FORTESCUE METALS GROUP LTD

MOUNT NICHOLAS 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 Nicholas Deposit have been geochemically characterised.

With the exception of the Black-Shales, all lithotypes should be classified as Non-Acid Forming (NAF), due to minute/negligible amounts of sulphide-minerals. Although the groundmass of these lithotypes should also be typically devoid of carbonate-minerals, the White-Shale from the Nummuldi-Member may be dominated by dolomite, and the Hematised-Shale/Hematite from this Member should contain at least traces of calcite/dolomite. 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 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 Nicholas 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_2SO_4/tonne
MPA	Maximum-Potential Acidity	Calculation	kg H_2SO_4/tonne
NAPP	Net-Acid-Producing Potential	Calculation	kg H_2SO_4/tonne
NAG	Net-Acid Generation	Testwork Result	kg H_2SO_4/tonne
NAF	Non-Acid Forming	Calculation: • Sulphide-S < 0.3 % • Sulphide-S ≥ 0.3 %, and negative-NAPP value with ANC/MPA ≥ 2.0	kg H_2SO_4/tonne
PAF	Potentially-Acid Forming	Calculation: • Sulphide-S ≥ 0.3 %, and any positive-NAPP value • Sulphide-S ≥ 0.3 %, and a negative-NAPP value with ANC/MPA < 2.0	kg H_2SO_4/tonne
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 **O_2-supply**, may instead be classified as PAF-[LL] in semi-arid/arid environments where the SOR is contolled 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 Nicholas Deposit located *c.* 110 kms 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.

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[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.[2]

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 Nicholas 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.

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[2] It should be noted that although four (4) samples of Black-Shales are indicated in Appendix A, only two (2) samples were received for testing.

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.[3]

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 H_2SO_4/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 O_2 to "$Fe(OH)_3$" and H_2SO_4, and the different weight-based units of % and kg H_2SO_4/tonne. The stoichiometry of pyrite-oxidation is discussed further in Appendix B.

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[3] NATA = National Association of Testing Authorities.

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

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 ≥ 0.3 %, both a negative NAPP value, and an ANC/MPA ratio ≥ 2.0.
- **PAF**: For Sulphide-S ≥ 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 SO_4/kg/week) [= *c.* 1-2 kg SO_4/tonne/year].[4] 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.[5]

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] "by-passes" 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

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[4] Although 'steady-state' SORs (at circum-neutral-pH) for Sulphide-S contents less than 0.3 % may indeed exceed 1-2 kg SO_4/tonne/year, such rates are generally restricted to either sedimentary forms (e.g. framboidal-pyrite), or hydrothermal-sulphides that are atypically reactive.

[5] 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".

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.

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).[6] This ANC/MPA ratio is employed in the present work.[7]

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).[8] 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]**

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[6] 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).

[7] 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.

[8] SO_4 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.

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.

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. 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 7.0-7.3, and EC-(1:2) values of 0.19-0.42 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 0.04-0.06 % (Table 3.1).

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

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[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 that ranged of 1.8-2.5 kg H_2SO_4/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 6.1-6.2, and NAG values less than 0.5 kg H_2SO_4/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 2.3-8.8, and EC-(1:2) values of 0.16-6.6 mS/cm (Table 3.1).

If the results for the samples of Black-Shales are excluded, then the pH-(1:2) values were greater than, or equal to, 6.0. In this case, the EC-(1:2) values were less than 0.9 mS/cm.

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

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[10] ANC values of 1.8-2.5 kg H_2SO_4/tonne is equivalent to *c.* 0.18-0.25 % (as "$CaCO_3$").

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

The samples of Black-Shales were strongly-acidic (viz. pH 2-3), and saline (sulphate-dominated), due to sulphide-oxidation.

3.2.2 Sulphur Forms

The samples had Total-S values of 0.02-11 % (Table 3.1).

If the results for the samples of Black-Shales are excluded, then the Total-S values were 0.02-0.07 %.

The samples of Black-Shales had Total-S values of 5.8-11 %, and SO_4-S values of 0.51-2.3 %. Alunite was identified in one of these samples (Table 4.3). An appreciable extent of sulphide-oxidation is therefore apparent in the samples of Black-Shales.

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

The samples of Black-Shales contained accessory-to-minor amounts of sulphide-minerals (viz. Sulphide-S contents ranging up to 10+ %).

3.2.3 Acid-Consuming Properties

The samples had ANC values that ranged from –17 kg H_2SO_4/tonne, to 710 kg H_2SO_4/tonne (Table 3.1).

The negative-ANC values recorded for the samples of Black-Shales reflects excess acidity in these samples, due to sulphide-oxidation.

If the results for the White-Shale and Hematised-Shale/Hematite from the Nummuldi-Member are excluded, then the ANC values of the remaining samples were less than 5-10 kg H_2SO_4/tonne.

The presence of reactive-carbonates (e.g. calcite) in the White-Shale and Hematised-Shale/Hematite samples was indicated by the effervescence (i.e. "fizzing") produced upon the addition ('in-the-cold') of HCl during the ANC-testwork. These samples also had CO_3-C values of 0.85-7.7 % (Table 3.1). The pH-Buffering properties of the White-Shale and Hematised-Shale/Hematite samples were determined via auto-titrations, and 0.05 M-H_2SO_4. The H_2SO_4-addition rates employed during the auto-titrations were *c.* 10^4-10^5 kg H_2SO_4/tonne/year, and correspond to SORs up to 10^5-10^6 faster than those typically observed for the weathering (at circum-neutral-pH) of "minute/trace-sulphides". The pH-buffering curves (Figure 1) exhibited a "linear-decrease" in pH with progressive acid-addition, associated with the dissolution of dolomite (and calcite).

The testwork results indicate that the samples typically had a very-low capacity to consume acid. However, the White-Shale and Hematised-Shale/Hematite samples derived from the Nummuldi-Member were variously calcareous, and so had a high capacity to consume acid. The White-Shale sample, in particular, was dominated by dolomite.

3.2.4 Acid-Formation Potential

If the results for the samples of Black-Shale are excluded, then the samples had NAG values less than 0.5 kg H_2SO_4/tonne, and NAG-pH values of 6.2-7.3 (Table 3.1).

The samples of Black-Shales had NAPP values of 180-290 kg H_2SO_4/tonne, NAG values of 150-180 kg H_2SO_4/tonne, and NAG-pH values of 2.5-2.8. There was good agreement between the calculated-NAPP, and measured-NAG, values for these samples.

