

## APPENDIX 8: GEOCHEMICAL CHARACTERISATION OF MINE WASTE – GRAEME CAMPBELL & ASSOCIATES (2004)

TECTONIC RESOURCES NL

# **KUNDIP & TRILOGY PROJECTS**

***GEOCHEMICAL CHARACTERISATION OF***

***MINE-WASTE SAMPLES***

***['STATIC-TESTWORK']***

**Implications for Mine-Waste Management**

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## 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	%
Sulphide-S	Sulphide Sulphur	Testwork Result [i.e. Sulphide-S = Total-S - Sulphate-S]	%
ANC	Acid-Neutralisation Capacity	Testwork Result	kg H <sub>2</sub> SO <sub>4</sub> /tonne
MPA	Maximum-Potential Acidity	Calculation	kg H <sub>2</sub> SO <sub>4</sub> /tonne
NAPP	Net-Acid-Producing Potential	Calculation	kg H <sub>2</sub> SO <sub>4</sub> /tonne
NAG	Net-Acid Generation	Testwork Result	kg H <sub>2</sub> SO <sub>4</sub> /tonne
NAF	Non-Acid Forming	Calculation: <ul style="list-style-type: none"> <li>• Sulphide-S &lt; 0.3 %</li> <li>• Sulphide-S ≥ 0.3 %, and negative-NAPP value with ANC/MPA ≥ 2.0</li> </ul>	
PAF	Potentially-Acid Forming	Calculation: <ul style="list-style-type: none"> <li>• Sulphide-S ≥ 0.3 %, and any positive-NAPP value</li> <li>• Sulphide-S ≥ 0.3 %, and a negative-NAPP value with ANC/MPA &lt; 2.0</li> </ul>	kg H <sub>2</sub> SO <sub>4</sub> /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 <sub>4</sub> /kg/week (or kg SO <sub>4</sub> /tonne/annum)

**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<sub>2</sub>-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, unpublished results]. The formation of "secondary-oxidation-products" (e.g. Fe-oxyhydroxides) as protective-coatings is generally enhanced during the "within-lag-phase-stage" of mine-waste weathering in semi-arid/arid environments, and so further curtails sulphide-oxidation rates.

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## 1.0 INTRODUCTION

Tectonic Resources NL (Tectonic) is developing the Kundip and Trilogy Projects located near Hopetoun, Western Australia.

The Kundip and Trilogy Deposits are located *c.* 10 kms from each other. Ore from the Kundip Deposit will be initially produced via open-pit-mining involving a number of small Pits, and then underground-mining. The waste-rock materials will be placed on waste-dumps in the vicinity of the Pits, and/or in Pits where mining has ceased. The Trilogy Deposit will be mined as an open-pit operation, and the waste-rock materials placed on waste-dumps in the vicinity of the Pit. Ore produced from each Deposit will be trucked to the Rav8 Project (located near Ravensthorpe) for treatment in the mill. Low-grade varieties of ore will also be trucked to the Rav8 Project for stockpiling and treatment, pending metallurgical evaluation, and Project economics.

Graeme Campbell & Associates Pty Ltd (GCA) was commissioned to carry out geochemical testwork on a range of regolith-material, waste-bedrock, and low-grade-ore samples, derived from the Kundip and Trilogy Deposits.

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

The testwork results are presented and discussed in this report, and implications for mine-waste management highlighted.<sup>2</sup>

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<sup>1</sup> A 'Static-Testwork' Programme comprises "whole-rock" analyses and tests.

<sup>2</sup> A related study on the geochemical character of waste-rock, low-grade-ore and soil samples derived from the Rav8 Nickel Project, is the subject of the GCA (1999) report.

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## 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 drill-core and RC-chips. The down-hole intervals were *c.* 1.0 m, and so allow assessment of mine-waste geochemistry at the "metre-scale" in terms of sulphide/carbonate abundance, and minor-element content.

*It is assumed that the samples submitted for testing are representative of the major types of mine-waste materials to be produced during mining of the Kundip and Trilogy Deposits.*

#### **Samples from Kundip Deposit**

The **14** samples provided to GCA for testing comprised:

- 3 samples of soil/regolith-materials;
- 8 samples of waste-bedrocks of varying lithology/alteration; and,
- 3 samples of low-grade-ores.



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The soil/regolith-profile is *c.* 40-50 m thick, and comprises a Clay-Rich-Zone (*c.* 10 m thick) overlying a Weathered-Saprolite-Zone. The waste-bedrocks largely comprise Fresh-Dacites.

The total-tonnage of waste-rock materials to be produced during open-pit-mining of the Kundip Deposit should be *c.* 1-2 million tonnes, corresponding mostly to regolith-materials. During the underground-mining operation, *c.* 0.1-0.2 million tonnes of waste-bedrocks should be produced. It should be noted that these estimates (as well as those presented below for the Trilogy Deposit) are **provisional only**, and subject to revision in the light of the evolving mine-plans, and geological-models.

#### Samples from Trilogy Deposit

The **16** samples provided for testing comprised:

- 3 samples of soil/regolith-materials;
- 10 samples of waste-bedrock(viz. Fresh-Phyllite); and,
- 3 samples of low-grade-ores.

The soil/regolith-profile is *c.* 30-40 m thick, and comprises a Clay-Rich-Zone (*c.* 3-5 m thick) overlying a Weathered-Shale-Zone. The waste-bedrocks comprise Fresh-Phyllite more-or-less exclusively, and this lithotype is at least partly-carbonaceous.

It is estimated that *c.* 5-10 million tonnes of waste-rock materials should be produced during open-pit-mining of the Trilogy Deposit. Of this total-waste-tonnage, *c.* 70 % should comprise regolith-materials, and *c.* 30 % waste-bedrocks (chiefly Fresh-Phyllite).

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### 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.<sup>3</sup>

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<sub>2</sub>SO<sub>4</sub>/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-

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<sup>3</sup> NATA = National Association of Testing Authorities.

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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.

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  $\geq$  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.

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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<sub>4</sub>/kg/week) [= *c.* 1-2 kg SO<sub>4</sub>/tonne/year].<sup>4</sup> 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.<sup>5</sup>

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-

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

<sup>5</sup> 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".

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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.

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).<sup>6</sup> This ANC/MPA ratio is employed in the present work.<sup>7</sup>

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).<sup>8</sup> 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

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<sup>6</sup> 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).

<sup>7</sup> 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.

<sup>8</sup> SO<sub>4</sub> 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.

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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.

