL	/MTR	/VOL	/MTR
Detection		2	10	1	0.1
Units		mg/l	uS/cm	mgHCO3/I	NONE
Sample Name					
Control Blank					
GCA9766-0 Raw		73	386	32	7.4
GCA9766-0 Raw	check	73	386	33	7.4

Element	Ag	AI	As	В	Ba	Bi	Ca	Cd	Со
Method	/MS	/OE	/MS	/OE	/MS	/MS	/OE	/MS	/MS
Detection	0.01	0.01	0.1	0.01	0.05	0.005	0.01	0.02	0.1
Units	ug/l	mg/l	ug/l	mg/l	ug/l	ug/l	mg/l	ug/l	ug/l
Sample Name									
Control Blank	0.01	0.02	Х	Х	Х	Х	Х	Х	Х
GCA9766-0 HNO3	0.09	0.44	1.8	0.2	74.48	Х	9.23	0.03	0.2
Alcoa-High3-MS	20.29		110		22.13	18.40		21.25	1057
Alcoa10-OES		1.82		1.13			47.77		

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GLS Job Code 143.0/1107963

Element	Cr	Cu	Fe-Sol	Hg	K	Mg	Mn	Мо	Na
Method	/OE	/OE	/OE	/MS	/OE	/OE	/OE	/MS	/OE
Detection	0.01	0.01	0.01	0.1	0.1	0.01	0.01	0.05	0.1
Units	mg/l	mg/l	mg/l	ug/l	mg/l	mg/l	mg/l	ug/l	mg/l
Sample Name									
Control Blank	Х	Х	Х	Х	Х	Х	Х	Х	Х
GCA9766-0 HNO3	Х	Х	0.38	Х	3.6	7.22	0.02	0.74	54.9
Alcoa-High3-MS				20.8				22.04	
Alcoa10-OES	0.47	0.24	1.91		3.6	55.09	0.47		228.7
Element	Ni	Р	Pb	S	Sb	Se	Si	Sn	Sr
Method	/OE	/OE	/MS	/OE	/MS	/MS	/OE	/MS	/MS
Detection	0.01	0.1	0.5	0.1	0.01	0.5	0.05	0.1	0.02
Units	mg/l	mg/l	ug/l	mg/l	ug/l	ug/l	mg/l	ug/l	ug/l
Sample Name									
Control Blank	Х	Х	Х	0.2	Х	Х	Х	Х	Х
GCA9766-0 HNO3	Х	Х	1.5	11.1	0.1	6.2	15.38	Х	60.2
Alcoa-High3-MS			21.4		23	114		22.6	1071.2
Alcoa10-OES	0.51	0.9		19.5			23.95		

Element	Th	TI	U	V	Zn
Method	/MS	/MS	/MS	/OE	/OE
Detection	0.005	0.01	0.005	0.01	0.01
Units	ug/l	ug/l	ug/l	mg/l	mg/l
Sample Name					
Control Blank	Х	Х	Х	Х	Х
GCA9766-0 HNO3	0.012	Х	0.044	Х	Х
Alcoa-High3-MS	19.11	19.8	18.79		
Alcoa10-OES				0.47	0.47

NATA ENDORSED DOCUMENT

Company Accreditation Number 3244

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NATA Signatory: Ann Evers

Ann Evers

Date: 30/06//2011



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Intertek

Dr G Campbell CAMPBELL, GRAEME and ASSOCIATES PTY LTD PO Box 247 BRIDGETOWN WA 6255

JOB INFORMATION

JOB CODE	143/1111212
No. of SAMPLES	8
CLIENT O/N	GCA 1112/2
PROJECT	Flinders PIOP
STATE	Column leachates
DATE RECEIVED	27/07/2011
DATE COMPLETED	16/08/2011

LEGEND

- X = Less than Detection Limit
- N/R = Sample Not Received
- = Result Checked
- () = Result still to come
- I/S = Insufficient Sample for Analysis
- E6 = Result X 1,000,000
- UA = Unable to Assay
- > = Value beyond Limit of Method

A series of column leachates were received as turbid column leachates, these samples were centrifuged and filtered (0.45um) a split was then taken and dosed with HNO3

The pH, EC and Cl of the "raw" samples was measured Genalysis method codes ENV-W001, ENV-W002 Due to the brown colour of the filtered raw samples the alkalinity was not measured

The HNO3 dosed filtered solution was analysed for the requested element suite (including S) by ICPMS and /or ICPOES: Genalysis method codes (ICP_W003, ICP_W004)

Results of analysis on:

Element		Cl	EC	pН
Method		/COL	/MTR	/MTR
Detection		2	10	0.1
Units		mg/l	uS/cm	NONE
Sample Name				
Control Blank		Х		
GCA9766-1 raw		5	70	6.9
GCA9766-1 raw	check	5	69	6.9
GCA9766-2 raw		Х	43	7
GCA9766-3 raw		Х	37	7
GCA9766-4 raw		Х	33	7