The testwork results indicate that, apart from the Black-Shales, all samples were classified as *NAF.*

The samples of Black-Shales are classified as *PAF-[Short-Lag].* *Since these samples are already strongly-acidic, there is no "lag-phase", as such, for these samples.*[12] *However, the 'ex-pit' varieties of this lithotype may have a "lag-phase" of at least days-to-weeks prior to the development of strongly-acidic conditions. Further investigations would be needed to confirm (or refine) this projection.*

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[12] Appreciable sulphide-oxidation has likely occurred in these samples between the time of drilling initially, and when actually tested.

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.[13] 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.[14] 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 indicates that the pyrite in this lithotype is only moderately enriched in chalcophyles.

The samples of White-Shale and Hematised-Shale/Hematite each contained dolomite (Table 4.3). The dolomite – dominant component – in the White-Shale sample was an end-member variety with almost non-detectable amounts of Fe/Mn when subjected to electron-microprobe analysis (see mineralogical report in Appendix C). The sample of Black-Shales mainly comprised alunite, kaolin and pyrite.

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

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[13] 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.

[14] 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 Black-Shales, the regoliths and waste-bedrocks to be produced during open-pit mining of the Mount Nicholas Deposit should be classified as NAF, due to minute/negligible amounts of sulphide-minerals.[15] Although the groundmass of these lithotypes should also be typically devoid of carbonate-minerals, the White-Shale from the Nummuldi-Member may be dominated by dolomite, and the Hematised-Shale/Hematite from this Member should contain at least traces of calcite/dolomite. 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 Black-Shales are classified as PAF-[Long-Lag].[16] However, based on economic evaluations, open-pit mining will not extend deep enough for the Black-Shales to be intersected (Ms Nicky Hogarth, *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 Nicholas Deposit.

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[15] NAF = Non-Acid Forming.

[16] PAF = Potentially-Acid Forming.

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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	DRILLHOILE & 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_2SO_4/tonne				
REGOLITH SAMPLES														
Sample of Tertiary-Alluvial														
GCA5254	300723	Hematite/Grey-Chert	MN086, 0-1	7.0	0.19	0.04	nm	0.04	nm	2.2	nc	<0.5	6.2	NAF
Samples of Tertiary-Detrital														
GCA5255	300725	Hematite/Goethite	MN120, 18-19	7.2	0.19	0.05	nm	0.05	nm	2.5	nc	<0.5	6.3	NAF
GCA5253	300724	Hematite/Limonitic-Goethite	MN150, 10-11	7.3	0.42	0.06	nm	0.06	nm	1.8	nc	<0.5	6.1	NAF
WASTE-BEDROCK SAMPLES														
Samples of Nummuldi-Member-[Competent]														
GCA5265	300735	Goethite/Hematite	MN047, 44-45	6.4	0.72	0.07	nm	0.07	nm	1.1	nc	<0.5	7.3	NAF
GCA5263	300733	Goethite/Hematite	MN021, 66-67	7.7	0.48	0.06	nm	0.06	nm	4.1	nc	<0.5	6.4	NAF
GCA5256	300726	Limonitic-Goethite/Limonite	MN118, 62-63	7.8	0.29	0.04	nm	0.04	nm	2.1	nc	<0.5	6.4	NAF
Samples of Nummuldi-Member-[Fine/Shaly]														
GCA5269	300739	Limonite/Limonitic-Shale	MN127, 41-42	6.0	0.84	0.07	nm	0.07	nm	2.7	nc	<0.5	6.8	NAF
GCA5266	300736	Hematised-Shale	MN044, 58-59	7.3	0.30	0.01	nm	0.01	nm	3.1	nc	<0.5	7.1	NAF
GCA5264	300734	Hematised-Shale/Hematite	MN021, 71-72	8.1	0.66	0.07	nm	0.07	0.85	75	nc	<0.5	7.2	NAF
GCA5259	300729	White-Shale	MN148, 45-46	8.8	0.35	0.02	nm	0.02	7.7	710	nc	<0.5	6.2	NAF
Samples of Nummuldi-Member-[Cherty/BIF]														
GCA5267	300737	Brown-Chert/Red-Shale	MN044, 64-65	8.3	0.16	0.06	nm	0.06	nm	1.3 (1.3)	nc	<0.5	7.1	NAF
GCA5261	300731	Grey-Chert/Yellow-Shale	MN080, 47-48	6.8	0.47	0.04	nm	0.04	nm	7.2	nc	<0.5 (<0.5)	6.3 (6.4)	NAF
GCA5258	300728	Brown-Grey-BIF/Limonite	MN143, 56-57	7.8	0.43	0.02	nm	0.02	nm	1.8	nc	<0.5	6.5	NAF
Samples of Jeerinah-Formation-[Weathered-Shales]														
GCA5268	300738	Pink/Purple-Shale	MN042, 41-42	6.5	0.64	0.05	nm	0.05	nm	1.8	nc	<0.5	7.0	NAF
GCA5262	300732	Kaolin/White-Yellow-Shale	MN342, 39-40	7.6	0.31	0.05	nm	0.05	nm	4.0 (4.1)	nc	<0.5	6.2	NAF
GCA5257	300727	White-Shale/Hematised-Shale	MN102, 39-40	7.8	0.26	0.02	nm	0.02	nm	3.0 (3.1)	nc	<0.5	6.3	NAF
Samples of Roy-Hill-Shale Member-[Black-Shales]														
GCA5260	300730	Black-Shales	MN089, 44-45	2.4	6.6	11	2.3	8.7	nm	-17	290	180	2.5	**PAF-[Short-Lag]**
GCA5270	300740	Black-Shales	MN211, 78-79	2.3	4.5	5.8	0.51	5.3	nm	-9.2	180	150	2.8	**PAF-[Short-Lag]**

