

FORTESCUE METALS GROUP LTD

MOUNT LEWIN DEPOSIT

GEOCHEMICAL CHARACTERISATION OF

MINE-WASTE SAMPLES

['STATIC-TESTWORK']

Implications for Mine-Waste Management

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EXECUTIVE SUMMARY

In this study, a range of regolith and waste-bedrock samples derived from the wall-waste-zone of the Mount Lewin Deposit have been geochemically characterised.

With the exception of the High-S varieties of Black-Shales, all lithotypes should be classified as Non-Acid Forming (NAF), due to minute/negligible amounts of sulphide-minerals. Enrichments in minor-elements in the NAF-lithotypes should only be slight (or non-existent), and soluble-salt contents should be low-to-moderate.

Although the High-S varieties of the Black-Shales are classified as Potentially-Acid Forming (PAF), based on economic evaluations, open-pit mining will not extend deep enough for the Black-Shales to be intersected.

In brief, assuming that the Black-Shales remain undisturbed *in situ*, no geochemical concerns are foreseen for the mine-waste materials to be produced during open-pit mining of the Mount Lewin Deposit.

SUMMARY OF TECHNICAL TERMS EMPLOYED IN THIS REPORT

ACRONYM	PARAMETER	DEFINITION/DETERMINATION	UNIT
AFP	Acid-Formation Potential		
ARD	Acid-Rock Drainage		
Total-S	Total Sulphur	Analysis Result	% (w/w)
Sulphide-S	Sulphide Sulphur	Testwork Result [i.e. Sulphide-S = Total-S - Sulphate-S]	% (w/w)
ANC	Acid-Neutralisation Capacity	Testwork Result	kg H ₂ SO ₄ /tonne
MPA	Maximum-Potential Acidity	Calculation	kg H ₂ SO ₄ /tonne
NAPP	Net-Acid-Producing Potential	Calculation	kg H ₂ SO ₄ /tonne
NAG	Net-Acid Generation	Testwork Result	kg H ₂ SO ₄ /tonne
NAF	Non-Acid Forming	Calculation:	kg H ₂ SO ₄ /tonne
		<ul style="list-style-type: none"> • Sulphide-S < 0.3 % • Sulphide-S ≥ 0.3 %, and negative-NAPP value with ANC/MPA ≥ 2.0 	
PAF	Potentially-Acid Forming	Calculation:	kg H ₂ SO ₄ /tonne
		<ul style="list-style-type: none"> • Sulphide-S ≥ 0.3 %, and any positive-NAPP value • Sulphide-S ≥ 0.3 %, and a negative-NAPP value with ANC/MPA < 2.0 	
PAF-[SL]	PAF-[Short-Lag]	Estimation [e.g. inferred from 'kinetic' testing]	
PAF-[LL]	PAF-[Long-Lag]	Estimation [e.g. inferred from 'kinetic' testing]	
SOR	Sulphide-Oxidation Rate	Testwork Result [e.g. obtained from 'kinetic' testing]	mg SO ₄ /kg/week,

Notes:

The **PAF-[SL]** classification applies to (initially circum-neutral) PAF-materials that may acidify (viz. pH less than 5) within a matter of weeks-to-months when subjected to "**aggressive-ambient-weathering**", corresponding to periods of at least a few days during which unsaturated-conditions prevail (via drainage/evaporation processes) between successive inundations that, in turn, occur semi-regularly (e.g. weekly-to-fortnightly "on-average" during most of the annual hydrological-cycle).

The **PAF-[LL]** classification applies to PAF-materials where exposure to the atmosphere for years (even decades, or longer) may be needed before acidification develops. Circum-neutral-pH during the "lag-phase" for such lithotypes is chiefly due to buffering reactions involving carbonate-minerals.

Climate directly influences the duration of the "lag-phase", and a sulphide-gangue assemblage classified as PAF-[SL] in a "humid" environment where the SOR is controlled by **O₂-supply**, may instead be classified as PAF-[LL] in semi-arid/arid environments where the SOR is controlled by **water-supply** (viz. frequency of "flushing-episodes") [Campbell 2004]. The formation of "secondary-oxidation-products" (e.g. Fe-oxyhydroxides) as protective-coatings is generally enhanced during the "lag-phase-stage" of mine-waste weathering in semi-arid/arid environments, and so further curtails sulphide-oxidation rates.

1.0 INTRODUCTION

Fortescue Metals Group Ltd is proposing to produce iron-ore from the Mount Lewin Deposit located *c.* 90 kms north-north-east of Newman, Western Australia.

Ore will be produced through open-pit mining, and the excavated waste-rock materials (viz. various types of regoliths and bedrocks) placed on waste-dumps located in the vicinity of the Pit.

Graeme Campbell & Associates Pty Ltd (GCA) was commissioned to carry out geochemical testwork on a range of regolith, and waste-bedrock, samples derived from the Mount Deposit.

The 'Static-Testwork' Programme focused on Acid-Formation Potential (AFP), Multi-Element Composition, and Mineralogy.¹

The testwork results are presented and discussed in this report, and implications for mine-waste management highlighted.

¹ A 'Static-Testwork' Programme comprises "whole-rock" analyses and tests.

2.0 STUDY APPROACH

Details of the sampling and testwork programmes, and the calculations and criteria employed for classifying the mine-waste samples into AFP categories, are presented and discussed in the following sections.

2.1 Testwork Programme

2.1.1 Samples

Details of the samples are presented in Appendix A.

The tested samples were derived from down-hole intervals of *c.* 1.0 m, and so allow assessment of mine-waste geochemistry, at the "metre-scale", in terms of sulphide/carbonate abundances, and minor-element content.

It is assumed that the samples submitted for testing herein are representative of the major types of mine-waste materials to be produced during open-pit mining of the Mount Lewin Deposit.

2.1.2 Testwork

The samples were assigned GCA Sample-Numbers, and relevant details recorded in the GCA Sample-Register. All samples were crushed (nominal 2 mm), and pulped (nominal 75 µm), for specific tests.

The testwork methods employed in this study are based on recognised procedures for the geochemical characterisation of mine-waste materials (e.g. AMIRA 2002; Morin and Hutt 1997; Smith 1992; Coastech Research 1991; BC AMD Task Force 1989).

Part of the testwork was carried out by SGS Environmental Service [SGS] (Welshpool), and Genalysis Laboratory Services [GLS] (Maddington). The analyses performed by SGS and GLS have NATA endorsement.²

Specialised testing (viz. auto-titrations and Net-Acid-Generation [NAG] Tests) was undertaken by Dr. Graeme Campbell in the GCA Testing-Laboratory (Bridgetown).

The mineralogical investigation was carried out by Dr. Roger Townend of Roger Townend & Associates (Malaga).

Details of the testwork methods are presented in Appendix B, and copies of the laboratory and mineralogical reports are presented in Appendix C.

2.2 Calculated Parameters

The Maximum-Potential-Acidity (MPA) values (in kg H₂SO₄/tonne) of the samples were 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. The stoichiometry of pyrite-oxidation is discussed further in Appendix B.

The Net-Acid-Producing-Potential (NAPP) values (in kg H₂SO₄/tonne) were calculated from the corresponding MPA and Acid-Neutralisation-Capacity (ANC) values (i.e. NAPP = MPA - ANC).

² NATA = National Association of Testing Authorities.

2.3 Classification Criteria

In terms of AFP, mine-waste materials may be classified into one of the following categories, viz.

- Non-Acid Forming (NAF).
- Potentially-Acid Forming (PAF).

There are **no** unifying, "standard" criteria for classifying the AFP of mine-waste materials (Campbell 2002a,b; Smith 1992), 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, and mineralogy.

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

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

In assessing the AFP of mine-waste materials, there is consensus (e.g. mining/environmental regulators in British Columbia, Canada) that lithotypes with Sulphide-S contents less than 0.3 % are unlikely to oxidise at rates fast enough to result in acidification (e.g. pH less than 4-5) [Soregaroli and Lawrence 1997]. This position assumes that the groundmass hosting such "trace-sulphides" is not simply quartz, and/or clays (Price *et al.* 1997), and that for a carbonate-deficient gangue, the sulphides are not unusually reactive (e.g. sulphide-oxidation rates [SORs] less than *c.* 20-40 mg

SO₄/kg/week) [= c. 1-2 kg SO₄/tonne/year].³ A "cut-off" of 0.3 % for Sulphide-S also accords with the findings of 'kinetic' testing conducted, since the late-1980s, by Dr. Graeme Campbell for mine-waste samples of diverse mineralogy in terms of AFP.

The ANC/MPA criteria for the NAF category reflects the need to compensate for "less-than-perfect" availability of alkalinity-forms (e.g. carbonates) for neutralisation of acid produced through pyrite-oxidation. A "less-than-perfect" availability of alkalinity-forms may arise from:

- (a) Restricted accessibility of acid to carbonate-grains.
- (b) Rate-limiting dissolution of carbonates-grains near pH=7.
- (c) Depletion of carbonate-minerals through rainfall-fed leaching within waste-dumps.⁴

Restricted accessibility of acid to the surfaces of carbonate-grains may occur at different spatial-scales (viz. at the "whole-rock-scale" in which Acid-Rock Drainage [ARD] "bypasses" carbonate-bearing materials via preferential-flow pathways within a waste-dump, and at the "grain-scale" in which the surfaces of individual carbonate-grains are "blinded/rimmed" by precipitates of Fe(III)-oxyhydroxides [e.g. ferrihydrite-type phases]). As shown by Li (1997), ferroan-carbonates (especially "Fe-rich" varieties) are prone to "surface-armouring/rimming" during dissolution: weathering of tailings-solids containing pyrite, ankerites and Mg-siderites produced acidic leachates when less than one-third of the carbonate-grains had dissolved.