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### 3.0 ACID-BASE CHEMISTRY AND SALINITY OF WASTE-ROCK SAMPLES (KUNDIP DEPOSIT)

The testwork results on the acid-base chemistry and salinity of the soil/regolith-material and waste-bedrock samples from the Kundip Deposit are presented in Table 3.1, and shown on Figure 1. These results are discussed in the following sections.

#### 3.1 Soil/Regolith-Materials

##### 3.1.1 pH and Salinity

The samples had pH-(1:2) values of 8.4-8.6, and EC-(1:2) values of 1.1-3.1 mS/cm (Table 3.1).<sup>9</sup>

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

*The testwork results indicate that the samples were mildly-alkaline (viz. pH 8-9), with 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 %).*

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<sup>9</sup> EC= Electrical-Conductivity. The pH-(1:2) and EC-(1:2) Tests are described in Appendix B.

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### 3.1.3 Acid-Consuming Properties

The samples had ANC values of 5.6-11 kg H<sub>2</sub>SO<sub>4</sub>/tonne (Table 3.1).<sup>10</sup>

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

### 3.1.4 Acid-Formation Potential

*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 8.2-9.2 and EC-(1:2) values of 0.26-2.2 mS/cm (Table 3.1).

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

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

### 3.2.2 Sulphur Forms

The samples had Total-S values of 0.03-1.6 %, and the samples tested for SO<sub>4</sub>-S had SO<sub>4</sub>-S values of 0.02-0.03 % (Table 3.1).

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<sup>10</sup> ANC values of 5.6-11 kg H<sub>2</sub>SO<sub>4</sub>/tonne are equivalent to c. 0.56-1.1 % (as "CaCO<sub>3</sub>").



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*The testwork results indicate that all samples, but one, contained minute-to-trace amounts of sulphide-minerals (viz. Sulphide-S contents ranging up to 0.2-0.3 %). Given the down-hole-intervals (viz. approximately 1 m) of the samples, these results indicate that, at the "metre-scale", the Fresh-Dacite and Fresh-Andesite lithotypes are typically characterised by meagre abundances of sulphide-minerals.*

*One sample of Fresh-Dacite contained accessory amounts of pyrite (Table 4.3), corresponding to a Sulphide-S content of 1-2 %.<sup>11</sup> However, this sample also contained "trace-calcite" (Table 4.3).*

### 3.2.3 Acid-Consuming Properties

The samples had ANC values within the range 2.8-93 kg H<sub>2</sub>SO<sub>4</sub>/tonne (Table 3.1).<sup>12</sup>

The samples tested for CO<sub>3</sub>-C had CO<sub>3</sub>-C values of 0.09-0.80 % (Table 3.1). The "Carbonate-ANC" values were consistent with the ANC values as measured based on the method of Sobek *et al.* (1978). The presence of reactive-carbonates (e.g. calcite) in the Fresh-Dacite samples was also indicated by the effervescence (i.e. "fizzing") produced upon the addition ('in-the-cold') of HCl during the ANC-testwork.

The pH-Buffering properties of selected Fresh-Dacite samples were determined via auto-titrations, and 0.05 M-H<sub>2</sub>SO<sub>4</sub>. The H<sub>2</sub>SO<sub>4</sub>-addition rates employed during the auto-titrations were *c.* 5-10 x 10<sup>4</sup> kg H<sub>2</sub>SO<sub>4</sub>/tonne/year, and correspond to SORs up to 10<sup>4</sup>-10<sup>5</sup> faster than those typically observed for the weathering (at circum-neutral-pH) of "trace/accessory-sulphides". The pH-buffering curves (Figure 1) exhibited a well-defined "inflection-point" near pH=6-7, associated with the dissolution of reactive-

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<sup>11</sup> The logged occurrence of pyrite in sample GCA5025 (Appendix A) is consistent with the testwork results.

<sup>12</sup> ANC values of 2.3-93 kg H<sub>2</sub>SO<sub>4</sub>/tonne are equivalent to *c.* 0.23-9.3 % (as "CaCO<sub>3</sub>").

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carbonates (e.g. calcite). Calcite was also identified in sample GCA5025 in the mineralogical study (Table 4.3).

*The testwork results indicate that the samples typically had a moderate-to-high capacity to consume acid. Furthermore, reactive-carbonates (e.g. calcite) contributed to acid-consumption, and pH-buffering.*

#### 3.2.4 Acid-Formation Potential

The samples had NAPP values that ranged from  $-44 \text{ kg H}_2\text{SO}_4/\text{tonne}$ , to  $-3.7 \text{ kg H}_2\text{SO}_4/\text{tonne}$  (Table 3.1).<sup>13</sup>

The samples had NAG-pH values of 6.3-8.3, and NAG values less than  $0.5 \text{ kg H}_2\text{SO}_4/\text{tonne}$  (Table 3.1).<sup>14</sup>

*The NAPP and ANC/MPA values, and the NAG-testwork results, indicate that all samples, but one, were classified as NAF.*

*Given the occurrence of "accessory-calcite" in sample GCA5025, this sample is classified as PAF-[Long-Lag]. Although difficult to predict accurately, under the Mediterranean climate of the mine-site, it would likely take years (and probably decades) for exposed "rock-fines" (viz.  $P_{100}$  of a few cms) to acidify through sulphide-oxidation.<sup>15</sup>*

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<sup>13</sup> NAPP values were not calculated for samples with Sulphide-S contents less than 0.1 %.

<sup>14</sup> It should be noted that the "Single-Addition" version of the NAG Test (AMIRA 2002) was employed in this study.

<sup>15</sup> A programme of 'kinetic' testing would be needed to confirm (or refine) this "first-pass" estimate of the "lag-phase" duration.

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#### 4.0 MULTI-ELEMENT COMPOSITION AND MINERALOGY OF WASTE-ROCK SAMPLES (KUNDIP DEPOSIT)

The multi-element composition and mineralogy of selected samples is indicated by the data presented in Tables 4.1-4.3.<sup>16</sup> The corresponding element-enrichments, as indicated by the values of the Geochemical-Abundance Index (GAI), are also presented in Table 4.1.<sup>17</sup> 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 Cu, Bi, and Se.

Sample GCA5025 (viz. Fresh-Dacite, Sulphide-S = 1.6 %) comprised mainly quartz, chlorite, biotite and plagioclase (Table 4.3). This sample also contained accessory amounts of pyrite and calcite.<sup>18</sup>

*The analysis results indicate that, geochemically, the assayed samples of soil/regolith-materials and waste-bedrocks were "clean" with low contents of environmentally-significant elements.*

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<sup>16</sup> The suite of elements listed in Table 4.1 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.

<sup>17</sup> The GAI is defined in Appendix B.