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 (mg/kg or %)					AVERAGE-CRUSTAL-ABUNDANCE (mg/kg or %)	GEOCHEMICAL-ABUNDANCE INDEX (GAI)				
	Hematite/ Grey-Chert (GCA5254)	Hematite/ Goethite (GCA5255)	Goethite/ Hematite (GCA5263)	Hematised-Shale/Hem. (GCA5264)	White-Shale (GCA5259)		Hematite/ Grey-Chert (GCA5254)	Hematite/ Goethite (GCA5255)	Goethite/ Hematite (GCA5263)	Hematised-Shale/Hem. (GCA5264)	White-Shale (GCA5259)
Al	5.3%	3.9%	3.8%	3.1%	4.6%	8.2%	0	0	0	0	0
Fe	24.6%	49.2%	54.7%	48.3%	2.3%	4.1%	2	3	3	3	0
Na	0.0021%	0.0028%	0.0063%	0.0075%	0.0055%	2.3%	0	0	0	0	0
K	0.55%	0.20%	0.11%	0.12%	0.071%	2.1%	0	0	0	0	0
Mg	0.14%	0.12%	0.24%	0.70%	8.0%	2.3%	0	0	0	0	1
Ca	0.058%	0.11%	0.11%	2.1%	12.4%	4.1%	0	0	0	0	1
Ag	0.2	0.2	0.3	0.8	0.3	0.07	1	1	2	3	2
Cu	66	31	35	29	34	50	0	0	0	0	0
Zn	89	15	77	61	160	75	0	0	0	0	1
Cd	<0.1	<0.1	0.2	0.3	1.3	0.11	0	0	0	1	3
Pb	36	41	16	14	13	14	1	1	0	0	0
Cr	190	240	56	58	51	100	0	1	0	0	0
Ni	71	28	63	75	55	80	0	0	0	0	0
Co	11	5.0	21	13	11	20	0	0	0	0	0
Mn	800	1,200	4,900	1,700	520	950	0	0	2	0	0
Hg	0.04	0.02	1.2	0.27	0.03	0.05	0	0	4	2	0
Sn	2.8	3.8	1.4	1.1	2.8	2.2	0	0	0	0	0
Sr	38	24	44	53	60	370	0	0	0	0	0
Ba	190	180	37	23	35	500	0	0	0	0	0
Th	10	14	6.9	4.7	7.7	12	0	0	0	0	0
U	1.9	3.0	8.3	4.3	1.9	2.4	0	0	1	0	0
Tl	0.40	<0.02	0.46	0.08	<0.02	0.6	0	0	0	0	0
V	160	250	77	61	49	160	0	0	0	0	0
As	40	48	120	58	3	1.5	4	4	6	5	0
Bi	0.49	1.3	0.45	0.24	0.09	0.048	3	4	3	2	0
Sb	2.9	8.1	2.5	1.7	0.53	0.2	3	5	3	3	1
Se	1.1	1.4	0.10	0.15	0.03	0.05	4	4	0	1	0
Mo	1.9	4.5	3.4	3.5	0.4	1.5	0	1	1	1	0
B	<50	56	83	120	<50	10	0	2	2	3	0
P	380	230	930	1,200	<20	1,000	0	0	0	0	0
F	280	230	220	230	700	950	0	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 (mg/kg or %)**			**AVERAGE-CRUSTAL-ABUNDANCE (mg/kg or %)**	**GEOCHEMICAL-ABUNDANCE INDEX (GAI)**		
	Grey-Chert/ Yellow-Shale (GCA5261)	**Kaolin/White-Yellow-Shale (GCA5262)**	**Black-Shales (GCA5260)**		**Grey-Chert/ Yellow-Shale (GCA5261)**	**Kaolin/White-Yellow-Shale (GCA5262)**	**Black-Shales (GCA5260)**
Al	5.7%	8.0%	7.0%	8.2%	0	0	0
Fe	20.2%	16.7%	8.3%	4.1%	2	1	0
Na	0.029%	0.053%	0.060%	2.3%	0	0	0
K	1.4%	2.9%	3.8%	2.1%	0	0	0
Mg	0.45%	1.8%	0.27%	2.3%	0	0	0
Ca	0.084%	0.83%	0.14%	4.1%	0	0	0
Ag	0.3	0.2	0.4	0.07	2	1	2
Cu	72	50	290	50	0	0	2
Zn	850	620	16	75	**3**	2	0
Cd	1.7	0.6	<0.1	0.11	**3**	2	0
Pb	22	92	40	14	0	2	1
Cr	81	87	57	100	0	0	0
Ni	270	140	32	80	1	0	0
Co	120	16	20	20	2	0	0
Mn	2,100	230	91	950	1	0	0
Hg	0.17	0.09	0.54	0.05	1	0	**3**
Sn	1.9	2.6	5.5	2.2	0	0	1
Sr	17	56	43	370	0	0	0
Ba	130	130	85	500	0	0	0
Th	6.8	8.7	5.0	12	0	0	0
U	3.3	3.5	1.7	2.4	0	0	0
Tl	7.2	0.64	1.3	0.6	**3**	0	1
V	140	160	76	160	0	0	0
As	98	64	29	1.5	**5**	**5**	**4**
Bi	0.37	0.51	0.43	0.048	**2**	**3**	**3**
Sb	30	15	1.6	0.2	**6**	**6**	2
Se	0.49	0.95	2.9	0.05	**3**	**4**	**5**
Mo	3.5	3.0	3.0	1.5	1	0	0
B	<50	110	<50	10	0	**3**	0
P	800	1,700	330	1,000	0	0	0
F	580	1,500	710	950	0	0	0

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

Table 4.3: Mineralogical Results for Waste-Bedrock Samples

White-Shale (GCA5259)		Hematised-Shale/Hematite (GCA5264)		Black-Shales (GCA5260)	
Component	**Abundance**	**Component**	**Abundance**	**Component**	**Abundance**
dolomite	dominant	goethite	dominant		
				alunite kaolin	major
quartz kaolin	minor	kaolin	minor	**pyrite**	minor
		dolomite **calcite** quartz	accessory	quartz graphite	accessory
chlorite goethite	trace			**dolomite** goethite	trace