³ Although 'steady-state' SORs (at circum-neutral-pH) for Sulphide-S contents less than 0.3 % may indeed exceed 1-2 kg SO₄/tonne/year, such rates are generally restricted to either sedimentary forms (e.g. framboidal-pyrite), or hydrothermal-sulphides that are atypically reactive.

⁴ Depletion of carbonate-minerals through dissolution in meteoric-waters is minimal in semi-arid settings, especially within the "hydrologically-active-zone" (e.g. top 2-3 m) of a waste-dump, since re-precipitation occurs during evapo-concentration when desiccating conditions return after "wet-spells".

To compensate for the effects of (a) to (c) above, some authors advocate that, for a mine-waste sample to be classified as NAF, it must have an ANC/MPA ratio of at least 3.0 (see review of earlier literature by Smith [1992]). In recent years, fundamental-research (especially estimation of reaction-rates for diverse sulphide/gangue-mineral assemblages), and field-experience at mining operations world-wide, have shown that the potential for ARD production is very low for mine-waste materials with ANC/MPA ratios greater than 2.0 (AMIRA 2002; Price *et al.* 1997, Currey *et al.* 1997, and Murray *et al.* 1995).⁵ This ANC/MPA ratio is employed in the present work.⁶

The risk posed by handling PAF-lithotypes during the working of a deposit is governed primarily by the duration of the "lag-phase" (i.e. the period during which sulphide-oxidation occurs, but acidification does not develop, due to buffering near pH=7 by gangue-phases).⁷ Although the "lag-phase" applicable to exposed mine-wastes at "field-scale" cannot be accurately predicted *a priori*, estimates (albeit approximate) are still needed to identify the exposure-times for the safe handling of PAF-lithotypes, and so reduce the risk for ARD production. Estimates of the "lag-phase" are invariably obtained through programmes of 'kinetic' testing (viz. Weathering-Columns). However, based on experience, "first-pass" estimates of the "lag-phase" may be made, and thereby used to further classify PAF-lithotypes into **PAF-[Short-Lag]** and **PAF-[Long-Lag]** sub-categories. Such "first-pass" estimates are necessarily provisional, and subject to revision, in the light of the outcomes of 'kinetic' testing, and field observations.

⁵ Such ANC/MPA ratios are consistent with those indicated from SORs, and carbonate-depletion rates, as reported in the International-Kinetic Database for mine-waste materials from around the world (Morin and Hutt 1997).

⁶ It should be noted that mining-regulators in Nevada (USA) classify a mine-waste sample as NAF, if it is characterised by an ANC/MPA ratio greater than 1.2 (US EPA 1994). This lower ANC/MPA ratio reflects the semi-arid conditions typically encountered at mine-sites in Nevada. Although utilised in the early-1990s, it is understood that an ANC/MPA ratio of 1.2 is still entertained by regulators in Nevada for "screening" PAF and NAF varieties of mine-wastes in semi-arid settings.

⁷ SO₄ is still produced by sulphide-oxidation during the "lag-phase", and appreciable amounts of soluble-forms of certain minor-elements (e.g. As) may be released at circum-neutral-pH during the "within-lag-phase-stage" of mine-waste weathering.

3.0 ACID-BASE CHEMISTRY AND SALINITY OF MINE-WASTE SAMPLES

The testwork results on the acid-base chemistry and salinity of the regolith and waste-bedrock samples are presented in Table 3.1, and shown on Figure 1.⁸ These results are discussed in the following sections.

3.1 Regoliths

3.1.1 pH and Salinity

The samples had pH-(1:2) values of 6.7-7.9, and EC-(1:2) values of 0.096-0.30 mS/cm (Table 3.1).⁹

Although not measured, the soluble-salts in the samples should be dominated by chlorides.

The testwork results indicate that the samples were circum-neutral (viz. pH 6-8), with low-to-moderate contents of soluble-salts.

3.1.2 Sulphur Forms

The samples had Total-S values of 0.02-0.05 % (Table 3.1).

The testwork results indicate that the samples contained negligible amounts of sulphide-minerals (viz. Sulphide-S contents less than 0.1 %).

⁸ For the purposes of this report, the regoliths correspond to the alluvium from the Quaternary and Tertiary, and the detritals from the Tertiary.

⁹ EC= Electrical-Conductivity. The pH-(1:2) and EC-(1:2) Tests (and other testwork) are described in Appendix B.

3.1.3 Acid-Consuming Properties

The samples had ANC values of 1.9-3.1 kg H₂SO₄/tonne (Table 3.1).¹⁰

The testwork results indicate that the samples had a very-low capacity to consume acid.

3.1.4 Acid-Formation Potential

The samples had NAG-pH values of 6.6-8.8, and NAG values less than 0.5 kg H₂SO₄/tonne (Table 3.1).¹¹ Therefore, under the strongly-oxidising conditions of the NAG-testwork, the samples did not acidify.

The testwork results indicate that the samples were classified as NAF.

3.2 Waste-Bedrocks

3.2.1 pH and Salinity

The samples had pH-(1:2) values of 6.1-8.0, and EC-(1:2) values of 0.091-1.8 mS/cm (Table 3.1).

The testwork results indicate that the samples were circum-neutral (viz. pH 8-9), with low-to-moderate contents of soluble-salts.

¹⁰ ANC values of 1.9-3.1 kg H₂SO₄/tonne is equivalent to c. 0.19-0.31 % (as "CaCO₃").

¹¹ It should be noted that the "Single-Addition" version of the NAG Test (AMIRA 2002) was employed in this study.

3.2.2 Sulphur Forms

The samples had Total-S values of 0.02-15.0 %, and the samples tested for SO₄-S had SO₄-S values of 0.03-0.17 % (Table 3.1).

If the result for the sample GCA5498 (i.e. Black-Shales) is excluded, then the Total-S values were 0.02-0.22 %.

The testwork results indicate that, apart from one of the Black-Shales samples, all samples contained negligible amounts of sulphide-minerals (viz. Sulphide-S contents less than 0.1-0.2 %).

The High-S sample of Black-Shales (GCA5498) contained major amounts of sulphide-minerals (viz. Sulphide-S content of 14-15 %).

3.2.3 Acid-Consuming Properties

The samples had ANC values of 1.4-240 kg H₂SO₄/tonne (Table 3.1).¹²

If the result for the High-ANC (and High-S) sample of Black-Shales (GCA5498) is excluded, then the ANC values of the remaining samples were less than 5-10 kg H₂SO₄/tonne.

The presence of reactive-carbonates (e.g. calcites) in sample GCA5498 was indicated by the effervescence (i.e. "fizzing") produced upon the addition ('in-the-cold') of HCl during the ANC-testwork. This sample also had an CO₃-C value of 3.5 % (Table 3.1). The pH-Buffering properties of sample GCA5498 were determined via auto-titrations, and 0.05 M-H₂SO₄. The H₂SO₄-addition rate employed during the auto-titration was c.

¹² ANC values of 1.4-240 kg H₂SO₄/tonne are equivalent to c. 0.14-24 % (as CaCO₃).

10^4 - 10^5 kg H₂SO₄/tonne/year, and correspond to SORs up to 10^3 - 10^4 faster than those typically observed for the circum-neutral weathering of "minor/major-sulphides". The pH-buffering curves (Figure 1) exhibited a "linear-decrease" in pH with progressive acid-addition, associated with the dissolution of ankerites and calcites (Table 4.3).

The testwork results indicate that the samples typically had a very-low capacity to consume acid.

However, the High-S sample of the Black-Shales had a high capacity to consume acid, due to ankerites and calcites.

3.2.4 Acid-Formation Potential

If the result for the High-S sample of Black-Shale is excluded, then the samples had NAG values less than 0.5 kg H₂SO₄/tonne, and NAG-pH values of 6.8-7.8 (Table 3.1).

Sample GCA5498 had a NAPP value of 230 kg H₂SO₄/tonne, a NAG value of 180 kg H₂SO₄/tonne, and a NAG-pH value of 2.4. There was good agreement between the calculated-NAPP, and measured-NAG, values.

The testwork results indicate that, apart from the High-S sample of Black-Shales, all samples were classified as NAF.

The High-S samples of Black-Shales is classified as PAF-[Long-Lag]¹³.

¹³ A programme of 'kinetic' testing (viz. Weathering-Columns) would be needed to fully assess the duration of the lag-phase for the High-S varieties of the Black-Shales.

4.0 MULTI-ELEMENT COMPOSITION AND MINERALOGY OF MINE-WASTE SAMPLES

The multi-element composition and mineralogy of selected samples is indicated by the data presented in Tables 4.1 to 4.3.¹⁴ The corresponding element-enrichments, as indicated by the values of the Geochemical-Abundance Index (GAI), are also presented in Tables 4.1 and 4.2.¹⁵ It should be noted that these element-enrichments are relative enrichments, based on the element contents typically recorded for unmineralised soils, regoliths and bedrocks (Bowen 1979).