<sup>18</sup> Although "trace-calcite" was identified in the mineralogical study (Table 4.3), the CO<sub>3</sub>-C and ANC values (Table 3.1) recorded for this sample indicate that the calcite (and possibly other carbonate-minerals) are more abundant.

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## 5.0 GEOCHEMISTRY AND MINERALOGY OF LOW-GRADE-ORE SAMPLES (KUNDIP DEPOSIT)

The testwork results for the low-grade-ore samples are presented in Tables 5.1-5.3.

The low-grade-ore samples were characterised by (Table 5.1):

- pH-(1:2) values of 8.3-9.0, and EC-(1:2) values of 0.70-0.84 mS/cm;
- Total-S values of 0.02-1.5 %, and SO<sub>4</sub>-S values of 0.03-0.04 %;
- ANC values of 3.7-17 kg H<sub>2</sub>SO<sub>4</sub>/tonne;
- NAPP values of 4.2-29 kg H<sub>2</sub>SO<sub>4</sub>/tonne; and,
- NAG-pH values of 4.3-7.2, and NAG values that ranged from less than 0.5 kg H<sub>2</sub>SO<sub>4</sub>/tonne, to 2.3 kg H<sub>2</sub>SO<sub>4</sub>/tonne.

The calculated-NAPP and measured-NAG values were consistent for the samples of Low-Grade-Oxide-Ore and Low-Grade-Transition-Ore (Table 5.1). However, this was not the case for the sample of Low-Grade-Primary-Ore (viz. NAPP value of 29 kg H<sub>2</sub>SO<sub>4</sub>/tonne, and NAG value less than 0.5 kg H<sub>2</sub>SO<sub>4</sub>/tonne [Table 5.1]).<sup>19</sup> It is suspected that soluble-Cu forms released during the NAG-testwork catalysed the decomposition of the H<sub>2</sub>O<sub>2</sub>-reagent. Although further testwork would be needed to confirm (or refine) this interpretation, it is clear that care is needed in assessing the acid-forming characteristics of the Low-Grade-Primary-Ore derived from the Kundip Deposit.<sup>20</sup>

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<sup>19</sup> The logged occurrence of pyrite in sample GCA5030 (Appendix A) is consistent with the Total-S and SO<sub>4</sub>-S values.

<sup>20</sup> Inconsistencies between calculated-NAPP and measured-NAG values are not uncommon for mine-waste samples where "secondary-Cu-sulphides" occur (Campbell, unpublished results).

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The samples were variously enriched in Cu, and in the case of the Low-Grade-Primary-Ore sample, also in Ag, Zn, Cd and Pb (Table 5.2). The Cu contents ranged up to c. 0.3-0.4 %.<sup>21</sup>

The Low-Grade-Oxide-Ore sample mainly comprised quartz, chlorite and muscovite (Table 5.3). The samples of the Low-Grade-Transition-Ore and Low-Grade-Primary-Ore also had a groundmass of mainly quartz, chlorite and muscovite. The sulphide-mineral suite in the Low-Grade-Transition-Ore sample comprised pyrite, digenite and covellite, whereas that in the Low-Grade-Primary-Ore sample comprised pyrite, chalcopyrite, galena and sphalerite.

*The testwork results indicate that the Low-Grade-Oxide-Ore sample was classified as NAF, and reflects a groundmass devoid of both sulphide- and carbonate-minerals. The contents of environmentally-significant elements in this sample were low.*

*The samples of the Low-Grade-Transition-Ore and Low-Grade-Primary-Ore were classified as PAF, and reflects "trace/accessory-sulphides" in a groundmass devoid of carbonate-minerals. Given the "mixed-sulphide-mineral-suite", it is felt premature, at this stage, to classify these samples as either PAF-[Short-Lag], or PAF-[Long-Lag]. A programme of 'kinetic-testwork' (viz. Weathering-Columns) would be needed to fully assess the weathering/solubility-behaviour of the Low-Grade-Transition-Ore and Low-Grade-Primary-Ore to be produced from the Kundip Deposit. Nonetheless, it is almost certain that soluble-Cu forms would be released with increasing weathering-history.*

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<sup>21</sup> Water-Extraction Tests showed that the content of Soluble-Cu in the low-grade-ore samples was less than 0.5 mg/kg.

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## 6.0 ACID-BASE CHEMISTRY AND SALINITY OF WASTE-ROCK SAMPLES (TRILOGY DEPOSIT)

The testwork results on the acid-base chemistry and salinity of the soil/regolith-material and waste-bedrock samples from the Trilogy Deposit are presented in Table 6.1, and shown on Figure 2. These results are discussed in the following sections.

### 6.1 Soil/Regolith-Materials

#### 6.1.1 pH and Salinity

The samples had pH-(1:2) values of 7.8-8.9, and EC-(1:2) values of 1.5-2.2 mS/cm (Table 6.1).

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

*The testwork results indicate that the samples were mildly-alkaline (viz. pH 8-9), with moderate contents of soluble-salts.*

#### 6.1.2 Sulphur Forms

The samples had Total-S values of 0.04-0.20 %, and the samples tested for SO<sub>4</sub>-S had SO<sub>4</sub>-S values of 0.17-0.18 % (Table 6.1).

*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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### 6.1.3 Acid-Consuming Properties

The samples had ANC values that ranged from less than 0.5 kg H<sub>2</sub>SO<sub>4</sub>/tonne, to 39-40 kg H<sub>2</sub>SO<sub>4</sub>/tonne (Table 6.1).<sup>22</sup>

The Light-Brown-Clay sample (viz. GCA5031) had a CO<sub>3</sub>-C value of 0.47 % (Table 6.1), and if all of the CO<sub>3</sub>-C occurred as "CaCO<sub>3</sub>", then the "Carbonate-ANC" value would be c. 38 kg H<sub>2</sub>SO<sub>4</sub>/tonne. Sample GCA5031 also produced vigorous "fizzing" in the ANC-testwork upon the addition ('in-the-cold') of HCl, and was characterised by an "inflection-point" near pH=6-7 during the auto-titration using dilute-H<sub>2</sub>SO<sub>4</sub> (Figure 2).

*The testwork results indicate that the Light-Brown-Clay sample had a high capacity to consume acid, and likely reflects the occurrence of "pedogenic-calcite" in the soil-profile. The samples of the regolith-materials from depth had a negligible capacity to consume acid.*

### 6.1.4 Acid-Formation Potential

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

## 6.2 Waste-Bedrocks

### 6.2.1 pH and Salinity

The samples had pH-(1:2) values of 5.2-9.8 and EC-(1:2) values of 0.20-1.4 mS/cm (Table 6.1).

The soluble-salts in the samples comprised chlorides and sulphates (Table 7.4).