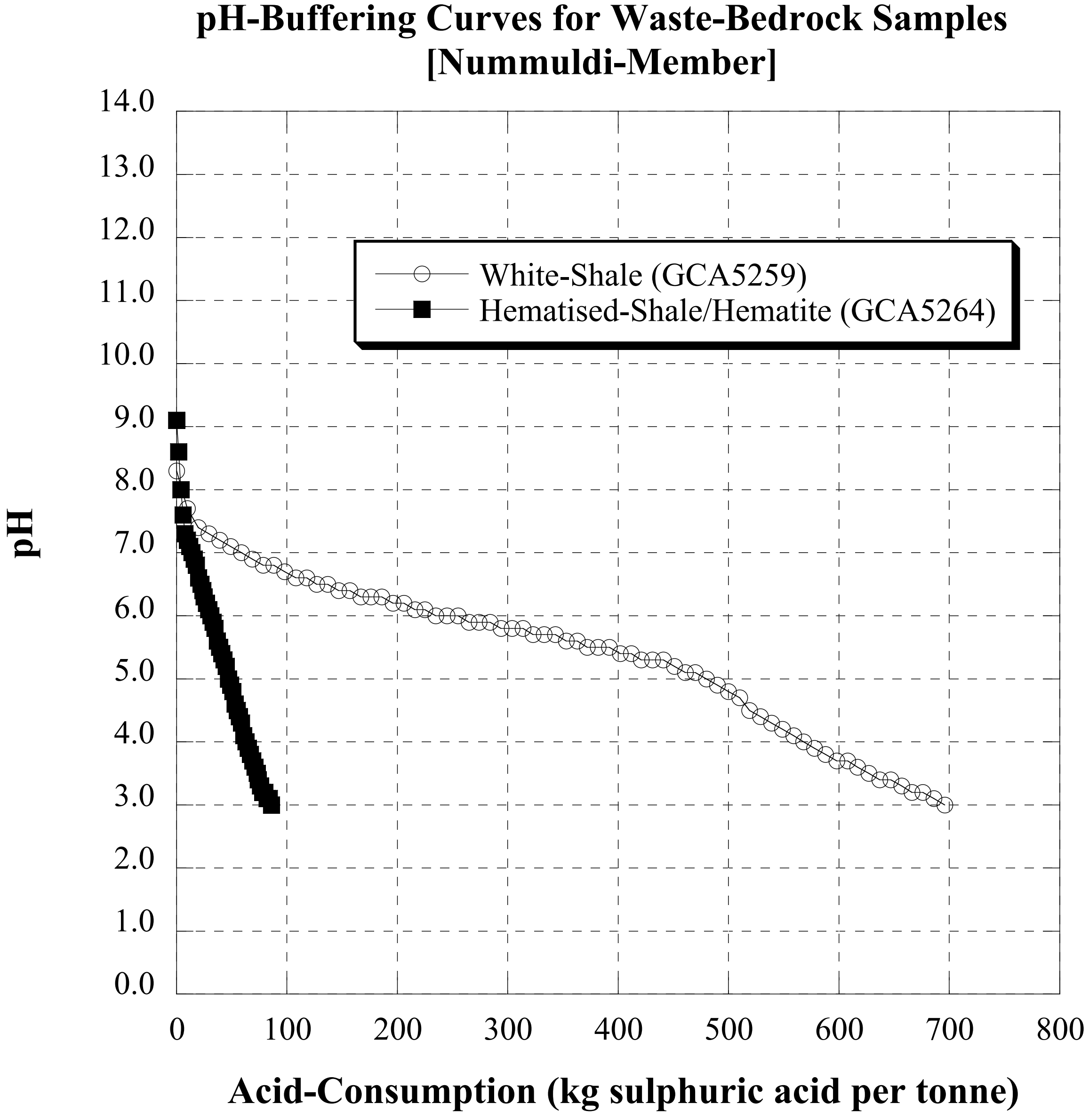
Note:

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

Refer mineralogical report in Apendix C for additional information.

FIGURE

Figure 1



Note: The H_2SO_4-addition rates employed in the auto-titrations correspond to sulphide-oxidation rates (SORs) of *c.* 1-7 x 10^6 mg SO_4/kg/week (= *c.* 5-35 x 10^4 kg H_2SO_4/tonne/year).

These SORs are therefore up to 10^5-10^6 **faster** than those typical for the weathering (at circum-neutral-pH) of mine-waste materials that contain "minute/trace-sulphides".

APPENDIX A

DETAILS OF SAMPLING PROGRAMME

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Mount Nicholas Mine Waste Geochemistry Study

Overview

A scope of works for a geochemical study of the potential mine waste at the Mount Nicholas site was outlined in an email from Graeme Campbell and Associates Pty Ltd. A sampling programme has been made based on the information it contained.

Sampling Programme

Twenty samples were selected, based on geological logging data, to represent the main stratigraphic units within the expected Mt. Nicholas mine excavation area. Details of these samples are summarized in the table below.

The Mt. Nicholas area was divided into three zones: northern, central and southern. From each zone at least one drill hole was chosen for each non-Tertiary stratigraphic sample. (See the attached map for the drill hole locations). Where possible, the 1m sample intervals selected are from below the groundwater level intersected during RC drilling.

Extra samples have been taken from the black shales, due to their potential acid-forming characteristics, and the Mus stratigraphic unit because of its variability in major lithologies and percentage iron.

One sample of the surface soil (0 to 1m depth of Tertiary alluvial) and two samples of the Tertiary detritals (representing regolith) were also selected.

The samples for this geochemistry study, summarized in the table below, are to be approximately 1 to 2kg each and split from individual RC bulk sample bags that remain on site.