The assayed samples had contents of most environmentally-significant elements below, or close to, those typically recorded for unmineralised soils and regoliths. Slight enrichments were apparent in some samples for As, Bi, Sb and Se. The composition of the assayed sample of Black-Shales (GCA5498) indicates that the pyrite in this lithotype is only moderately enriched in chalcophyles.

Sample GCA5498 mainly comprised quartz, muscovite, pyrite and ankerite (Table 4.3). This sample also contained accessory amounts of goethite and graphite and traces of calcite.

The analysis results indicate that, geochemically, the assayed samples were "clean" with low contents of environmentally-significant elements.

¹⁴ The suite of elements listed in Tables 4.1 and 4.2 is grouped into (a) the major-elements (viz. Na, K, Mg, Ca, Al and Fe) making-up the lattices of primary-silicates, clays, sesquioxides and carbonates, and (b) minor-elements. A distinction is made between minor-elements which, under neutral-to-alkaline conditions, occur (i) as cationic-hydrolysis forms (e.g. Cu), and (ii) as anions/oxyanions (e.g. As). Anionic forms may exhibit moderate solubility under neutral-to-alkaline conditions.

¹⁵ The GAI is defined in Appendix B.

5.0 CONCLUSIONS

Based on the testwork results obtained in this study, it is concluded that, with the exception of the High-S varieties of Black-Shales, the regoliths and waste-bedrocks to be produced during open-pit mining of the Mount Lewin Deposit should be classified as NAF, due to minute/negligible amounts of sulphide-minerals.¹⁶ Enrichments in minor-elements in the NAF-lithotypes should only be slight (or non-existent), and soluble-salt contents should be low-to-moderate.

The High-S varieties of the Black-Shales are classified as PAF-[Long-Lag].¹⁷ However, based on economic evaluations, open-pit mining will not extend deep enough for the Black-Shales to be intersected (Mr Ben Garnet, *pers. commun.*).

In brief, assuming that the Black-Shales remain undisturbed in situ, no geochemical concerns are foreseen for the mine-waste materials to be produced during open-pit mining of the Mount Lewin Deposit.

¹⁶ NAF = Non-Acid Forming.

¹⁷ PAF = Potentially-Acid Forming.

6.0 REFERENCES

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TABLES

Table 3.1: Acid-Base-Analysis, Salinity and Net-Acid-Generation Results for Regolith and Waste-Bedrock Samples

GCA-SAMPLE NO.	SITE-SAMPLE NO.	LITHOTYPE	DRILLHOLE & DOWN-HOLE INTERVAL (m)	pH-(1:2)	EC-(1:2) [mS/cm]	TOTAL-S (%)	SO ₄ -S (%)	Sulphide-S (%)	CO ₃ -C (%)	ANC	NAPP	NAG	NAG-pH	AFP CATEGORY
										kg H ₂ SO ₄ /tonne				
Sample of Quaternary-Alluvium (Qa)														
GCA5516	25019	KI>SI	ML0289, 0-1	6.7	0.096	0.05	nm	0.05	nm	2.2	nc	<0.5	7.3	NAF
Sample of Tertiary-Alluvium (Ta)														
GCA5499	25009	Klp>Ch	ML0216, 5-6	7.6	0.19	0.04	nm	0.04	nm	2.7	nc	<0.5	7.2	NAF
Sample of Tertiary-Semi-Mature-Detritals (Tds)														
GCA5500	25015	Ho>Sh	ML0074, 2-3	7.6	0.12	0.04	nm	0.04	nm	1.9	nc	<0.5	6.6	NAF
Sample of Tertiary-Immature-Detritals (Tdi)														
GCA5501	25003	KI>Ch	ML0194, 2-3	7.9	0.18	0.02	nm	0.02	nm	2.6	nc	<0.5	6.5	NAF
Sample of Tertiary-Mature-Detritals (Tdm)														
GCA5502	25005	GOM>VGH	ML0192, 4-5	7.7	0.30	0.03	nm	0.03	nm	3.1	nc	<0.5	8.8	NAF
Sample of Chert (Ch)														
GCA5503	25006	HSM/GSM	ML0219, 12-13	8.0	0.13	0.09	nm	0.09	nm	1.6	nc	<0.5	7.1	NAF
Sample of Cavity-Fill (Cf)														
GCA5504	25012	OGF/HSF	ML0221, 31-32	7.4	0.28	0.04	nm	0.04	nm	1.9	nc	<0.5 (<0.5)	7.4 (7.1)	NAF
Sample of Nummuldi-Member (Mus)														
GCA5505	25011	NS/GHF	ML0213, 35-36	7.5	0.21	0.03	nm	0.03	nm	6.0	nc	<0.5	7.2	NAF
Samples of Nummuldi-Member (Mum)														
GCA5506	25013	HOM	ML0241, 25-26	7.6	0.16	0.03	nm	0.03	nm	4.1	nc	<0.5	7.3	NAF
GCA5507	25021	GHM/GOM	ML0196, 35-36	7.7	0.28	0.22	0.03 (0.04)	0.19	nm	10	-4.1	<0.5	7.0	NAF
Samples of Nummuldi-Member (Muf)														
GCA5508	25017	HSP/GHF	ML0159, 11-12	6.1 (6.1)	1.1 (1.1)	0.08	nm	0.08	nm	1.4	nc	<0.5	6.8	NAF
GCA5509	25007	GOM/HOM	ML0218, 38-39	6.7	0.12	0.05	nm	0.05	nm	2.8 (2.9)	nc	<0.5	7.2	NAF
Sample of Nummuldi-Member (Mut)														
GCA5510	25004	GHM/HSM	ML0193, 22-23	7.6	0.14	0.05	nm	0.05	nm	2.5	nc	<0.5	7.8	NAF
Sample of Nummuldi-Member (Muh)														
GCA5511	25014	HOK	ML0239, 11-12	7.6	0.094	0.03	nm	0.03	nm	2.6	nc	<0.5	7.5	NAF
Sample of Nummuldi-Member (Mub)														
GCA5512	25002	GHM/HSF	ML0095, 35-36	7.7	0.29	0.03	nm	0.03	nm	2.6	nc	<0.5	7.1	NAF
Sample of Nummuldi-Member (Muk)														
GCA5513	25008	MUK/GHF	ML0217, 24-25	7.3	0.091	0.02	nm	0.02	nm	2.5	nc	<0.5	7.3	NAF
Sample of Nummuldi-Member (Mu)														
GCA5514	25016	HO/LO	ML0047, 36-37	7.4	0.55	0.09	nm	0.09	nm	2.3	nc	<0.5	7.2	NAF
Samples of Jeerinah-Formation (Jr)														
GCA5015	25018	WS/RS	ML0161, 32-33	7.7	0.11	0.02	nm	0.02	nm	2.1	nc	<0.5	7.4	NAF
GCA5498	25020	Black-Shales	ML0330, 33-34	7.3 (7.2)	1.8 (1.8)	15.0	0.17	14.9	3.5	230 (240)	230	180	2.4	PAF-[Long-Lag]
GCA5517	25010	Black-Shales	ML0214, 56-57	7.3	0.38	0.04	nm	0.0	nm	5.5	nc	<0.5 (<0.5)	7.7 (7.3)	NAF

Notes:
 EC = Electrical Conductivity; ANC = Acid-Neutralisation Capacity; AFP = Acid-Formation Potential; NAF = Non-Acid Forming; PAF = Potentially-Acid Forming; nm = not measured; nc = not calculated.
 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) and EC-(1:2).
 Values in parentheses represent duplicates.

Table 4.1: Multi-Element-Analysis Results for Regolith and Waste-Bedrock Samples

Note: Refer Appendix B for the definition of the Geochemical-Abundance-Index (GAI) indicated in this table.