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<sup>22</sup> An ANC value of 39-40 kg H<sub>2</sub>SO<sub>4</sub>/tonne is equivalent to c. 3.9-4.0 % (as "CaCO<sub>3</sub>").

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*The testwork results indicate that the samples were typically circum-neutral (viz. pH 6-8), with low-to-moderate contents of soluble-salts. Samples with pH values of 5-6 tended to have Sulphide-S contents greater than 1 % (see Section 6.2.2 below), and this pH-regime likely reflects the "gutless-groundmass" of such samples (i.e. paucity of carbonate-minerals).*

### 6.2.2 Sulphur Forms

The samples had Total-S values of 0.12-3.3 %, and SO<sub>4</sub>-S values of 0.05-0.57 % (Table 6.1).<sup>23</sup>

The SO<sub>4</sub>-S values at least partly reflect "sulphosalts" (e.g. anglesite [PbSO<sub>4</sub>]) derived from the oxidation/alteration of base-metal-sulphides (e.g. galena, and Cu-sulphides).

*The testwork results indicate that the samples were typically characterised by trace-to-accessory amounts of sulphide-minerals (viz. Sulphide-S contents ranging up to 2-3 %).*

### 6.2.3 Acid-Consuming Properties

The samples had ANC values that ranged from less than 0.5 kg H<sub>2</sub>SO<sub>4</sub>/tonne, to 1.5 kg H<sub>2</sub>SO<sub>4</sub>/tonne (Table 6.1). Such ANC values (as determined by the method based on Sobek *et al.* [1978]) are "low" for waste-bedrocks generally, and reflects the "quartz-rich/felsic" nature of the Fresh-Phyllite from the Trilogy Deposit.

*The testwork results indicate that the samples had a negligible capacity to consume acid.*

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<sup>23</sup> The logged occurrences of pyrite in the Fresh-Phyllite samples (Appendix A) were consistent with the testwork results, although the abundance of pyrite in sample GCA5041 was visually underestimated.



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#### 6.2.4 Acid-Formation Potential

The samples had NAPP values of 3.7-92 kg H<sub>2</sub>SO<sub>4</sub>/tonne (Table 6.1).<sup>24</sup>

The samples had NAG-pH values of 2.8-6.6, and NAG values that ranged from less than 0.5 kg H<sub>2</sub>SO<sub>4</sub>/tonne, to 19 kg H<sub>2</sub>SO<sub>4</sub>/tonne (Table 6.1).

*The NAPP and ANC/MPA values, and the NAG-testwork results, indicate that the samples were typically classified as PAF, and reflects "trace/accessory-sulphides" in a (quartzose) groundmass devoid of carbonate-minerals.*

*At least some of the PAF samples would be further classified as PAF-[Short-Lag], due to the occurrence of marcasite (and other reactive varieties of sulphide-minerals), and a "gutless-groundmass" with an inability to buffer at circum-neutral-pH.<sup>25</sup> If "rock-fines" of such Fresh-Phyllite were left exposed, acidic (viz. pH values less than 4) conditions would likely occur within a matter of months generally, and possibly within days-to-weeks during winter-months. A programme of 'kinetic' testing would be needed to better predict the "lag-phase" during weathering of the Fresh-Phyllite. Irrespective of the time-scales associated with oxidation of the sulphide-minerals, it is clear that soluble-Cu and -Pb forms will be released from exposed Fresh-Phyllite with increasing weathering-history.*

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<sup>24</sup> NAPP values were not calculated for samples with Sulphide-S contents less than 0.1 %.

<sup>25</sup> Although approximate, the occurrence of reactive varieties of sulphide-minerals was also apparent from the "time-to-peak-reaction" in the NAG-testwork.

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## 7.0 MULTI-ELEMENT COMPOSITION AND MINERALOGY OF WASTE-ROCK SAMPLES (TRILOGY DEPOSIT)

The multi-element composition, minor-element solubility and mineralogy of selected samples is indicated by the data presented in Tables 7.1-7.5.

The samples of the soil/regolith-materials had contents of most environmentally-significant elements below, or close to, those typically recorded for unmineralised soils and regoliths. Slight enrichments were apparent for Pb, As, Bi, Se and B. However, the sample of Saprolitic-Phyllite (viz. GCA5033, Table 7.3) was an exception, with a Pb content of 2,500 mg/kg. Such Pb should be essentially "fixed" within the crystal-lattices of sesquioxides/clays, as shown recently by Li *et al.* (2003) for samples of soil/regolith-materials derived from Gossan Hill, Western Australia.

The samples of Fresh-Phyllite were variously enriched in an array of minor-elements, mostly chalcophyles (viz. Cu, Pb, Ag, Hg, As, Bi, Sb and Se). Of this suite of enriched-elements, Cu and Pb stand-out (viz. Cu contents ranging up to *c.* 5,000 mg/kg, and Pb contents ranging up to 2,700 mg/kg). The Hg contents ranging up to *c.* 8-9 mg/kg are also appreciable.

Water-Extraction Tests were performed on selected Fresh-Phyllite samples to assess soluble-Cu and -Pb forms at circum-neutral-pH. The contents of soluble-Cu forms ranged up to *c.* 100-200 mg/kg, and the contents of soluble-Pb forms ranged up to *c.* 10-20 mg/kg (Table 7.4). Although preliminary, these results provide a broad measure of the amounts of soluble-Cu and -Pb forms that may potentially be released from "rock-fines" in the 'ex-pit' stream of Fresh-Phyllite. Release of such soluble-metal forms would increase as exposed waste-bedrock undergoes weathering.

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Sample GCA5041 (viz. Fresh-Phyllite, Sulphide-S = 3.0 %) was dominated by quartz over muscovite (Table 7.5). This sample also contained accessory amounts of pyrite, and traces of marcasite, digenite, covellite, and chalcocite.