Element	Ag	AI	As	В	Ba	Bi	Ca	Cd
Method	/MS	/OE	/MS	/OE	/MS	/MS	/OE	/MS
Detection	0.01	0.01	0.1	0.01	0.05	0.005	0.01	0.02
Units	ug/l	mg/l	ug/l	mg/l	ug/l	ug/l	mg/l	ug/l
Sample Name								
Control Blank	0.02	Х	Х	0.03	Х	Х	Х	Х
GCA9766-1 HNO3	0.18	2.64	0.6	0.22	18.5	Х	2.45	0.24
GCA9766-2 HNO3	0.22	2.56	0.4	0.14	20.02	Х	2.52	0.09
GCA9766-3 HNO3	0.16	2.14	0.2	0.14	17.08	Х	1.95	0.06
GCA9766-4 HNO3	0.19	1.64	0.3	0.12	13.55	Х	1.53	0.06
Alcoa17-MS	5.2		28.1		5.94	4.736		5.5
Alcoa11-OES		1.97		1			51.78	
Element	Со	Cr	Cu	Fe-Sol	Hg	K	Mg	Mn
Method	/MS	/OE	/OE	/OE	/MS	/OE	/OE	/OE
Detection	0.1	0.01	0.01	0.01	0.1	0.1	0.01	0.01
Units	ug/l	mg/l	mg/l	mg/l	ug/l	mg/l	mg/l	mg/l
Sample Name								
Control Blank	0.1	Х	Х	Х	Х	Х	Х	Х
GCA9766-1 HNO3	0.6	Х	0.03	1.54	Х	1.3	1.78	0.02
GCA9766-2 HNO3	0.5	Х	0.02	1.38	Х	1.1	1.85	0.02
GCA9766-3 HNO3	0.4	Х	0.01	1.13	Х	0.9	1.47	0.01
GCA9766-4 HNO3	0.3	Х	0.02	0.82	Х	0.8	1.14	0.01
Alcoa17-MS	566.8				5.7			
Alcoa11-OES		0.53	0.54	2.07		3.9	49.89	0.53
-				_	-		a :	
Element	Mo	Na	NI (OF	P	Pb	S (OF	Sb	Se
Method	/MS	/0E	/OE	/OE	/MS	/OE	/MS	/MS
Detection	0.05	0.1	0.01	0.1	0.5	0.1	0.01	0.5
	ug/l	mg/l	mg/l	mg/l	ug/l	mg/l	ug/l	ug/I
Sample Name	X	X	X	N N	X	N N	X	N N
	X	X	X	X	X	X	X	X
GCA9766-1 HNO3	3.57	14.1	X	X	6.6	1.9	0.21	0.5
GCA9766-2 HNO3	3.3	9.4	X	X	6.6	0.7	0.18	X
GCA9766-3 HNU3	2.89	8.2	X	X	5.2	0.4	0.2	X
GCA9766-4 HNO3	2.84	1.1	X	X	4.2	0.2	0.23	X
AICOAT /-IVIS	5.54		0.71		5.5	46.5	5.55	27.1
Alcoa11-OES		253.9	0.51	1		18.8		

Element	Si	Sn	Sr	Th	TI	U	V	Zn
Method	/OE	/MS	/MS	/MS	/MS	/MS	/OE	/OE
Detection	0.05	0.1	0.02	0.005	0.01	0.005	0.01	0.01
Units	mg/l	ug/l	ug/l	ug/l	ug/l	ug/l	mg/l	mg/l
Sample Name								
Control Blank	Х	Х	Х	0.011	Х	Х	Х	Х
GCA9766-1 HNO3	20.72	0.1	19.42	0.04	0.02	0.197	Х	0.04
GCA9766-2 HNO3	17.53	0.1	18.98	0.034	0.01	0.188	Х	0.04
GCA9766-3 HNO3	17.71	0.1	14.66	0.03	Х	0.167	Х	0.04
GCA9766-4 HNO3	17.67	Х	11.89	0.023	Х	0.129	Х	0.02
Alcoa17-MS		5.6	547.81	4.935	4.72	5.048		
Alcoa11-OES	16.6						0.54	0.55

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NATA Signatory: Ann Evers

Ann Evers

Date: 16/08//2011



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Intertek

Dr G Campbell CAMPBELL, GRAEME and ASSOCIATES PTY LTD PO Box 247 BRIDGETOWN WA 6255

JOB INFORMATION

JOB CODE	143/1111962
No. of SAMPLES	4
CLIENT O/N	GCA 1112
PROJECT	Flinders PIOP
STATE	Column leachates
DATE RECEIVED	10/08/2011
DATE COMPLETED	31/08/2011