Regards,

David Storey
Geologist for FMG
13 May 2004

Summary of samples selected for the Mt. Nicholas mine waste geochemistry study

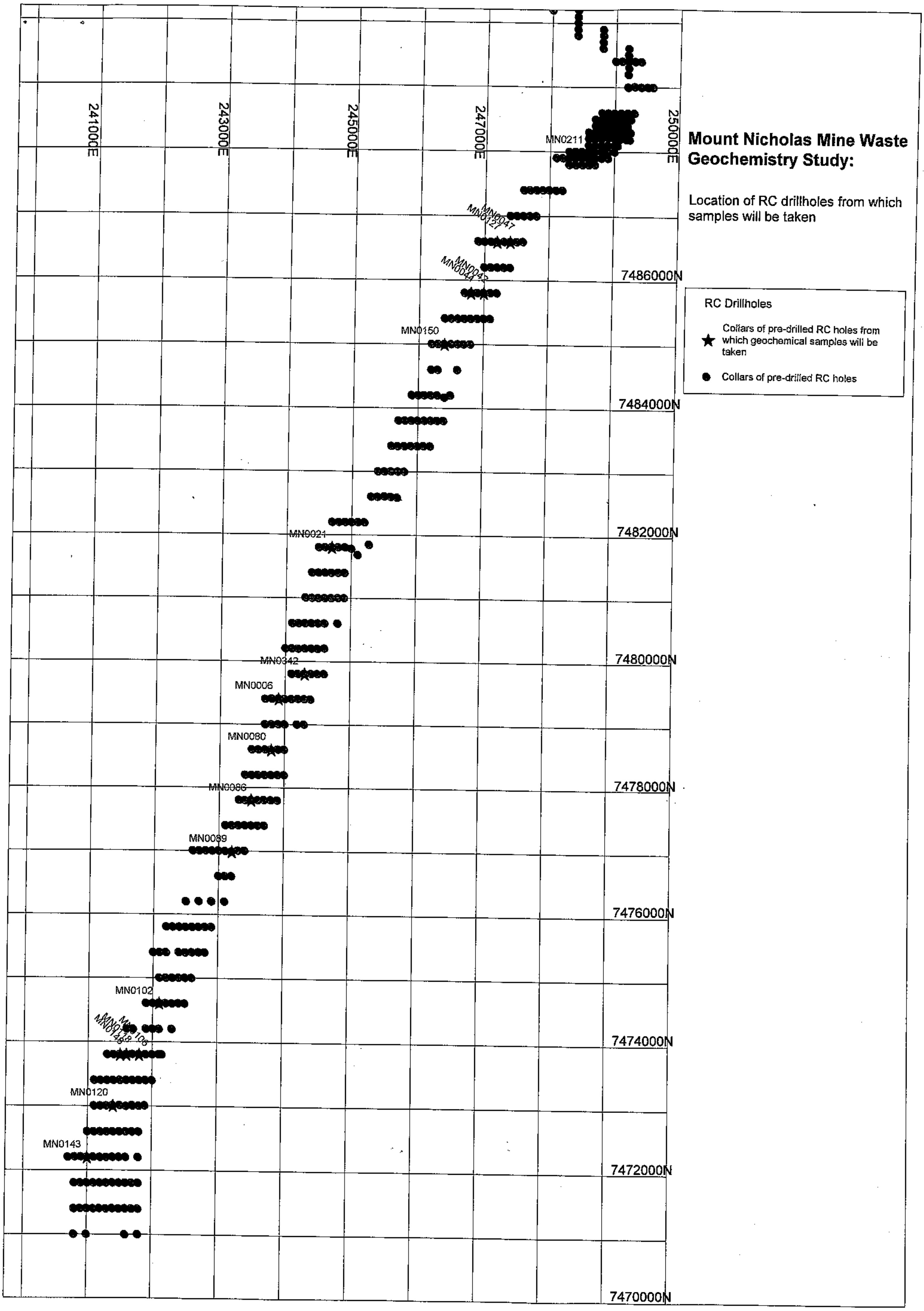
Hole ID	Easting	Northing	Sample Depth		Water Table/m below collar	Stratigraphy	Major Lithologies	Fe%
			From	To				
MN086	243498	7477802	0	1	Unknown	Ta	Hematite, grey chert	21.6
MN120	241394	7473003	18	19	35	Td	Hematite, goethite	50.5
MN150	246400	7485000	10	11	Unknown	Td	Hematite, limonitic goethite, goethite	39.6
MN047	247398	7486599	44	45	18	Muo	Goethite, hematite	55.4
MN021	244700	7481801	66	67	60	Muo	Goethite, hematite	52.1
MN118	241599	7473801	62	63	40	Muo	Limonitic goethite, limonite	52.4
MN127	247195	7486598	41	42	Estimated 33m	Mus	Limonite, limonitic shale	31.1
MN044	246800	7485799	58	59	51	Mus	Hematised shale	38.6
MN021	244700	7481801	71	72	60	Mus	Hematised shale, hematite	49.4
MN148	241500	7473800	45	46	45	Mus	White shale	3.5*
MN044	246800	7485799	64	65	51	Mub	Brown chert, red shale	12.4
MN080	243798	7478598	47	48	Unknown. Estimated below 50m	Mub	Grey chert, yellow shale	18.9*
MN143	240998	7472199	56	57	34	Mub	Brown BIF, grey BIF, limonite	31.1*
MN042	246998	7485801	41	42	25	Fj	Pink/purple shale	34.9*
MN342	244300	7479800	39	40	Unknown. Estimated below 50m	Fj	Kaolin, white shale, yellow shale	11.0*
MN102	242100	7474604	39	40	Unknown. Estimated below 40m	Fj	White shale, hematised shale	32.1*
MN211	241796	7473802	78	79	75	Jr	Black shales	5.3*
MN006	243903	7479405	62	63	55	Jr	Black shales	25.0*
MN106	241796	7473802	61	62	40	Jr	Black shales	6.4*
MN089	243205	7476988	44	45	Unknown. Estimated below 50m	Jr	Black shales	7.6*

Stratigaphy	
Ta	Tertiary alluvial
Td	Tertiary detrital
Muo	Nammuldi member; competent material
Mus	Nammuldi member; fine (shaly) material
Mub	Nammuldi member; cherty or BIF material
Fj	Jerrinah formation (weathered/light coloured shales)
Jr	Roy Hill shale member (black shales)

* Fe% from a 2m composite

Mount Nicholas Mine Waste Geochemistry Study:

Location of RC drillholes from which samples will be taken



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 (SO_4-S).
- Acid-Neutralisation-Capacity (ANC), 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]

---

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

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 SO_4-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 SO_4-S values were determined by the Na_2CO_3-Extraction Method (Lenahan and Murray-Smith 1986).[3] The difference between the Total-S and SO_4-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 estimating the ANC values of mine-waste materials (Morin and Hutt 1997; BC AMD Task Force 1989).

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

[3] The Na_2CO_3-reagent extracts SO_4-S which occurs as soluble sulphates, and calcium sulphates (e.g. gypsum and anhydrite). It also extracts SO_4 sorbed to the surfaces of sesquioxides, clays and silicates. However, SO_4 present as barytes ($BaSO_4$) is not extracted, and SO_4 associated with jarositic-type and alunitic-type compounds are incompletely extracted.

The samples were reacted with dilute HCl for *c.* 2 hours at 80-90 ^{o}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 H_2SO_4-consumption rates 'of-the-order' $10^{-11}/10^{-12}$ moles/m^2/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 SO_4/kg/week (= *c.* 0.1-1.0 kg H_2SO_4/tonne/year).[5] Maintenance of circum-neutral-pH through dissolution/hydrolysis of primary-silicates is therefore restricted to <u>both</u> "mineral-fines", <u>and</u> slow rates of pyrite weathering.

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[4] Two drops of 30 % (w/w) H_2O_2 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 H_2O_2 reagent is <u>not</u> part of the methodology described by Sobek *et al.* (1978).

[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 %).

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 pH-Buffering Properties

The pH-Buffering properties of selected samples were determined via a Metrohm® 736 Titrino auto-titrator, and 0.05 M-H_2SO_4.

The auto-titrations comprised regular addition of the H_2SO_4 reagent to monotonically decrease the pH values of the test-suspensions to 3.0.[6] The Start-pH values of the suspensions were *c.* 8-9. Under the testwork conditions employed, the H_2SO_4-addition rates correspond to SORs 'of-the-order' 10^6-10^7 mg SO_4/kg/week (i.e. 'of-the-order' 10^4-10^5 kg H_2SO_4/tonne/year) , and so represent very-rapid rates of acid addition.

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

B1.4 NAPP Calculations

The NAPP values of the samples were calculated from the Total-S, SO_4-S and ANC values, assuming that **all** of the Non-Sulphate-S occurs in the form of pyrite. The

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[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 H_2SO_4/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-H_2SO_4 titrant.

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:

$$FeS_2 + 15/4\ O_2 + 7/2\ H_2O = 2SO_4^{2-} + 4H^+ + \text{"}Fe(OH)_3\text{"}$$

It may be shown that, if the Sulphide-S (in %S) occurs as pyrite, then the amount of acid (in kg H_2SO_4/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-O_2' 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.