*The analysis results indicate that, geochemically, the samples of soil/regolith-materials were typically "clean" with low contents of environmentally-significant elements. However, the Saprolitic-Phyllite from depth may be enriched in Pb (e.g. Pb contents of 0.2-0.3 %), due to inheritance from the underlying Fresh-Phyllite. Although such Pb should be "fixed" within the crystal-lattices of sesquioxides/clays, further investigation would be needed to assess the bio-availability of Pb in the event that Saprolitic-Phyllite forms part of the rooting-zone of vegetation on the waste-dumps. In any case, to safeguard against concerns arising from dusting and erosion, any soil/regolith-material that is appreciably enriched in Pb should not be placed within the Surface-Zone (e.g. top 0-1 m) of the waste-dumps. Suppression of dust formation will also likely need to be addressed during the handling of such soil/regolith-materials in order to satisfy occupational-health requirements.<sup>26</sup>*

*The samples of the Fresh-Phyllite were variously enriched in an array of chalcophyles. Enrichment in Cu and Pb stood-out with Cu and Pb contents ranging up to 0.5 % and 0.2-0.3 %, respectively). Furthermore, at circum-neutral-pH, "rock-fines" may release appreciable amounts of soluble-Cu and -Pb forms. The enrichment of chalcophyles in the Fresh-Phyllite further heightens the need for isolation of this PAF-lithotype from O<sub>2</sub> and meteoric-waters.*

*Suppression of dusting will likely be needed during the handling of soil/regolith-materials and waste-bedrocks that are appreciably enriched in Cu, Pb, etc.*

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<sup>26</sup> Occupational-health requirements in terms of dusting/inhalation are beyond the expertise of Dr. Graeme Campbell.

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## 8.0 GEOCHEMISTRY AND MINERALOGY OF LOW-GRADE-ORE SAMPLES (TRILOGY DEPOSIT)

The testwork results for the low-grade-ore samples are presented in Tables 8.1-8.4.

The low-grade-ore samples were characterised by (Table 8.1):

- pH-(1:2) values of 5.2-6.4, and EC-(1:2) values of 0.78-1.6 mS/cm;
- Total-S values of 0.23-4.9 %, and SO<sub>4</sub>-S values of 0.15-0.38 %;
- ANC values that ranged from less than 0.5 kg H<sub>2</sub>SO<sub>4</sub>/tonne, to 3.9 kg H<sub>2</sub>SO<sub>4</sub>/tonne;
- NAPP values ranging up to 150 kg H<sub>2</sub>SO<sub>4</sub>/tonne; and,
- NAG-pH values of 2.8-5.4, and NAG values of 0.7-22 kg H<sub>2</sub>SO<sub>4</sub>/tonne.

The calculated-NAPP value (viz. 150 kg H<sub>2</sub>SO<sub>4</sub>/tonne) for the Low-Grade-Primary-Ore was several-fold greater than the measured-NAG value (viz. 22 kg H<sub>2</sub>SO<sub>4</sub>/tonne), and likely reflects decomposition of the H<sub>2</sub>O<sub>2</sub>-reagent catalysed by soluble-Cu forms released during the NAG-testwork.

The samples were variously enriched in an array of chalcophyles (viz. Cu, Pb, Ag, Hg, As, Bi, Sb, Se and B) [Table 8.2]. The Cu and Pb contents ranged up to *c.* 0.8-0.9 % and 1.1 %, respectively. The Hg and As contents ranged up to *c.* 9-10 mg/kg and *c.* 1,200 mg/kg, respectively.

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Water-Extraction Tests were performed to assess soluble-Cu and –Pb forms at circum-neutral-pH. The contents of soluble-Cu forms ranged up to *c.* 70-80 mg/kg, and the contents of soluble-Pb forms ranged up to *c.* 20-30 mg/kg (Table 8.3).

The Low-Grade-Oxide-Ore sample was dominated by quartz over muscovite (Table 8.4). The samples of the Low-Grade-Transition-Ore and Low-Grade-Primary-Ore were also dominated by quartz, and the sulphide-mineral suite in the Low-Grade-Transition-Ore sample comprised pyrite and azurite. The sulphide-mineral suite in the Low-Grade-Primary-Ore sample comprised pyrite, covellite, chalcocite, digenite and galena. This sample also contained trace amounts of graphite.

*The testwork results indicate that the samples of the Low-Grade-Oxide-Ore and Low-Grade-Transition-Ore were classified as NAF, and reflect groundmasses devoid of both sulphide- and carbonate-minerals.*

*The sample of the Low-Grade-Primary-Ore was classified as PAF, and reflects "accessory-sulphides" in a groundmass devoid of carbonate-minerals. In all likelihood, this ore sample may be further classified as PAF-[Short-Lag].*

*All low-grade-ore samples were significantly enriched in Cu and Pb, and contained soluble-Cu and –Pb forms that would be released at circum-neutral-pH. Such Cu- and Pb-solubility should increase with weathering-history.*

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## 9.0 CONCLUSIONS AND MANAGEMENT IMPLICATIONS

In the present study, samples of soil/regolith-material, waste-bedrocks, and low-grade-ores derived from the Kundip Deposit, and Trilogy Deposit, have been geochemically characterised.

Details of the sampling programme, testwork methods employed in this study, and approach to classifying the samples into AFP categories, are presented in Section 2, and Appendices A and B.<sup>27</sup> All testwork results are presented, and fully interpreted, in Sections 3 to 8.

Based on the testwork results obtained in this study, implications for mine-waste management are outlined in the following sections.

### 9.1 Kundip Project

#### 9.1.1 Waste-Rock Management

Geochemically, the soil/regolith-materials should be benign. The suitability of these materials for sheeting/covering of the waste-dumps, as part of site-closure works, should be largely governed by their physical characteristics (e.g. particle-size grading, sodicity, tendency for slaking/dispersion, etc.). The physical properties of the soil/regolith-materials should therefore be established before their site-wide usage for sheeting/covering, and other applications.

Overall, the Fresh-Dacite should pose no concerns for acidification, and/or release of soluble forms of minor-elements. This waste-bedrock should be suitable for rock-armouring as part of erosion-control measures, construction of the safety-bund around

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<sup>27</sup> AFP = Acid-Formation Potential.

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the Pit-perimeter at decommissioning, and other applications where competent/chunky-rock will need to be exposed in the longer-term following site-closure. However, in such applications every effort should be made to ensure that there is no more than "trace-pyrite" in the Fresh-Dacite left exposed.

### 9.1.2 Low-Grade-Ore Management

Although few samples were tested herein, the Low-Grade-Oxide-Ore should be classified as NAF, whereas the Low-Grade-Transition-Ore and Low-Grade-Primary-Ore should be classified as PAF.<sup>28</sup> The low-grade-ores should be enriched in Cu, so that soluble-Cu forms should be released during weathering.

It may be prudent for the low-grade-ore stockpile(s) to abut the waste-dump at the Rav8 Project, so that if not all of the low-grade-ore is treated in the mill, the stockpile(s) may be merged with the waste-dump via a "cut-and-push" operation. Depending on the quantities, and spatial-distribution, of "PAF/Metal-Enriched" varieties of low-grade-ores at site-closure, a "store/release-cover" (e.g. Wilson 1997, 2000) constructed using (benign) soil/regolith-materials may be needed to isolate sulphide-grains from meteoric-waters arising from episodic-rainfall. In this case, information would be required on the physical characteristics (especially soil-hydraulic properties [e.g. soil-water retention curve]) of the soil/regolith-materials employed for the "store/release-cover".