ELEMENT	TOTAL-ELEMENT-CONTENT (% or mg/kg)				AVERAGE-CRUSTAL-ABUNDANCE (mg/kg or %)	GEOCHEMICAL-ABUNDANCE-INDEX (GAI)			
	KI>SI	Klp>Ch	KI>Ch	OGF/HSF		KI>SI	Klp>Ch	KI>Ch	OGF/HSF
	(GCA5516)	(GCA5499)	(GCA5501)	(GCA5504)		(GCA5516)	(GCA5499)	(GCA5501)	(GCA5504)
Al	7.4%	10.1%	2.1%	4.5%	8.2%	0	0	0	0
Fe	23.8%	34.6%	19.5%	43.8%	4.1%	2	2	2	3
Na	0.024%	0.026%	0.016%	0.067%	2.3%	0	0	0	0
K	1.8%	0.032%	0.026%	0.38%	2.1%	0	0	0	0
Mg	0.38%	0.19%	0.069%	0.25%	2.3%	0	0	0	0
Ca	0.046%	0.12%	0.043%	0.11%	4.1%	0	0	0	0
Ag	0.3	0.2	0.1	0.3	0.07	2	1	0	2
Cu	170	51	5	140	50	1	0	0	1
Zn	86	72	63	230	75	0	0	0	1
Cd	0.3	0.2	0.1	2.3	0.11	1	0	0	4
Pb	44	24	8	39	14	1	0	0	1
Cr	280	250	51	59	100	1	1	0	0
Ni	28	78	12	96	80	0	0	0	0
Co	55	21	1.8	150	20	1	0	0	2
Mn	2,500	4,100	400	60,000	950	1	2	0	5
Hg	0.27	0.08	0.05	0.05	0.05	2	0	0	0
Sn	2.4	3.0	0.7	1.1	2.2	0	0	0	0
Sr	21	22	6.1	130	370	0	0	0	0
Ba	96	270	28	1,300	500	0	0	0	1
Th	8.2	18	3.2	5.9	12	0	0	0	0
U	2.7	3.3	0.85	2.7	2.4	0	0	0	0
Tl	3.0	0.21	0.19	2.5	0.6	2	0	0	1
V	130	200	59	220	160	0	0	0	0
As	130	18	11	25	1.5	6	3	2	3
Bi	0.58	0.76	0.28	0.91	0.048	3	3	2	4
Sb	6.6	1.7	1.4	1.1	0.2	4	3	2	2
Se	1.0	1.2	0.29	0.18	0.05	4	4	2	1
Mo	23	0.8	1.2	1.3	1.5	3	0	0	0
B	58	<50	<50	<50	10	2	0	0	0
P	230	270	150	1,000	1,000	0	0	0	0
F	650	290	76	200	950	0	0	0	0

Note: Average-crustal abundance of elements based on Bowen (1979).

Table 4.2: Multi-Element-Analysis Results for Waste-Bedrock Samples

Note: Refer Appendix B for the definition of the Geochemical-Abundance-Index (GAI) indicated in this table.

ELEMENT	TOTAL-ELEMENT-CONTENT (% or mg/kg)				AVERAGE-CRUSTAL-ABUNDANCE (mg/kg or %)	GEOCHEMICAL-ABUNDANCE-INDEX (GAI)			
	GHM/HSM (GCA5510)	GHM/HSF (GCA5012)	MUK/GHF (GCA5513)	Black-Shales (GCA5498)		GHM/HSM (GCA5510)	GHM/HSF (GCA5012)	MUK/GHF (GCA5513)	Black-Shales (GCA5498)
Al	8.5%	0.85%	2.3%	3.8%	8.2%	0	0	0	0
Fe	29.7%	67.1%	61.4%	15.1%	4.1%	2	3	3	1
Na	0.051%	0.021%	0.0064%	0.061%	2.3%	0	0	0	0
K	0.52%	0.029%	0.064%	2.0%	2.1%	0	0	0	0
Mg	0.33%	0.11%	0.15%	1.8%	2.3%	0	0	0	0
Ca	0.18%	0.048%	0.031%	6.9%	4.1%	0	0	0	0
Ag	0.4	0.2	0.1	0.2	0.07	2	1	0	1
Cu	93	1	76	130	50	0	0	0	1
Zn	69	140	250	470	75	0	0	1	2
Cd	0.1	0.5	1.6	1.8	0.11	0	2	3	3
Pb	37	28	15	34	14	1	0	0	1
Cr	710	20	39	110	100	2	0	0	0
Ni	98	38	150	95	80	0	0	0	0
Co	16	13	92	45	20	0	0	2	1
Mn	1,400	3,900	8,500	2,300	950	0	1	3	1
Hg	0.06	0.06	0.04	0.71	0.05	0	0	0	3
Sn	5.2	0.3	0.5	2.7	2.2	1	0	0	0
Sr	47	15	22	21	370	0	0	0	0
Ba	350	72	52	180	500	0	0	0	0
Th	17	1.4	2.3	5.1	12	0	0	0	0
U	3.0	2.8	4.8	1.6	2.4	0	0	0	0
Tl	0.35	0.14	0.12	3.6	0.6	0	0	0	2
V	450	350	25	60	160	1	1	0	0
As	89	16	40	60	1.5	5	3	4	5
Bi	1.3	0.18	0.16	0.74	0.048	4	1	1	3
Sb	6.5	1.2	1.1	2.5	0.2	4	2	2	3
Se	1.2	0.06	0.18	4.9	0.05	4	0	1	6
Mo	3.1	3.0	1.1	2.8	1.5	0	0	0	0
B	<50	<50	<50	56	10	0	0	0	2
P	390	1,500	1,200	280	1,000	0	0	0	0
F	300	110	140	480	950	0	0	0	0

Note: Average-crustal abundance of elements based on Bowen (1979).

Table 4.3: Mineralogical Results for Waste-Bedrock Sample (Black-Shales)

Black-Shales (GCA5498)	
Component	Abundance
quartz muscovite	major
ankerite pyrite	minor
goethite graphite	accessory
calcite	trace

Note:

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

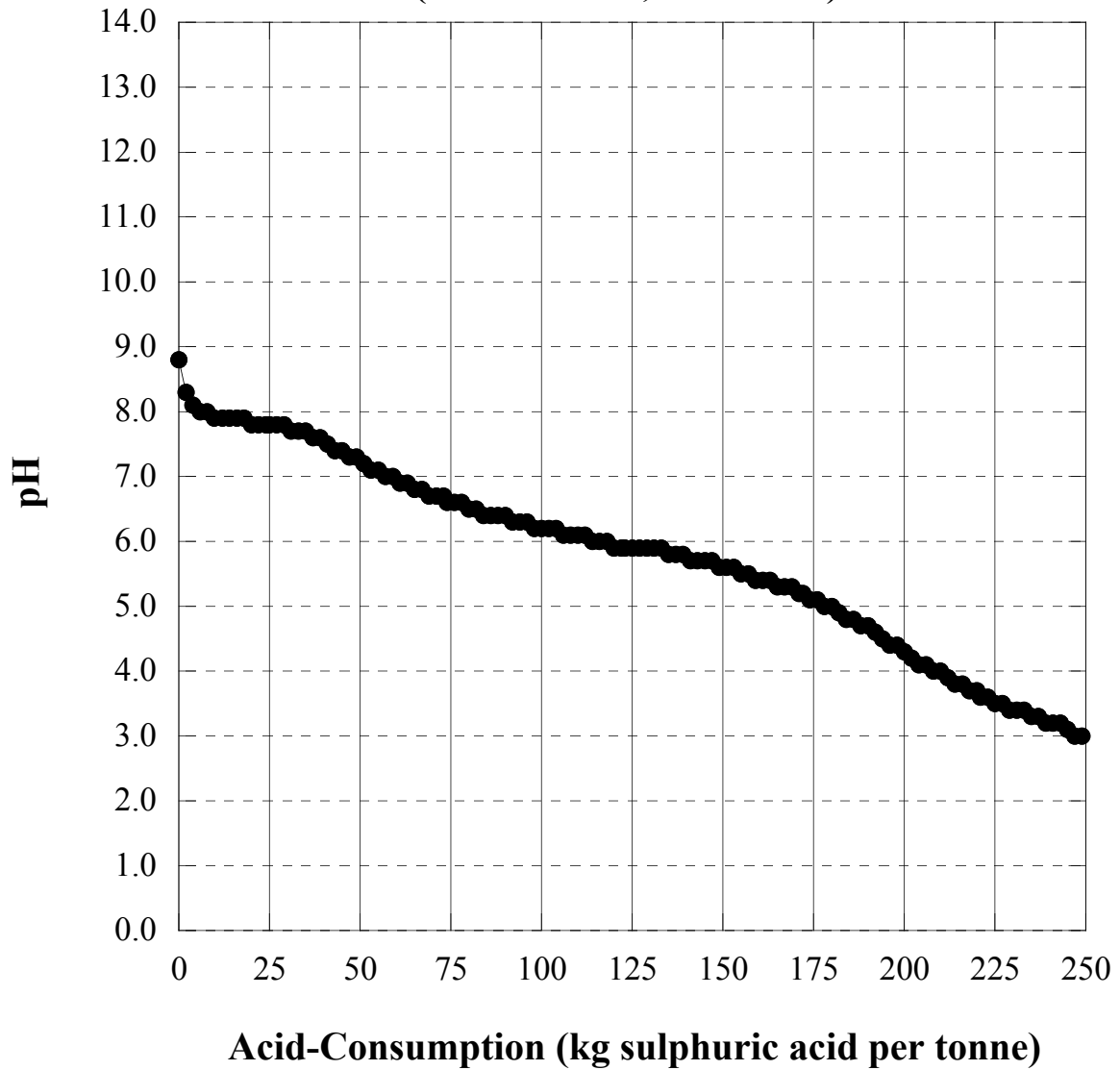
When analysed via an electron-microprobe during the scanning-electron-microscopy (SEM) work, ankerite grains had the following composition, viz.

- $(Mg_{0.24}Fe_{0.15}Mn_{0.02}Ca_{0.59})CO_3$
- $(Mg_{0.30}Fe_{0.17}Mn_{0.02}Ca_{0.57})CO_3$

FIGURE

Figure 1

**pH-Buffering Curve for Waste-Bedrock Sample
(Black-Shales, GCA5498)**



Note: The H₂SO₄-addition rate employed in the auto-titration corresponds to a sulphide-oxidation rate (SOR) of *c.* 1-2 x 10⁶ mg SO₄/kg/week (= *c.* 5-10 x 10⁴ kg H₂SO₄/tonne/year).