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 H_2O_2 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) H_2O_2 solution (prepared from A.R.-grade H_2O_2) was adjusted to pH=4.5 using dilute NaOH. In addition, the boiling treatment to decompose residual, unreacted-H_2O_2 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-$CuSO_4$ to the test mixtures, followed by boiling again for *c.* 2 hours). The addition of Cu(II) salts catalyses the decomposition of residual H_2O_2, 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-H_2O_2. 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 %, and ANC values less than *c.* 10 kg H_2SO_4/tonne (as typically recorded for a felsic/mafic-gangue that is void of carbonates). Furthermore, oxidation by H_2O_2 is generally at least 10^3 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

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[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.

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]

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.

---

[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).

APPENDIX C

LABORATORY REPORTS

Roger Townend and Associates
Consulting Mineralogists

G CAMPBELL AND ASSOC,
PO BOX 247,
BRIDGETOWN
WA

28-7-2004

OUR REF 21029

YOUR REF. 0417

XRD/PLM/SEM ANALYSES OF 3 SAMPLES

FROM MT NICHOLAS IRON ORE PROJECT.

R TOWNEND

RESULTS XRD/PLM/SEM

Correspondence to Box 3129, Malaga D.C. WA 6945
ACN 069 920 476 ABN 92 076 109 663

GCA	5259	5260	5264
QUARTZ	MINOR	ACCESSORY	ACCESSORY
DOLOMITE	DOMINANT	TRACE	ACCESSORY
CALCITE			ACCESSORY
KAOLIN	MINOR	MAJOR	MINOR
CHLORITE	TRACE		
ALUNITE		MAJOR	
GOETHITE	TRACE	TRACE	DOMINANT
PYRITE		MINOR	
GRAPHITE		ACCESSORY	

The dolomite in 5259 is essentially an end member, ie no Fe or Mn.

8 July, 2004

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

Our Reference:	81227
Your Reference:	GCA0417
NATA Accreditation:	2562(1705)

Dear Sir

On the 24th of May 2004 you forwarded test work instructions for eighteen (18) waste rock samples which were received on the 26th of May 2004 at our laboratory. The samples were initially oven-dried at 40°C, then crushed to a nominal 2mm particle size with a sub sample of this then pulped to a nominal -75µm particle size.

Approximately 100g of the crushed split samples (GCA5254, GCA5255, GCA5263, GCA5264, GCA5259, GCA5261, GCA5262, GCA5260) were sent to Genalysis Laboratory Services as requested. Approximately 50g of the crushed split samples (GCA5264, GCA5259, GCA5260) were sent to Roger Townend and Associates as requested. The sample retained was sub sampled for moisture and the dried sample pulped to a nominal 75µm particle size for sulphur analysis. Additional paperwork was received on the 10th of June 2004 requesting carbon form analysis on GCA5259 and GCA5264.

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 (%w/w)	Total Carbon (%w/w)	Total Organic Carbon (% w/w)	Carbonate Carbon CO$_3$-C (% w/w)
GCA5253	7.3	420	0.06	NA	NA	NA	NA
GCA5254	7.0	190	0.04	NA	NA	NA	NA
GCA5255	7.2	190	0.05	NA	NA	NA	NA
GCA5256	7.8	290	0.04	NA	NA	NA	NA
GCA5257	7.8	260	0.02	NA	NA	NA	NA
GCA5258	7.8	430	0.02	NA	NA	NA	NA
GCA5259	8.8	350	0.02	NA	7.7	0.03	7.7
GCA5260	2.4	6600	11	2.3	NA	NA	NA
GCA5261	6.8	470	0.04	NA	NA	NA	NA
GCA5262	7.6	310	0.05	NA	NA	NA	NA
GCA5263	7.7	480	0.06	NA	NA	NA	NA
GCA5264	8.1	660	0.07	NA	0.93	0.08	0.85
GCA5265	6.4	720	0.07	NA	NA	NA	NA

GCA5266	7.3	300	0.01	NA	NA	NA	NA
GCA5267	8.3	160	0.006	NA	NA	NA	NA
GCA5268	6.5	640	0.05	NA	NA	NA	NA
GCA5269	6.0	840	0.07	NA	NA	NA	NA
GCA5270	2.3	4500	5.8	0.51	NA	NA	NA

NOTES:

1. *Sulphate Sulphur was determined on the oven-dried (40°C) crushed sample by Na_2CO_3 extraction, $BaSO_4$ Precipitation. Sulphate Sulphur was only determined on samples where Total Sulphur equals or exceeds 0.1% w/w.*
2. *Total Sulphur, Total Carbon and Total Organic Carbon (noncarbonate or acid insoluble carbon) were determined on 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 WM078414 (NATA1936).*
3. *Carbonate is calculated as difference between Total Carbon and Total Organic Carbon.*

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)
GCA5253	0	5.0027	23.00	0.1N	Nil	Nil	1.4	1.8
GCA5254	0	5.0083	22.60	0.1N	Nil	Nil	1.3	2.2
GCA5255	0	5.0031	22.30	0.1N	Nil	Nil	1.2	2.5
GCA5256	0	5.0064	22.80	0.1N	Nil	Nil	1.4	2.1
GCA5257	0	5.0038	21.80	0.1N	Nil	Nil	1.4	3.0
RPT GCA5257	0	5.0088	21.70	0.1N	Nil	Nil	1.4	3.1
GCA5258	0	5.0059	23.00	0.1N	Nil	Nil	1.3	1.8
GCA5259	2	1.1402	8.40	1N	Moderate	Nil	0.7	710
GCA5260	0-1	5.0099	42.30	0.1N	Nil	Nil	1.4	-17
GCA5261	0-1	5.0067	17.50	0.1N	Nil	Nil	1.4	7.2
GCA5262	0-1	5.0413	20.80	0.1N	Nil	Nil	1.4	4.0
RPT GCA5262	0-1	5.0031	20.70	0.1N	Nil	Nil	1.3	4.1
GCA5263	0-1	5.0014	20.70	0.1N	Nil	Nil	1.4	4.1
GCA5264	2	2.0395	18.80	0.5N	Moderate	Nil	0.8	75
GCA5265	0-1	5.0909	23.80	0.1N	Nil	Nil	1.2	1.1
GCA5266	0-1	5.0348	21.70	0.1N	Nil	Nil	1.4	3.1
GCA5267	0	5.0079	23.50	0.1N	Nil	Nil	1.2	1.3
RPT GCA5267	0	5.0043	23.60	0.1N	Nil	Nil	1.3	1.3
GCA5268	0	5.0028	23.00	0.1N	Nil	Nil	1.3	1.8
GCA5269	0	5.0095	22.10	0.1N	Nil	Nil	1.4	2.7
GCA5270	0	5.0004	34.30	0.1N	Nil	Nil	1.4	-9.2
ANC Std20		2.0072	17.10	0.1N	-	-	1.4	19

CLIENT: Graeme Campbell & Associates Pty Ltd OUR REFERENCE: 81227
PROJECT NO: GCA0417

NOTES:

1. *Acid neutralisation capacity was determined on oven-dried (40°C) crushed sample. Unless otherwise stated, 25mL of HCl is used. Reagent blank titre of 0.1N NaOH was 24.90mL.*
2. *ANC Std20 is an internally produced standard of $CaCO_3$ and quartz pulped to a nominal 75µm particle size which has a nominal ANC of 20kg of H_2SO_4/tonne.*
3. *This procedure is based on Sobek et al, 1978.*

Yours faithfully,

STEVEN EDMETT	JANICE VENNING
Client Liaison Manager	Manager, Perth

This report supersedes out preliminary results sent by facsimile on the 25th of June 2004.