It may be necessary to implement dusting-control measures during handling of the low-grade-ores, due to the enrichment in Cu.

### 9.1.3 Pit-Lake-Water Quality

At cessation of mining activities, the Pit may contain a pit-lake, due to water-table recovery, and/or accumulation of runoff-waters from pit-walls. It is understood that

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hydrogeological investigations are in hand, and will allow assessment of the water-balance for the decommissioned-Pit. The local-groundwaters are saline (e.g. salinity [as TDS] of *c.* 10-30 g/L), so that the pit-lake-water should also be saline.<sup>29</sup> Given the occurrence of carbonate-minerals within the Fresh-Dacite, the pit-water should have a circum-neutral-pH, due to buffering by the submerged pit-wall-bedrocks. Although soluble-Cu forms may be released to the pit-lake-water, it is difficult to quantify *a priori* the potential Cu-solubility. A programme of 'kinetic' testing, and hydrogeochemical modelling, would be needed to assess Cu-solubility behaviour in the pit-lake-water.

## 9.2 Trilogy Deposit

### 9.2.1 Waste-Rock Management

Geochemically, the soil/regolith-materials should be largely benign. However, the Saprolitic-Phyllite (especially at depth) may be enriched in Pb, so that testing should be performed to ensure that any "Pb-enriched" varieties of soil/regolith-materials are **not** placed within the rooting-zone (e.g. top 0-2 m) of vegetation on the waste-dumps. The physical properties of the soil/regolith-materials should be established before their site-wide usage for sheeting/covering applications, as for the Kundip Deposit (Section 9.1.1).

The Fresh-Phyllite is classified as PAF, and probably mostly as PAF-[Short-Lag]. The typical "trace/accessory-sulphide" assemblage within a quartzose/felsic-groundmass devoid of carbonate-minerals means that this lithotype has the potential to be a source of Acid-Rock Drainage (ARD). Furthermore, the Fresh-Phyllite is generally enriched in an array of chalcophyles (especially Cu and Pb). It is **mandatory** that the Fresh-Phyllite is selectively handled, and placed on the waste-dumps, so that it is isolated

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<sup>28</sup> NAF = Non-Acid Forming; PAF = Potentially-Acid Forming.

<sup>29</sup> TDS = Total-Dissolved Solids.



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from O<sub>2</sub>, and meteoric-waters. The sheeting/burial-layer will need to function as a "store/release-cover" whereby recharge of the underlying Fresh-Phyllite is both minimal, and infrequent (e.g. 'of-the-order' 10 mm per annum in a "wet-year"). It may be necessary to undertake water-balance modelling to optimise the thickness, and performance of the sheeting/cover-system. However, volumetrically, there should be ample regolith-materials for deep-burial of the Fresh-Phyllite on the waste-dumps. The provision for deep-burial should therefore be central to the waste-dump design and construction.

It will be necessary to source "benign-waste-bedrocks" for rock-armouring as part of erosion-control measures, construction of the safety-bund around the Pit-perimeter at decommissioning, and other applications where competent/chunky-rock will need to be exposed in the longer-term following site-closure. Given the findings of this study, it is crucial that testing of Total-S, Total-Cu and Total-Pb is undertaken to "screen" waste-bedrocks earmarked for construction applications. Since S-, Cu- and Pb-contents in the waste-bedrocks of the Trilogy Deposit should be correlated, a preliminary "cut-off" for Total-S of 0.2 % may be suitable for "screening" purposes. However, this preliminary "cut-off" value would need to be confirmed (or refined) through further investigation.

It will likely be necessary to implement dusting-control measures during handling of the Fresh-Phyllite, due to the enrichment in Cu and Pb.<sup>30</sup>

### 9.2.2 Low-Grade-Ore Management

The Low-Grade-Oxide-Ore and Low-Grade-Transition-Ore should be classified as NAF, whereas the Low-Grade-Primary-Ore should be classified as PAF. The latter is likely further classified as PAF-[Short-Lag]. All types of low-grade-ores should be significantly enriched in Cu and Pb.

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<sup>30</sup> Related measures may be needed when handling "Pb-rich" varieties of the Saprolitic-Phyllite, etc.

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The strategy needed for low-grade-ore management is similar to that outlined for the Kundip Deposit (see Section 9.1.2).

It will likely be necessary to implement dusting-control measures during handling of the low-grade-ores, due to the enrichment in Cu and Pb.

### 9.2.3 Pit-Lake-Water Quality

At cessation of mining activities, the Pit may contain a pit-lake, and it is understood that hydrogeological investigations are in hand to allow assessment of the water-balance for the decommissioned-Pit. The local-groundwaters are saline (e.g. salinity [as TDS] of *c.* 30-40 g/L), so that the pit-lake-water should also be saline. Given the lack of carbonate-minerals within the Fresh-Phyllite, the pit-water may become acidic through sulphide-oxidation. In this case, provision would need to be made for pH-adjustment through lime-dosing. The pH-regime of the pit-lake-water will depend closely on the "lag-phase" associated with sulphide-oxidation, and the time-scales for submergence of the Fresh-Phyllites. Given the Cl-dominated salinity of the pit-lake-water, Pb-solubility may be enhanced through the formation of Pb-chloro-solution complexes. A more-complete assessment of pit-lake-water quality would require information on sulphide-oxidation-rates, and metal-release-rates, as obtained via 'kinetic' testing, as well as hydrogeochemical modelling of Pb- and Cu-solubility.

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## **TABLES**

**Table 3.1: Acid-Base-Analysis, Salinity and Net-Acid-Generation Results for Samples of Soil/Regolith-Materials and Waste-Bedrocks (Kundip Deposit)**