This SOR is therefore up to 10³-10⁴ **faster** than those typical for the weathering (at circum-neutral-pH) of mine-waste materials that contain "minor/major-sulphides".

APPENDIX A

DETAILS OF SAMPLING PROGRAMME

Sample Number	RC Hole ID	Easting	Northing	Sample Depth		End of RC hole depth/m	Stratigraphy	Min 1	Min 2	Min 3	Min 4	Standing Water Level/m below collar	Comments
				From	To								
25019	ML0289	211399	7490201	0	1	70	Qa	Kl	Sl				Waste
25009	ML0216	207400	7495498	5	6	52	Ta	Klp	Ch	Gom	Hsm		Waste
25015	ML0074	225900	7494813	2	3	22	Tds	Ho	Sh	Go			Waste
25003	ML0194	208998	7494093	2	3	34	Tdi	Kl	Ch	Sh			Waste
25005	ML0192	208998	7494498	4	5	16	Tdm	Gom	Vgh	Hsm			Waste
25006	ML0219	207378	7494497	12	13	82	Ch	Hsm	Ghm				Waste
25012	ML0221	207397	7494099	31	32	58	Cf	ogf	hsf	mi	pi		Waste
25011	ML0213	207399	7495298	35	36	64	Mus	Ns	Ghf	Rs			Waste
25013	ML0241	205802	7495106	25	26	46	Mum	Hom					Ore
25021	ML0196	208991	7493705	35	36	70	Mum	Ghm	Gom				Ore
25017	ML0159	212598	7492900	11	12	28	Muf	Hsp	Ghf				Ore
25007	ML0218	207401	7494898	38	39	46	Muf	Gom	Hom	Mn			Waste
25004	ML0193	209002	7494298	22	23	28	Mut	Ghm	Hsm	Ch			Waste
25014	ML0239	205802	7495499	11	12	58	Muh	Hok					Waste
25002	ML0095	227099	7495199	35	36	64	Mub	Ghm	Hsf	Gom			Waste
25008	ML0217	207404	7494691	24	25	58	Muk	Ghf	Rs				Waste
25016	ML0047	225902	7494498	36	37	54	Mu	Ho	Lo				Waste
25018	ML0161	212599	7492600	32	33	34	Jr	Ws	Rs	Ch	Ghm		Waste
25020	ML0330	210200	7492600	33	34	40	Jr	Bs	Py				Waste
25010	ML0214	207400	7495099	56	57	58	Jf	Bs	Ch				Waste

**STRATIGRAPHIC AND TEXTURAL CODES
GENERAL CHICHESTER RANGES
(revised June 2004)**

Stratigraphic Codes

Ta	Tertiary alluvium
Tdi	Tertiary immature detritals
Tds	Tertiary semi-mature detrital
Tdm	Tertiary mature detritals
Hc	Hardcap
Hso	Secondary Mineralization ('ore')
Cf	Cavity Fill
MU _h	Nammuldi member – Primary Mineralization <i>Bedded iron mineralization, hard</i>
MU _m	Nammuldi member – Primary Mineralization <i>Bedded iron mineralization, medium</i>
MU _f	Nammuldi member – Primary Mineralization <i>Bedded iron mineralization, friable</i>
MU _s	Nammuldi member – Goethitic and hematitic shales
MU _k	Nammuldi member – Shale unmineralized
MU _t	Nammuldi member – Transition Zone: Interbedded sequence of mineralized and unmineralized material at the base of the bedded iron mineralization.
MU _b	Nammuldi member – BIF (chert, shales)
F _j	Jerrinah Formation
J _r	Roy Hill Shale (commonly leached kaolonitic or black shale when fresh)

Textural Codes

MINERALS	Hematite	Hematite-Goethite	Goethite	Ochreous Goethite	Hematitic Shale	Goethitic Shale	Non-enriched Shale	Cavity Fill	Clays
HARDNESS									
Hard	HOH	GHHd							
		GHHp	GOH						
		VGH							
Medium	HOM	GHM	GOM		HSM	GSM	SHM	CFM	KLM
Friable	HOF	GHF		OGF	HSF	GSF	SHF	CFF	KLF
Powdery	HOP	GHP		OGP	HSP	GSP	SHP	CFP	KLP

APPENDIX B

TESTWORK METHODS

APPENDIX B

TESTWORK METHODS

B1.0 ACID-BASE-CHEMISTRY AND SALINITY TESTWORK

The acid-base chemistry and salinity of the regolith and waste-bedrock samples was assessed by determining:

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

Relevant details of the testwork methods employed are discussed briefly below. Further details are presented in the laboratory reports (see Appendix C).

B1.1 pH-(1:2) and EC-(1:2) Tests

Measurements of pH and EC were performed on slurries prepared using deionised-water, and a solid:water ratio of *c.* 1:2 (w/w). The sample slurries were allowed to age in contact with the air for *c.* 24 hours, prior to measuring pH and EC.¹

The resulting pH-(1:2) and EC-(1:2) values provide a measure of the inherent acidity/alkalinity and salinity of the samples.²

B1.2 Total-S and SO₄-S Tests

The Total-S values were measured by Leco combustion (@ 1300 °C) with detection of evolved SO_{2(g)} by infra-red spectroscopy.

The SO₄-S values were determined by the Na₂CO₃-Extraction Method (Lenahan and Murray-Smith 1986).³ The difference between the Total-S and SO₄-S values indicates the Sulphide-S (strictly Non-Sulphate-S) content.

B1.3 Acid-Consuming Properties

B1.3.1 ANC Tests

The ANC values of the samples were determined by a procedure based on that of Sobek *et al.* (1978). This procedure is essentially the "standard" method employed for

¹ The sample slurries were stirred at the beginning of the testwork, and once again immediately prior to measuring pH and EC.

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

³ The Na₂CO₃-reagent extracts SO₄-S 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 silicates. However, SO₄ present as barytes (BaSO₄) is not extracted, and SO₄ associated with jarositic-type and alunitic-type compounds are incompletely extracted.

estimating the ANC values of mine-waste materials (Morin and Hutt 1997; BC AMD Task Force 1989).

The samples were 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.⁴ The simmering step for *c.* 2 hours differs slightly from the heating treatment of the Sobek *et al.* procedure wherein the test mixtures are heated to near boiling until reaction is deemed to be complete (*viz.* gas evolution not visually apparent), followed by boiling for one minute. In terms of dissolution of carbonate, primary-silicate and oxyhydroxide minerals, this variation to the Sobek *et al.* method is inconsequential.

The Sobek *et al.* (1978) procedure exposes mine-waste samples to both strongly-acidic conditions (e.g. pH of 1-2), and a near-boiling temperature. Provided excess acid is added, this method ensures that carbonate-minerals (including ferroan and manganoan varieties) are dissolved quantitatively, and that at least traces of ferro-magnesian silicates (e.g. amphiboles, pyroxenes, chlorites, micas, etc.), and feldspars, are dissolved. However, under circum-neutral (*viz.* pH 6-8) conditions required for mine-waste and environmental management, the dissolution of ferro-magnesian silicates is kinetically extremely slow (e.g. see review-monograph by White and Brantley [1995]). Near pH=7, the dissolution rates (under 'steady-state' conditions, and in the absence of inhibiting alteration-rims) of mafic-silicates and feldspars generally correspond to H₂SO₄-consumption rates 'of-the-order' 10⁻¹¹/10⁻¹² moles/m²/s (White and Brantley 1995). As a guide, for minerals of sub-mm grading, such silicate-dissolution rates correspond to Sulphide-Oxidation Rates (SORs) ranging up to 'of-the-order' 1-10 mg

⁴ Two drops of 30 % (w/w) H₂O₂ were added to the test mixtures as the pH=7 end-point was approached, so that any 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 acidification/digestion step. Such potential bias in ANC values may be marked for mine-waste samples in which "Fe-rich" ferroan-carbonates (e.g. siderite) dominate acid consumption. The addition of the H₂O₂ reagent is not part of the methodology described by Sobek *et al.* (1978).

SO₄/kg/week (= c. 0.1-1.0 kg H₂SO₄/tonne/year).⁵ Maintenance of circum-neutral-pH through dissolution/hydrolysis of primary-silicates is therefore restricted to both "mineral-fines", and slow rates of pyrite weathering.

Despite the aggressive-digestion conditions employed, the ANC values determined by the Sobek *et al.* (1978) method allow an informed, initial "screening" of mine-waste materials in terms of acid-consuming and pH-buffering properties, especially when due account is taken of gangue mineralogy (Morin and Hutt 1997). Jambor *et al.* (2000, 2002) have presented a compendium of 'Sobek-ANC' values for specific classes of primary-silicates, and assists interpretation of the ANC values recorded for mine-waste materials of varying mineralogy.

B1.3.2 CO₃-C Values

The CO₃-C value is the difference between the Total-C and Total-Organic-C (TOC) values.

The Total-C was measured by Leco combustion (@ 1300 °C) with detection of evolved CO_{2(g)} by infra-red spectroscopy. The TOC was determined by Leco combustion on a sub-sample which had been treated with strong HCl to decompose carbonate-minerals.