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_2SO_4/ tonne)
				pH	EC (µS/cm)		
GCA5533	4.3	Reaction peaked overnight	5.6	6.1	43	0.20	<0.5
GCA5254	4.4	Reaction peaked overnight	6.0	6.2	43	0.40	<0.5
GCA5255	5.4	Reaction peaked overnight	5.9	6.3	45	0.30	<0.5
GCA5256	5.7	Reaction peaked within 30 minutes (?)	7.5	6.4	38	0.30	<0.5
GCA5257	5.0	Reaction peaked overnight	6.3	6.3	73	0.30	<0.5
GCA5258	6.8	Reaction peaked within 30 minutes (?)	7.8	6.5	70	0.30	<0.5
GCA5259	4.7	Reaction peaked within 3 hours	7.3	6.2	110	0.40	<0.5
GCA5260	1.17	Reaction peaked within 3 hours	2.5	2.5	3,500	41.40	180
GCA5261	5.3	Reaction peaked within 3 hours	7.8	6.3	46	0.30	<0.5
GCA5261 (Repeat)	4.2	Reaction peaked within 3 hours	8.1	6.4	41	0.20	<0.5
GCA5262	5.5	Reaction peaked overnight	6.1	6.5	44	0.40	<0.5
GCA5263	4.8	Reaction peaked within 3 hours	7.6	6.4	44	0.20	<0.5
Blank	6.0		5.7	7.1	51	-	<0.5

Notes: Test conditions based on those described by Miller *et al.* (1997). 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. Test mixtures boiled for *c.* 2 hours to accelerate reaction with H_2O_2. Then, after allowing the test mixtures to cool, 1.0 mL of 0.016 M-$CuSO_4$ 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 (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
18th July 2004

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_2SO_4/ tonne)
				pH	EC (µS/cm)		
GCA5264	4.1	Reaction peaked with 3 hours	10.3	7.2	120	-	<0.5
GCA5265	5.8	Reaction peaked with 3 hours	7.2	7.3	59	-	<0.5
GCA5266	4.5	Reaction peaked with 3 hours	8.0	7.1	49	-	<0.5
GCA5267	5.7	Reaction peaked with 3 hours	8.2	7.1	41	-	<0.5
GCA5268	4.3	Reaction peaked with 3 hours	7.8	7.0	43	-	<0.5
GCA5269	5.1	Reaction peaked overnight	5.5	6.8	85	0.20	<0.5
GCA5270	1.00	Reaction peaked with 3 hours	2.6	2.8	2,200	29.20	150
Blank	6.0		5.7	7.1	51	-	<0.5

Notes: Test conditions based on those described by Miller *et al.* (1997). 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. Test mixtures boiled for *c.* 2 hours to accelerate reaction with H_2O_2. Then, after allowing the test mixtures to cool, 1.0 mL of 0.016 M-$CuSO_4$ 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 (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
18th July 2004

Graeme Campbell & Associates Pty Ltd

Laboratory Report

pH-BUFFERING TESTWORK (GCA5259)

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H_2SO_4/tonne)	pH	Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H_2SO_4/tonne)	pH
0.00	0.0	8.3	18.00	441	5.3
0.40	9.8	7.7	18.40	451	5.2
0.80	19.6	7.4	18.80	461	5.1
1.20	29.4	7.3	19.20	470	5.1
1.60	39.2	7.2	19.60	480	5.0
2.00	49.0	7.1	20.00	490	4.9
2.40	58.8	7.0	20.40	500	4.8
2.80	68.6	6.9	20.80	510	4.7
3.20	78.4	6.8	21.20	519	4.5
3.60	88.2	6.8	21.60	529	4.4
4.00	98.0	6.7	22.00	539	4.3
4.40	108	6.6	22.40	549	4.2
4.80	118	6.6	22.80	559	4.1
5.20	127	6.5	23.20	568	4.0
5.60	137	6.5	23.60	578	3.9
6.00	147	6.4	24.00	588	3.8
6.40	157	6.4	24.40	598	3.7
6.80	167	6.3	24.80	608	3.7
7.20	176	6.3	25.20	617	3.6
7.60	186	6.3	25.60	627	3.5
8.00	196	6.2	26.00	637	3.4
8.40	206	6.2	26.40	647	3.4
8.80	216	6.1	26.80	657	3.3
9.20	225	6.1	27.20	666	3.2
9.60	235	6.0	27.60	676	3.2
10.00	245	6.0	28.00	686	3.1
10.40	255	6.0	28.40	696	3.0
10.80	265	5.9			
11.20	274	5.9			
11.60	284	5.9			
12.00	294	5.8			
12.40	304	5.8			
12.80	314	5.8			
13.20	323	5.7			
13.60	333	5.7			
14.00	343	5.7			
14.40	353	5.6			
14.80	363	5.6			
15.20	372	5.5			
15.60	382	5.5			
16.00	392	5.5			
16.40	402	5.4			
16.80	412	5.4			
17.20	421	5.3			
17.60	431	5.3			

Note: Titration performed using a Metrohm® 736 Titrino auto-titrator, and 0.05 M-H_2SO_4. Equilibration time between titrant additions was 15 minutes. 0.20 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 = -15 mV (pH=7.00); slope-point = 159 mV (pH=4.00); 97.7 % 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
4th July 2004

Graeme Campbell & Associates Pty Ltd

Laboratory Report

pH-BUFFERING TESTWORK (GCA5264)