GCA-SAMPLE NO.	LITHOTYPE	DRILLHOLE & DOWN-HOLE INTERVAL (m)	pH-(1:2)	EC-(1:2) [mS/cm]	TOTAL-S (%)	SO <sub>4</sub> -S (%)	Sulphide-S (%)	CO <sub>3</sub> -C (%)	ANC	NAPP	NAG	NAG-pH	ANC/MPA RATIO	AFP CATEGORY
									kg H <sub>2</sub> SO <sub>4</sub> /tonne					
<b>Samples of Soil/Regolith-Materials</b>														
GCA5017	Red-Brown-Clay	KP075, 0-1	8.4	3.1	0.05	nm	0.05	nm	11	nc	<0.5	7.1	nc	NAF
GCA5018	Saprolite-Dacite	KP076, 14-15	8.4	2.4	0.02	nm	0.02	nm	5.8	nc	<0.5	6.8	nc	NAF
GCA5019	Saprolite-Dacite	KP076, 30-31	8.6	1.1	0.02	nm	0.02	nm	5.6	nc	<0.5	7.2	nc	NAF
<b>Samples of Waste-Bedrocks</b>														
GCA5020	Sl.-Weath.-Dacite	KP076, 50-51	8.6	0.58	0.03	nm	0.03	nm	3.6	nc	<0.5	6.3	nc	NAF
GCA5021	Sl.-Weath.-Dacite/Andesite	KP076, 56-57	8.5	0.54	0.04	nm	0.04	nm	3.2 (2.8)	nc	<0.5	6.3	nc	NAF
GCA5022	Fresh-Dacite	KP106, 140-141	8.3	1.1	0.10	0.02	0.08	0.17	21	nc	<0.5	7.6	nc	NAF
GCA5023	Fresh-Dacite	KP106, 144-145	8.2	2.2	0.20	0.02	0.18	nm	9.3	-3.7	<0.5	7.1	1.6	NAF
GCA5025	Fresh-Dacite	KP110, 148-149	8.4	0.44	1.6	0.03	1.6	0.80	93	-44	<0.5	7.0	1.8	<b>PAF-[Long-Lag]</b>
GCA5026	Fresh-Dacite	KP101, 137-138	8.9	0.26	0.27	0.02	0.25	0.20	15 (15)	-7.3	<0.5	7.2	1.9	NAF
GCA5027	Fresh-Dacite	KP101, 150-151	9.2 (9.1)	0.21 (0.22)	0.04	nm	0.04	0.69	60	nc	<0.5	8.3	nc	NAF
GCA5024	Fresh-Andesite	KP110, 145-146	8.4	2.0	0.16	0.03	0.13	0.09	12	-8.0	<0.5	7.0	2.0	NAF

Notes:

EC = Electrical Conductivity; ANC = Acid-Neutralisation Capacity; NAPP = Net-Acid-Producing Potential; NAG = Net-Acid Generation; AFP = Acid-Formation Potential;

NAF = Non-Acid Forming; PAF = Potentially-Acid Forming; 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), EC-(1:2) and NAG-pH.

Values in parentheses represent duplicates.



**Table 4.1: Multi-Element-Analysis Results for Samples of Soil/Regolith-Materials and Waste-Bedrocks (Kundip Deposit)**

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)		
	Red-Brown-Clay (GCA5017)	Saprolite-Dacite (GCA5018)	Fresh-Dacite (GCA5025)		Red-Brown-Clay (GCA5017)	Saprolite-Dacite (GCA5018)	Fresh-Dacite (GCA5025)
Al	8.5%	9.9%	6.6%	8.2%	0	0	0
Fe	7.3%	5.7%	5.4%	4.1%	0	0	0
Na	0.94%	1.2%	1.1%	2.3%	0	0	0
K	1.1%	1.0%	2.0%	2.1%	0	0	0
Mg	1.7%	3.3%	1.6%	2.3%	0	0	0
Ca	0.55%	1.4%	1.1%	4.1%	0	0	0
C	0.44%	0.03%	0.86%	0.048%	3	0	4
Ag	0.2	0.2	0.4	0.07	1	1	2
Cu	840	22	610	50	3	0	3
Zn	56	44	110	75	0	0	0
Cd	0.3	0.4	0.6	0.11	1	1	2
Pb	110	3	13	14	2	0	0
Cr	210	270	83	100	0	1	0
Ni	200	230	140	80	1	1	0
Co	47	38	120	20	1	0	2
Mn	270	610	1,100	950	0	0	0
Hg	0.05	0.02	<0.01	0.05	0	0	0
Sn	1.5	1.1	9.1	2.2	0	0	1
Sr	47	63	54	370	0	0	0
Ba	200	120	49	500	0	0	0
Th	5.5	4.2	1.9	12	0	0	0
U	1.3	1.3	0.96	2.4	0	0	0
Tl	0.19	0.13	0.18	0.6	0	0	0
V	140	150	77	160	0	0	0
As	8	7	4	1.5	2	2	1
Bi	0.61	0.10	0.53	0.048	3	0	3
Sb	0.63	0.43	0.31	0.2	1	1	0
Se	1.1	0.04	0.70	0.05	4	0	3
Mo	2.8	2.0	0.8	1.5	0	0	0
B	59	<50	<50	10	2	0	0
P	180	430	310	1,000	0	0	0
F	200	200	250	950	0	0	0

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

**Table 4.2: Selected-Assay Results for Samples of Soil/Regolith-Materials and Waste-Bedrocks (Kundip Deposit)**

GCA-SAMPLE NO.	LITHOTYPE	C (%)	Cu (mg/kg)	Pb (mg/kg)	Zn (mg/kg)	Cd (mg/kg)
<b>Sample of Soil/Regolith-Materials</b>						
GCA5019	Saprolite-Dacite	0.04	32	4	33	0.3
<b>Samples of Waste-Bedrocks</b>						
GCA5020	Sl.-Weath.-Dacite	0.04	230	6	62	0.3
GCA5021	Sl.-Weath.-Dacite/Andesite	0.05	970	15	29	0.3
GCA5022	Fresh-Dacite	0.25	37	4	19	0.2
GCA5023	Fresh-Dacite	0.15	860	35	99	0.5
GCA5026	Fresh-Dacite	0.22	630	6	53	0.3
GCA5027	Fresh-Dacite	0.79	78	3	37	0.3
GCA5024	Fresh-Andesite	0.16	820	38	110	0.6

**Table 4.3: Mineralogical Results for Sample of Waste-Bedrock (Kundip Deposit)**

<b>Fresh-Dacite (GCA5025)</b>	
<b>Component</b>	<b>Abundance</b>
quartz	major
chlorite biotite plagioclase	minor
<b>pyrite</b> magnetite	accessory
<b>calcite</b> epidote rutile	trace

Note:

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

Refer mineralogical report in Appendix C for additional information.