B1.3.3 pH-Buffering Properties

The pH-Buffering properties of the Black-Shales sample (GCA5498) were determined via a Metrohm[®] 736 Titrino auto-titrator, and 0.05 M-H₂SO₄.

The auto-titration comprised regular addition of the H₂SO₄ reagent to monotonically decrease the pH value of the test-suspension to 3.0.⁶ The Start-pH value of the

⁵ 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 0.5 %).

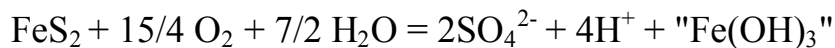
suspension was *c.* 9. Under the testwork conditions employed, the H₂SO₄-addition rate corresponds to an SOR 'of-the-order' 10⁶ mg SO₄/kg/week (i.e. 'of-the-order' 10⁴-10⁵ kg H₂SO₄/tonne/year) , and so represent a very-rapid rate of acid addition.

Further details of the auto-titration are presented in the laboratory reports (Appendix C).

B1.4 NAPP Calculations

The NAPP values of the samples were calculated from the Total-S, SO₄-S and ANC values, assuming that all of the Non-Sulphate-S occurs in the form of pyrite. The NAPP calculations serve as a starting point in the assessment of the acid-formation potential of sulphide-bearing materials.

The complete oxidation of pyrite may be described by:



It may be shown that, if the Sulphide-S (in %S) occurs as pyrite, then the amount of acid (in kg H₂SO₄/tonne) produced through complete-oxidation is given by **30.6 x %S**.

Note: 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.

⁶ It should be noted that, in titrating to a pH=3.0 end-point, any Fe(II) released through acid attack of ferroan-silicates and -carbonates is not quantitatively oxidised to Fe(III). Furthermore, under the conditions employed in the auto-titration, the equivalent of *c.* 0.5 kg H₂SO₄/tonne was required to decrease the pH of the "solution-only" (i.e. without waste-rock sample) to pH=3.0. No correction was made for such "electrolyte-consumption" of the 0.05 M-H₂SO₄ titrant.

B1.5 NAG Tests

The NAG Test is a direct measure of a sample's potential to produce acid through sulphide oxidation, and also provides an indication of the reactivity of the sulphides, and the availability of the alkalinity-forms contributing to the ANC (AMIRA 2002; Miller *et al.* 1997, 1994).

In this test, the sample is reacted with H₂O₂ to rapidly oxidise contained sulphides, and allow the produced acid to react with the acid-neutralising materials (e.g. carbonates). The NAG Test supplements the NAPP-based assessment of the acid-formation potential of mine-waste materials (Morin and Hutt 1997).

The procedure employed in this study is based on that for the 'Static-NAG Test' (AMIRA 2002; Miller *et al.* 1994, 1997). The Start-pH of the 15 % (w/w) H₂O₂ solution (prepared from A.R.-grade H₂O₂) was adjusted to pH=4.5 using dilute NaOH. In addition, the boiling treatment to decompose residual, unreacted-H₂O₂ following overnight reaction was carried out in two stages (*viz.* boiling for *c.* 2 hours initially, cooling and addition of 1 mL of 0.02 M-CuSO₄ to the test mixtures, followed by boiling again for *c.* 2 hours). The addition of Cu(II) salts catalyses the decomposition of residual H₂O₂, and thereby prevents "positive-blank" values being obtained (O'Shay *et al.* 1990).⁷ Pulped K-feldspar was employed for the blanks run for the NAG testwork.

Prior to the boiling steps, the pH values of the test-mixture suspensions are measured, and invariably correspond to an "overnight-period" of reaction. Such pH values reflect buffering under ambient conditions without accelerated dissolution of gangue-phases through boiling to decompose any unreacted-H₂O₂. In the interpretation of NAG-testwork data, it is important to take note of the pH values recorded prior to the boiling steps, especially for mine-waste samples that have both Sulphide-S contents less than 1

⁷ Where mine-waste samples contain sufficient Cu, then Cu(II) forms will be released to solution during the NAG Test, especially at low pH.

%, and ANC values less than *c.* 10 kg H₂SO₄/tonne (as typically recorded for a felsic/mafic-gangue that is void of carbonates). Furthermore, oxidation by H₂O₂ is generally at least 10³ faster than the SORs recorded during 'kinetic' testing (e.g. Weathering-Columns) of mine-waste samples. If circum-neutral conditions are to prevail during NAG testwork, then the rate of acid consumption by gangue-phases must be proportionately faster (c.f. rates for 'ambient-weathering'), and is essentially restricted to pH-Buffering by carbonates (viz. calcites, dolomites and ankerites) that are not unduly ferroan. This aspect must also be borne in mind when interpreting NAG-testwork data, especially for mine-waste materials that contain "trace-sulphides" in a carbonate-void gangue, since the dissolution/hydrolysis kinetics of primary-silicates (both felsic- and mafic-silicates) are strongly pH-dependent.

B2.0 MULTI-ELEMENT ANALYSES

The total content of a wide range of major- and minor-elements in selected samples was determined through the use of various digestion and analytical techniques. The detection-limits employed in these analyses are appropriate for environmental investigations.

Element enrichments were identified using the *Geochemical Abundance Index (GAI)*.⁸

The GAI quantifies an assay result for a particular element in terms of the average-crustal-abundance of that element.⁹

⁸ The GAI was developed by Förstner *et al* (1993), and is defined as:

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

where:

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

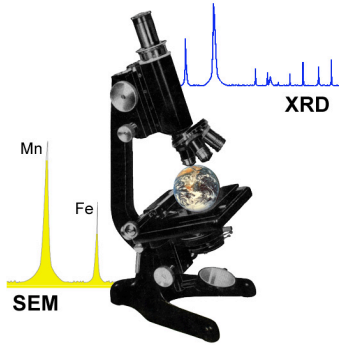
B_n = "background" content of the n-th element in the sample.

⁹ The average-crustal-abundances of the elements for the GAI calculations are based on the values listed in Bowen (1979).

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.

APPENDIX C

LABORATORY REPORTS



*Roger Townend and
Associates
Consulting Mineralogists*

G CAMPBELL AND ASSOC,

17-12-2004

PO BOX 247,

BRIDGETOWN

WA 6255

OUR REF 21195

YOUR REF. 0417/2

XRD/PLM/SEM ANALYSIS OF ONE SAMPLE.

(MT LEWIN)

R TOWNEND

Correspondence to Box 3129, Malaga D.C. WA 6945

ACN 069 920 476 ABN 92 076 109 663

RESULTS XRD/PLM/SEM

GCA	5498
QUARTZ	MAJOR
MUSCOVITE	MAJOR
ANKERITE	MINOR
CALCITE	TRACE
PYRITE	MINOR
GOETHITE	ACCESSORY
GRAPHITE	ACCESSORY

WT%	ANKERITE 1	ANKERITE 2
MgO	9.4	12.1
FeO	10.8	9.5
CaO	33.2	32.0
MnO	1.5	1.2



2 December, 2004

Graeme Campbell & Associates Pty Ltd
Attn: Dr G Campbell
PO Box 247
BRIDGETOWN WA 6255

Our Reference: 84763
Your Reference: GCA0417/2
NATA Accreditation: 2562(1705)

Dear Sir

On the 2nd of November 2004 you forwarded test work instructions for twenty (20) waste rock samples that were received on 22nd October 2004 at our laboratory via Fortescue Minerals. As per your instructions all samples were crushed to a nominal 2mm and pulped to a nominal 75µm. Approximately 50 grams of the pulps were sent to Graeme Campbell and Associates.

Results of all test work performed follow:

Sample Number	pH (1:2) (pH Units)	Conductivity (1:2) µs/cm	Total Sulphur, S (%w/w)	Sulphate Sulphur, SO ₄ -S (Na ₂ CO ₃) (%w/w)
GCA5498	7.3	1,800	15.0	0.17
RPT GCA5498	7.2	1,800	-	NA
GCA5499	7.6	190	0.039	NA
GCA5500	7.6	120	0.032	NA
GCA5501	7.9	180	0.015	NA
GCA5502	7.7	300	0.022	NA
GCA5503	8.0	130	0.081	NA
GCA5504	7.4	280	0.034	NA
GCA5505	7.5	210	0.028	NA
GCA5506	7.6	160	0.021	NA
GCA5507	7.7	280	0.22	0.035
RPT GCA5507	-	-	-	0.028
GCA5508	6.1	1,100	0.077	NA
RPT GCA5508	6.1	1,100	-	NA
GCA5509	6.7	120	0.045	NA
GCA5510	7.6	140	0.041	NA
GCA5511	7.6	94	0.026	NA
GCA5512	7.7	290	0.021	NA
GCA5513	7.3	91	0.018	NA
GCA5514	7.4	550	0.088	NA
GCA5515	7.7	110	0.011	NA
GCA5516	6.7	96	0.048	NA
GCA5517	7.3	380	0.039	NA

CLIENT: Graeme Campbell & Associates Pty Ltd
PROJECT NO: GCA0417/2

OUR REFERENCE: 84763

NOTES:

1. Sulphate sulphur was determined on the nominal 2mm crushed sample by Na_2CO_3 extraction, BaSO_4 precipitation.
2. Total sulphur was determined on pulped sample by LECO induction furnace, IR detection, and is reported on that basis. This test work was performed by SGS Minerals Services, Welshpool, report number WM082322 (NATA 1936).