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H_2SO_4/tonne)	pH
0.00	0.0	9.1
0.40	2.0	8.6
0.80	3.9	8.0
1.20	5.9	7.6
1.60	7.8	7.3
2.00	9.8	7.2
2.40	12	7.1
2.80	14	7.0
3.20	16	6.9
3.60	18	6.8
4.00	20	6.6
4.40	22	6.5
4.80	24	6.4
5.20	25	6.3
5.60	27	6.2
6.00	29	6.1
6.40	31	6.0
6.80	33	5.9
7.20	35	5.8
7.60	37	5.6
8.00	39	5.5
8.40	41	5.4
8.80	43	5.3
9.20	45	5.2
9.60	47	5.0
10.00	49	4.9
10.40	51	4.8
10.80	53	4.6
11.20	55	4.5
11.60	57	4.4
12.00	59	4.3
12.40	61	4.1
12.80	63	4.0
13.20	65	3.9
13.60	67	3.8
14.00	69	3.7
14.40	71	3.6
14.80	73	3.5
15.20	74	3.4
15.60	76	3.3
16.00	78	3.2
16.40	80	3.2
16.80	82	3.1
17.20	84	3.1
17.60	86	3.0

Note: Titration performed using a Metrohm® 736 Titrino auto-titrator, and 0.05 M-H_2SO_4. 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 = -15 mV (pH=7.00); slope-point = 158 mV (pH=4.00); 9787 % 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
4th July 2004

ANALYTICAL REPORT

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

JOB INFORMATION

JOB CODE : 143.0/0403931
No. of SAMPLES : 8
No. of ELEMENTS : 32
CLIENT O/N : GCA0417
SAMPLE SUBMISSION No. :
PROJECT : Mt Nicholas Iron Ore Project
STATE : Solid
DATE RECEIVED : 21/06/2004
DATE COMPLETED : 23/07/2004
DATE PRINTED : 23/07/2004

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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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 rock materials.

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

The results have been determined according to Genalysis method 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 SO-3 and Genalysis in-house standards AE12,TKC3, TKCLOW-1 and HgSTD-3.

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

NATA Signatory: A Evers

Date: 23rd July 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 GCA5254	0.2	5.28%	40	X	183.5	0.49	580	X	10.8	184
0002 GCA5255	0.2	3.84%	48	56	175.3	1.22	1026	X	5.0	231
0003 GCA5259	0.3	4.52%	3	X	34.2	0.09	12.39%	1.3	10.6	51
0004 GCA5260	0.4	7.00%	29	X	84.2	0.43	1306	X	19.7	57
0005 GCA5261	0.3	5.62%	98	X	127.2	0.37	837	1.7	117.6	81
0006 GCA5262	0.2	7.92%	64	105	128.2	0.51	8268	0.6	16.0	87
0007 GCA5263	0.3	3.75%	114	83	36.6	0.45	1008	0.2	20.5	56
0008 GCA5264	0.8	3.01%	58	118	22.8	0.24	2.06%	0.3	12.4	58
CHECKS										
0001 GCA5254	0.1	5.73%	38	X	184.0	0.49	700	X	10.6	203
STANDARDS										
0001 AE12										
0002 HgSTD-3										
0003 SO-3										
0004 TKCLOW-1	5.3	4.20%	169		555.5	4.41	1.23%	1.3	40.1	405
0005 TKCLOW-1				1267						
BLANKS										
0001 Control Blank	X	X	X	X	X	X	X	X	X	X

ANALYSIS

ELEMENTS	Cu	F	Fe	Hg	K	Mg	Mn	Mo	Na	Ni
UNITS	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm
DETECTION	1	50	0.01	0.01	20	20	1	0.1	20	1
DIGEST	A/	DH/	D/	CM/	A/	A/	A/	A/	A/	A/
ANALYTICAL FINISH	OES	SIE	OES	CVAP	OES	OES	OES	MS	OES	OES
SAMPLE NUMBERS										
0001 GCA5254	66	280	24.52	0.04	5489	1333	800	1.9	202	71
0002 GCA5255	31	223	49.12	0.02	1960	1119	1197	4.5	241	28
0003 GCA5259	34	700	2.25	0.03	704	7.96%	517	0.4	437	55
0004 GCA5260	284	710	8.23	0.54	3.72%	2697	91	3.0	592	32
0005 GCA5261	72	571	20.11	0.17	1.39%	4439	2084	3.5	287	267
0006 GCA5262	50	1426	16.61	0.09	2.85%	1.71%	222	3.0	530	132
0007 GCA5263	35	212	54.63	1.17	1008	2334	4824	3.4	306	63
0008 GCA5264	29	227	48.29	0.27	1127	6987	1664	3.5	379	75
CHECKS										
0001 GCA5254	72	292	24.24	0.04	6115	1449	850	1.8	219	76
STANDARDS										
0001 AE12										
0002 HgSTD-3				0.32						
0003 SO-3		324								
0004 TKCLOW-1	540				1.66%	9486	818	87.5	1.43%	576
0005 TKCLOW-1			25.27							
BLANKS										
0001 Control Blank	X	X	0.05	X	X	X	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 GCA5254	379	36	294	2.84	1.07	2.8	37.15	9.95	0.40	1.88
0002 GCA5255	228	41	420	8.09	1.32	3.8	23.01	13.81	X	2.98
0003 GCA5259	X	13	X	0.53	0.03	2.8	59.38	7.64	X	1.89
0004 GCA5260	329	40	11.68%	1.58	2.88	5.5	42.65	4.99	1.26	1.67
0005 GCA5261	800	22	931	29.20	0.49	1.9	16.50	6.72	7.20	3.26
0006 GCA5262	1636	92	590	14.17	0.95	2.6	55.88	8.67	0.64	3.50
0007 GCA5263	924	16	393	2.46	0.10	1.4	43.17	6.90	0.46	8.26
0008 GCA5264	1128	14	270	1.68	0.15	1.1	52.34	4.69	0.08	4.22

CHECKS										
0001 GCA5254	396	38	354	2.76	1.14	2.8	37.50	10.32	0.43	1.97

STANDARDS										
0001 AE12					0.51					
0002 HgSTD-3										
0003 SO-3										
0004 TKCLOW-1	1640	217	6044	56.59		48.5	156.95	36.02	1.80	6.71
0005 TKCLOW-1										

BLANKS										
0001 Control Blank	X	X	X	X	0.01	X	X	X	X	X

ANALYSIS

ELEMENTS	V	Zn
UNITS	ppm	ppm
DETECTION	2	1
DIGEST	A/	A/
ANALYTICAL FINISH	OES	OES
SAMPLE NUMBERS		
0001 GCA5254	153	89
0002 GCA5255	241	15
0003 GCA5259	49	155
0004 GCA5260	76	16
0005 GCA5261	137	849
0006 GCA5262	156	616
0007 GCA5263	77	200
0008 GCA5264	61	209
CHECKS		
0001 GCA5254	169	98
STANDARDS		
0001 AE12		
0002 HgSTD-3		
0003 SO-3		
0004 TKCLOW-1	89	306
0005 TKCLOW-1		
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.