LEGEND

- X = Less than Detection Limit
- N/R = Sample Not Received
- = Result Checked
- () = Result still to come
- I/S = Insufficient Sample for Analysis
- E6 = Result X 1,000,000
- UA = Unable to Assay
- > = Value beyond Limit of Method

A series of column leachates were received, some were slurries. These samples were centrifuged and filtered (0.45um) a split was then taken and dosed with HNO3

The pH, EC and Cl of each "raw" sample was measured using Genalysis method codes: ENV-W001, ENV-W002, and ENV_W013

The alkalinity was not measured due to the brown colour of the solutions

The HNO3 dosed filtered solution was analysed for the requested element suite (including S) by ICPMS and /or ICPOES: Genalysis method codes (ICP_W003, ICP_W004). The charge balance was not calculated **Results of analysis on:**

Element		CI	EC	pН
Method		/COL	/MTR	/MTR
Detection		2	10	0.1
Units		mg/l	uS/cm	NONE
Sample Name				
Control Blank		Х		
GCA9766-5 Raw		Х	32	7
GCA9766-5 Raw	check	Х	31	7.1
GCA9766-6 Raw		Х	26	6.9
N191		96		

Element	Ag	AI	As	В	Ва	Bi	Ca	Cd
Method	/MS	/OE	/MS	/OE	/MS	/MS	/OE	/MS
Detection	0.01	0.01	0.1	0.01	0.05	0.005	0.01	0.02
Units	ug/l	mg/l	ug/l	mg/l	ug/l	ug/l	mg/l	ug/l
Sample Name								
Control Blank	0.01	0.02	Х	0.02	Х	Х	Х	Х
GCA9766-5 HNO3	0.19	0.73	Х	0.13	17.43	0.006	1.02	0.03
GCA9766-6 HNO3	0.23	0.71	0.5	0.14	12.37	Х	0.99	0.02
Alcoa17-MS	5.08		26.7		6.08	4.671		5.52
Alcoa11-OES		2.01		0.99			51.09	

15 Davison Street, Maddington WA 6109 PO Box 144, Gosnells WA 6990 T +61 8 9251 8100 I F +61 8 9251 8110 ABN 32 008 787 237 www.intertek.com www.genalysis.com.au

Element	Со	Cr	Cu	Fe-Sol	Hg	К	Mg	Mn
Method	/MS	/OE	/OE	/OE	/MS	/OE	/OE	/OE
Detection	0.1	0.01	0.01	0.01	0.1	0.1	0.01	0.01
Units	ug/l	mg/l	mg/l	mg/l	ug/l	mg/l	mg/l	mg/l
Sample Name								
Control Blank	Х	Х	0.02	Х	Х	Х	Х	Х
GCA9766-5 HNO3	0.2	Х	0.02	0.39	0.2	0.7	0.67	Х
GCA9766-6 HNO3	0.2	Х	0.01	0.34	Х	0.7	0.65	Х
Alcoa17-MS	572.2				5.6			
Alcoa11-OES		0.52	0.53	2.06		3.8	49.77	0.51
Element	Мо	Na	Ni	Р	Pb	S	Sb	Se
Method	/MS	/OE	/OE	/OE	/MS	/OE	/MS	/MS
Detection	0.05	0.1	0.01	0.1	0.5	0.1	0.01	0.5
Units	ug/l	mg/l	mg/l	mg/l	ug/l	mg/l	ug/l	ug/l
Sample Name								
Control Blank	Х	Х	Х	Х	Х	Х	Х	Х
GCA9766-5 HNO3	3.37	6.7	Х	Х	4	0.3	0.25	Х
GCA9766-6 HNO3	3.79	5.2	Х	Х	4.2	0.3	0.22	Х
Alcoa17-MS	5.58				5.5		5.76	28.3
Alcoa11-OES		245.3	0.49	0.9		16.4		
Element	Si	Sn	Sr	Th	TI	U	V	Zn
Method	/OE	/MS	/MS	/MS	/MS	/MS	/OE	/OE
Detection	0.05	0.1	0.02	0.005	0.01	0.005	0.01	0.01
Units	mg/l	ug/l	ug/l	ug/l	ug/l	ug/l	mg/l	mg/l
Sample Name								
Control Blank	Х	Х	Х	Х	Х	Х	Х	Х
GCA9766-5 HNO3	17.28	Х	7.34	0.007	0.01	0.076	Х	Х
GCA9766-6 HNO3	15.86	Х	7.75	Х	Х	0.081	Х	0.01
Alcoa17-MS		5.6	549.86	5.218	4.92	5.144		
Alcoa11-OES	18.04						0.51	0.52

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NATA Signatory: Ann Evers

Ann Evers

Date: 31/08//2011



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FLINDERS MINES LIMITED GEOCHEMICAL CHARACTERISATION OF MINE WASTE AND TAILINGS IMPLICATIONS FOR MINE WASTE MANAGEMENT

APPENDIX C

