Acid Neutralisation Capacity (ANC):

Sample Number	Fizz Rating	Sample Weight (g)	Titre NaOH (mL)	Normality HCl/NaOH (N)	Initial Effervescence	Effervescence on Warming	ANC Solution pH	ANC (kg H_2SO_4 /tonne)
GCA5498	2	1.2188	19.30	1N	Moderate	Nil	0.7	230
RPT GCA5498	2	1.0328	19.90	1N	Moderate	Nil	0.7	240
GCA5499	1	5.0183	22.40	0.1N	Slight	Nil	1.5	2.7
GCA5500	0	5.0111	23.20	0.1N	Nil	Nil	1.5	1.9
GCA5501	0	5.0029	22.50	0.1N	Nil	Nil	1.4	2.6
GCA5502	0	5.0060	22.00	0.1N	Nil	Nil	1.4	3.1
GCA5503	0	5.0190	23.50	0.1N	Nil	Nil	1.4	1.6
GCA5504	1	5.0069	23.20	0.1N	Nil	Nil	1.5	1.9
GCA5505	1	5.0038	19.00	0.1N	Nil	Nil	1.6	6.0
GCA5506	0	5.0028	21.00	0.1N	Nil	Nil	1.5	4.1
GCA5507	0	5.0073	14.80	0.1N	Nil	Nil	1.7	10
GCA5508	1	5.0095	23.70	0.1N	Nil	Nil	1.4	1.4
GCA5509	0	5.0018	22.30	0.1N	Nil	Nil	1.5	2.8
RPT GCA5509	0	5.0047	22.20	0.1N	Nil	Nil	1.5	2.9
GCA5510	0	5.0078	22.60	0.1N	Nil	Nil	1.4	2.5
GCA5511	0	5.0024	22.50	0.1N	Nil	Nil	1.4	2.6
GCA5512	0	5.0093	22.50	0.1N	Nil	Nil	1.4	2.6
GCA 5513	0	5.0019	22.60	0.1N	Nil	Nil	1.4	2.5
GCA 5514	0	5.0026	22.80	0.1N	Nil	Nil	1.4	2.3
GCA 5515	0	5.0048	23.00	0.1N	Nil	Nil	1.4	2.1
GCA 5516	0	5.0018	22.90	0.1N	Nil	Nil	1.4	2.2
GCA 5517	1	5.0072	19.50	0.1N	Nil	Nil	1.5	5.5
ANC Std 20		2.0000	17.00	0.1N	Nil	Nil	1.5	19.9

CLIENT: Graeme Campbell & Associates Pty Ltd

OUR REFERENCE: 84763

PROJECT NO: GCA0417/2

NOTES:

1. Acid neutralisation capacity was determined on the nominal 2mm crushed sample. Unless otherwise stated, 25mL of HCl is used. Reagent blank titre of 0.1N NaOH was 25.20mL and 1N NaOH was 25.10mL.
2. ANC Std20 is an internally produced standard of CaCO₃ and quartz pulped to a nominal 75µm particle size which has nominal ANC of 20kg of H₂SO₄/tonne.
3. This procedure is based on Sobek et al, 1978.

Yours faithfully,

Steven Edmett.

STEVEN EDMETT
Client Liaison Manager

J. Venning

JANICE VENNING
Manager, Perth

This report supersedes our preliminary results sent by facsimile on the 16th November 2004.



NATA Endorsed Test Report

This document may not be reproduced except in full.

NATA Accredited Laboratory No. 2562

2 December, 2004

Graeme Campbell & Associates Pty Ltd
Attn: Dr G Campbell
PO Box 247
BRIDGETOWN WA 6255

Our Reference: 85238
Your Reference: GCA0417/2 Additional Analysis
NATA Accreditation: 2562(1705)

Dear Sir

On the 16th November 2004 you forwarded test work instructions for one (1) waste rock sample that was received on the 27th October 2004 at our laboratory.

Results of all test work performed follow:

Sample Number	Total Carbon, C (% w/w)	Total Inorganic Carbon (% w/w)	Carbonate Carbon, CO ₃ -C (% w/w)
GCA5498	5.81	2.36	3.50

NOTES:

1. *Total carbon and total organic carbon (noncarbonate or acid insoluble carbon) were determined on the air dried pulped sample by LECO induction furnace, IR detection, and is reported on that basis. This test work was performed by SGS Minerals Services, Welshpool, report number WM082660 (NATA1936).*
2. *Carbonate carbon is determined as the difference between total carbon and total organic carbon.*

Yours faithfully,

Steven Edmatt.

STEVEN EDMETT
Client Liaison Manager

J. Venning

JANICE VENNING
Manager, Perth

This report supersedes our preliminary results sent by facsimile on the 25th November 2004.



NATA Endorsed Test Report

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NATA Accredited Laboratory No. 2562

Graeme Campbell & Associates Pty Ltd Laboratory Report
NET-ACID-GENERATION (NAG) TESTWORK

Sample Number	Sample Weight (g)	Comments	pH of Test Mixture Before Boiling Step	Test Mixture After Boiling Step		Titre [0.1 M-NaOH] (mL)	NAG (kg H ₂ SO ₄ /tonne)
				pH	EC (µS/cm)		
GCA5498	1.00	Reaction peaked overnight	2.5	2.4	3,900	35.50	180
GCA5499	3.9	Reaction peaked overnight	6.5	7.2	43	-	<0.5
GCA5500	3.8	Reaction peaked overnight	6.4	6.6	36	0.30	<0.5
GCA5501	4.1	Reaction peaked overnight	6.5	6.5	37	0.40	<0.5
GCA5502	3.7	Reaction peaked overnight	9.5	8.8	59	-	<0.5
GCA5503	4.1	Reaction peaked overnight	5.8	7.1	40	-	<0.5
GCA5504	3.4	Reaction peaked within 2 minutes	8.2	7.4	47	-	<0.5
GCA5504 (Repeat)	3.1	Reaction peaked within 2 minutes	8.2	7.1	52	-	<0.5
Blank	4.6		5.6	7.1	71	-	<0.5

Notes: Test conditions based on those described by Miller *et al.* (1997). 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. Test mixtures boiled for *c.* 2 hours to accelerate reaction with H₂O₂. Then, after allowing the test mixtures to cool, 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 (O'Shay *et al.* 1990). K-Feldspar was employed for the Blanks. Samples labelled with an asterisk signifies that 0.5 M-NaOH employed.

Dr GD Campbell
24th November 2004

Graeme Campbell & Associates Pty Ltd Laboratory Report
NET-ACID-GENERATION (NAG) TESTWORK

Sample Number	Sample Weight (g)	Comments	pH of Test Mixture Before Boiling Step	Test Mixture After Boiling Step		Titre [0.1 M-NaOH] (mL)	NAG (kg H ₂ SO ₄ /tonne)
				pH	EC (µS/cm)		
GCA5505	3.7	Reaction peaked within 5 minutes	7.6	7.2	56	-	<0.5
GCA5506	4.6	Reaction peaked within 3 hours	6.7	7.3	39	-	<0.5
GCA5507	4.8	Reaction peaked within 3 hours	7.2	7.0	110	-	<0.5
GCA5508	4.1	Reaction peaked within 1-2 minutes (!)	7.2	6.8	87	0.10	<0.5
GCA5509	5.1	Reaction peaked overnight (?)	6.3	7.2	38	-	<0.5
GCA5510	5.1	Reaction peaked within 3 hours	7.1	7.8	34	-	<0.5
GCA5511	4.9	Reaction peaked within 30 minutes	8.1	7.5	61	-	<0.5
GCA5512	4.6	Reaction peaked overnight (?)	6.2	7.1	35	-	<0.5
GCA5513	4.7	Reaction peaked within 30 minutes	7.4	7.3	30	-	<0.5
GCA5514	4.9	Reaction peaked overnight (?)	6.4	7.2	56	-	<0.5
GCA5515	4.3	Reaction peaked within 3 hours	7.6	7.4	33	-	<0.5
GCA5516	3.8	Reaction peaked within 3 hours	7.6	7.3	33	-	<0.5
GCA5517	4.4	Reaction peaked within 3 hours	7.8	7.6	43	-	<0.5
GCA5517 (Repeat)	4.8	Reaction peaked within 3 hours	7.9	7.7	44	-	<0.5
Blank	6.6		6.1	7.3	71	-	<0.5

Notes: Test conditions based on those described by Miller *et al.* (1997). 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. Test mixtures boiled for *c.* 2 hours to accelerate reaction with H₂O₂. Then, after allowing the test mixtures to cool, 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 (O'Shay *et al.* 1990). K-Feldspar was employed for the Blanks. Samples labelled with an asterisk signifies that 0.5 M-NaOH employed.

Dr GD Campbell
2nd December 2004

Laboratory Report

pH-BUFFERING TESTWORK (GCA5498)

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H₂SO₄/tonne)	pH	Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H₂SO₄/tonne)	pH
0.00	0.0	8.8	16.00	78	6.6
0.40	2.0	8.3	16.40	80	6.5
0.80	3.9	8.1	16.80	82	6.5
1.20	5.9	8.0	17.20	84	6.4
1.60	7.8	8.0	17.60	86	6.4
2.00	9.8	7.9	18.00	88	6.4
2.40	12	7.9	18.40	90	6.4
2.80	14	7.9	18.80	92	6.3
3.20	16	7.9	19.20	94	6.3
3.60	18	7.9	19.60	96	6.3
4.00	20	7.8	20.00	98	6.2
4.40	22	7.8	20.40	100	6.2
4.80	24	7.8	20.80	102	6.2
5.20	25	7.8	21.20	104	6.2
5.60	27	7.8	21.60	106	6.1
6.00	29	7.8	22.00	108	6.1
6.40	31	7.7	22.40	110	6.1
6.80	33	7.7	22.80	112	6.1
7.20	35	7.7	23.20	114	6.0
7.60	37	7.6	23.60	116	6.0
8.00	39	7.6	24.00	118	6.0
8.40	41	7.5	24.40	120	5.9
8.80	43	7.4	24.80	122	5.9
9.20	45	7.4	25.20	123	5.9
9.60	47	7.3	25.60	125	5.9
10.00	49	7.3	26.00	127	5.9
10.40	51	7.2	26.40	129	5.9
10.80	53	7.1	26.80	131	5.9
11.20	55	7.1	27.20	133	5.9
11.60	57	7.0	27.60	135	5.8
12.00	59	7.0	28.00	137	5.8
12.40	61	6.9	28.40	139	5.8
12.80	63	6.9	28.80	141	5.7
13.20	65	6.8	29.20	143	5.7
13.60	67	6.8	29.60	145	5.7
14.00	69	6.7	30.00	147	5.7
14.40	71	6.7	30.40	149	5.6
14.80	73	6.7	30.80	151	5.6
15.20	74	6.6	31.20	153	5.6
15.60	76	6.6	31.60	155	5.5

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H ₂ SO ₄ /tonne)	pH	Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H ₂ SO ₄ /tonne)	pH
32.00	157	5.5	41.60	204	4.1
32.40	159	5.4	42.00	206	4.1
32.80	161	5.4	42.40	208	4.0
33.20	163	5.4	42.80	210	4.0
33.60	165	5.3	43.20	212	3.9
34.00	167	5.3	43.60	214	3.8
34.40	169	5.3	44.00	216	3.8
34.80	171	5.2	44.40	218	3.7
35.20	172	5.2	44.80	220	3.7
35.60	174	5.1	45.20	221	3.6
36.00	176	5.1	45.60	223	3.6
36.40	178	5.0	46.00	225	3.5
36.80	180	5.0	46.40	227	3.5
37.20	182	4.9	46.80	229	3.4
37.60	184	4.8	47.20	231	3.4
38.00	186	4.8	47.60	233	3.4
38.40	188	4.7	48.00	235	3.3
38.80	190	4.7	48.40	237	3.3
39.20	192	4.6	48.80	239	3.2
39.60	194	4.5	49.20	241	3.2
40.00	196	4.4	49.60	243	3.2
40.40	198	4.4	50.00	245	3.1
40.80	200	4.3	50.40	247	3.0
41.20	202	4.2	50.80	249	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.

Calibration of pH-Glass Electrode:

Immediately prior to titration: asymmetry potential = -14 mV (pH=7.00); slope-point = 162 mV (pH=4.00); 99.0 % of Nernstian response for 25 °C.

Immediately following titration: pH=7.00 buffer read pH=7.03 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
19th November 2004

ANALYTICAL REPORT

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

JOB INFORMATION

JOB CODE : 143.0/0409314
 No. of SAMPLES : 8
 No. of ELEMENTS : 32
 CLIENT O/N : GCA0417/2
 SAMPLE SUBMISSION No. :
 PROJECT : MT LEWIN ORE PROJECT
 STATE : Solid
 DATE RECEIVED : 19/11/2004
 DATE COMPLETED : 14/12/2004
 DATE PRINTED : 14/12/2004

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

MAIN OFFICE AND LABORATORY

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Anderbolt, Gauteng, South Africa 1459.

Tel: +27 11 918 0869 Fax: +27 11 918 0879

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 \$1.50 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 \$50.00 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 8 samples, as listed in the report, were received as being waste rocks.

The sample required drying at 45 degrees Celcius prior to being fine pulverised in a zirconia bowl.

The results have been determined according to Genalysis methods numbers : SL_W001 (A), SL_W007 (BP/), ENV_W012 (DH/SIE), SL_W013 (D/) and SL_W012 (CM/) for the digests and ICP_W004 (/OES), ICP_W005 (/MS) and AAS_W004 (/CVAP).

The results included the assay of blanks and international reference standard SARM1 and SO-2 and Genalysis in-house standards TKC4, AE12 and HgSTD-3.

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

NATA Signatory: T K Chan

Date: 14th December 2004

ANALYSIS

ELEMENTS	Ag	Al	As	B	Ba	Bi	Ca	Cd	Co	Cr
UNITS	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
DETECTION	0.1	20	1	50	0.1	0.01	10	0.1	0.1	2
DIGEST	A/	A/	A/	D/	A/	A/	A/	A/	A/	A/
ANALYTICAL FINISH	MS	OES	MS	OES	MS	MS	OES	MS	MS	OES
SAMPLE NUMBERS										
0001 GCA5498	0.2	3.77%	60	56	172.4	0.74	6.82%	1.8	45.0	109
0002 GCA5499	0.2	10.01%	18	X	268.5	0.76	1146	0.2	20.1	245
0003 GCA5501	0.1	2.10%	11	X	27.9	0.28	429	0.1	1.8	51
0004 GCA5504	0.3	4.48%	25	X	1242.4	0.91	1054	2.3	142.0	59
0005 GCA5510	0.4	8.43%	89	X	340.9	1.23	1727	0.1	15.6	705
0006 GCA5512	0.2	8490	16	X	71.4	0.18	473	0.5	13.0	20
0007 GCA5513	0.1	2.26%	40	X	51.1	0.16	310	1.6	91.4	39
0008 GCA5516	0.3	7.35%	130	58	95.7	0.58	454	0.3	54.8	276
CHECKS										
0001 GCA5498	0.3	3.76%	61	58	176.8	0.76	6.72%	1.8	43.7	105
STANDARDS										
0001 AE12										
0002 HgSTD-3										
0003 SARM1				X						
0004 SO-2										
0005 TKC4	17.9	5.68%	634		1063.6	33.10	1.83%	5.6	152.0	942
BLANKS										
0001 Control Blank	0.1	X	X	X	X	0.02	X	X	X	X

ANALYSIS

ELEMENTS	P	Pb	S	Sb	Se	Sn	Sr	Th	Tl	U
UNITS	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
DETECTION	20	2	10	0.05	0.01	0.1	0.05	0.01	0.02	0.01
DIGEST	A/	A/	A/	A/	BP/	A/	A/	A/	A/	A/
ANALYTICAL FINISH	OES	MS	OES	MS	MS	MS	MS	MS	MS	MS
SAMPLE NUMBERS										
0001 GCA5498	275	34	12.45%	2.47	4.82	2.7	32.05	5.05	3.53	1.56
0002 GCA5499	269	24	371	1.65	1.14	3.0	21.84	17.11	0.21	3.29
0003 GCA5501	150	8	191	1.31	0.29	0.7	6.10	3.11	0.19	0.85
0004 GCA5504	997	39	334	1.04	0.18	1.1	125.61	5.87	2.48	2.69
0005 GCA5510	384	37	440	6.44	1.19	5.2	46.26	16.60	0.35	2.92
0006 GCA5512	1456	28	199	1.19	0.06	0.3	14.89	1.40	0.14	2.78
0007 GCA5513	1114	15	138	1.01	0.18	0.5	21.53	2.24	0.12	4.73
0008 GCA5516	227	44	480	6.55	1.00	2.4	20.72	8.18	2.97	2.65
CHECKS										
0001 GCA5498	269	35	12.25%	2.42	4.87	2.7	32.15	5.15	3.68	1.61
STANDARDS										
0001 AE12					0.56					
0002 HgSTD-3										
0003 SARM1										
0004 SO-2										
0005 TKC4	1547	1713	1.21%	193.38		7.1	494.81	152.21	15.13	17.22
BLANKS										
0001 Control Blank	X	X	X	X	X	X	X	0.01	X	X

ANALYSIS

ELEMENTS	V	Zn
UNITS	ppm	ppm
DETECTION	2	1
DIGEST	A/	A/
ANALYTICAL FINISH	OES	OES
SAMPLE NUMBERS		
0001 GCA5498	60	462
0002 GCA5499	193	72
0003 GCA5501	59	63
0004 GCA5504	213	229
0005 GCA5510	444	69
0006 GCA5512	345	135
0007 GCA5513	25	248
0008 GCA5516	129	86
CHECKS		
0001 GCA5498	60	449
STANDARDS		
0001 AE12		
0002 HgSTD-3		
0003 SARM1		
0004 SO-2		
0005 TKC4	355	1121
BLANKS		
0001 Control Blank	X	X

METHOD CODE DESCRIPTION

A/MS

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

A/OES

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

BP/MS

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

D/OES

Sodium peroxide fusion (Zirconium crucibles) and Hydrochloric acid to dissolve the melt. Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.

DH/SIE

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

CM/CVAP

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