**Table 5.1: Acid-Base-Analysis, Salinity and Net-Acid-Generation Results for Samples of Low-Grade-Ores (Kundip Deposit)**

GCA-SAMPLE NO.	LITHOTYPE	DRILLHOLE & DOWN-HOLE INTERVAL (m)	pH-(1:2)	EC-(1:2) [mS/cm]	TOTAL-S (%)	SO <sub>4</sub> -S (%)	Sulphide-S (%)	ANC	NAPP	NAG	NAG-pH	ANC/MPA RATIO	AFP CATEGORY
								kg H <sub>2</sub> SO <sub>4</sub> /tonne					
GCA5028	LG-Oxide-Ore	KP053, 16-17	9.0	0.70	0.02	nm	0.02	3.7	nc	<0.5 (<0.5)	7.1 (7.2)	nc	NAF
GCA5029	LG-Transition-Ore	KP056, 62-63	8.7	0.84	0.28	0.03	0.25	3.5	4.2	2.3	4.3	0.45	PAF
GCA5030	LG-Primary-Ore	KP103, 77-78	8.3	0.72	1.5	0.04	1.5	17	29	<0.5 (<0.5)	6.1 (6.2)	0.37	PAF

Notes:

EC = Electrical Conductivity; ANC = Acid-Neutralisation Capacity; NAPP = Net-Acid-Producing Potential; NAG = Net-Acid Generation; AFP = Acid-Formation Potential;

NAF = Non-Acid Forming; PAF = Potentially-Acid Forming; 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), EC-(1:2) and NAG-pH.

Values in parentheses represent duplicates.

**Table 5.2: Multi-Element-Analysis Results for Samples of Low-Grade-Ores (Kundip Deposit)**

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)		
	LG-Oxide-Ore (GCA5028)	LG-Transition-Ore (GCA5029)	LG-Primary-Ore (GCA5030)		LG-Oxide-Ore (GCA5046)	LG-Transition-Ore (GCA5045)	LG-Primary-Ore (GCA5044)
Al	7.8%	6.9%	7.6%	8.2%	0	0	0
Fe	5.4%	14%	11%	4.1%	0	1	1
Na	1.1%	0.059%	1.3%	2.3%	0	0	0
K	2.0%	0.20%	1.1%	2.1%	0	0	0
Mg	1.6%	5.0%	4.0%	2.3%	0	1	0
Ca	0.11%	0.046%	0.74%	4.1%	0	0	0
C	0.11%	0.04%	0.67%	0.048%	1	0	3
Ag	0.1	0.5	1.4	0.07	0	2	4
Cu	840	3,000	3,200	50	3	5	5
Zn	35	39	820	75	0	0	3
Cd	0.3	0.3	3.8	0.11	1	1	5
Pb	27	25	560	14	0	0	5
Cr	32	220	85	100	0	1	0
Ni	50	160	150	80	0	0	0
Co	57	84	86	20	1	1	2
Mn	400	810	1,900	950	0	0	0
Hg	<0.01	0.02	0.18	0.05	0	0	1
Sn	1.3	0.8	1.8	2.2	0	0	0
Sr	34	34	18	370	0	0	0
Ba	250	41	190	500	0	0	0
Th	3.0	2.4	3.2	12	0	0	0
U	0.93	0.95	1.6	2.4	0	0	0
Tl	0.14	<0.02	0.40	0.6	0	0	0
V	69	120	77	160	0	0	0
As	5	3	16	1.5	1	0	3
Bi	0.59	0.16	1.1	0.048	3	1	4
Sb	0.18	0.18	0.33	0.2	0	0	0
Se	0.23	0.24	0.33	0.05	2	2	2
Mo	1.1	0.5	2.7	1.5	0	0	0
B	53	<50	<50	10	2	0	0
P	270	120	430	1,000	0	0	0
F	200	150	270	950	0	0	0

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

**Table 5.3: Mineralogical Results for Samples of Low-Grade-Ores (Kundip Deposit)**

Low-Grade-Oxide-Ore (GCA5028)		Low-Grade-Transition-Ore (GCA5029)		Low-Grade-Primary-Ore (GCA5030)	
Component	Abundance	Component	Abundance	Component	Abundance
quartz	major	quartz chlorite	major	quartz chlorite	major
chlorite muscovite	minor			muscovite plagioclase	minor
biotite plagioclase	accessory	muscovite	accessory		
goethite rutile	trace	<b>pyrite</b> <b>digenite</b> <b>covellite</b> goethite rutile	trace	<b>pyrite</b> <b>chalcopyrite</b> <b>galena</b> <b>sphalerite</b> <b>siderite</b>	trace

Note:

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

Refer mineralogical report in Apendix C for additional information.

**Table 6.1: Acid-Base-Analysis, Salinity and Net-Acid-Generation Results for Samples of Soil/Regolith-Materials and Waste-Bedrocks (Trilogy Deposit)**

GCA-SAMPLE NO.	LITHOTYPE	DRILLHOLE & DOWN-HOLE INTERVAL (m)	pH-(1:2)	EC-(1:2) [mS/cm]	TOTAL-S (%)	SO <sub>4</sub> -S (%)	Sulphide-S (%)	CO <sub>3</sub> -C (%)	ANC	NAPP	NAG	NAG-pH	ANC/MPA RATIO	AFP CATEGORY
									kg H <sub>2</sub> SO <sub>4</sub> /tonne					
<b>Samples of Soil/Regolith-Materials</b>														
GCA5031	Light-Brown-Clay	MYC114, 1-2	8.9	2.2	0.04	nm	0.04	0.47	40 (39)	nc	<0.5	8.4	nc	NAF
GCA5032	Saprolitic-Phyllite	MYC117, 10-11	8.0	1.5	0.20	0.18	0.02	nm	<0.5	nc	<0.5	7.1	nc	NAF
GCA5033	Saprolitic-Phyllite	MYC117, 20-21	7.8	1.9	0.15	0.17	<0.01	nm	0.7	nc	<0.5	6.5	nc	NAF
<b>Samples of Waste-Bedrocks</b>														
GCA5034	Fresh-Phyllite	MYC117, 40-41	9.8	0.40	0.12	0.10 (0.09)	0.03	nm	1.5	nc	<0.5	6.6	nc	NAF
GCA5035	Fresh-Phyllite	MYC117, 45-46	6.4	0.77	1.9	0.10	1.8	nm	0.8	55	18	2.8	0.01	PAF
GCA5036	Fresh-Phyllite	MYC117, 50-51	6.7	0.23	0.56	0.05	0.51	nm	0.7 (0.9)	15	7.2	3.1	0.04	PAF
GCA5037	Fresh-Phyllite	MYC117, 55-56	8.4 (8.8)	0.20	0.28	0.12	0.16	nm	1.2	3.7	<0.5	5.2	0.24	PAF
GCA5038	Fresh-Phyllite	MYC117, 60-61	5.8	1.0	1.2	0.45	0.75	nm	<0.5	23	11	2.9	nc	PAF
GCA5039	Fresh-Phyllite	MYC121, 45-46	8.0	0.46	0.26	0.17	0.09	nm	1.3	nc	<0.5	5.8	nc	NAF
GCA5040	Fresh-Phyllite	MYC121, 50-51	5.7	1.1	0.65	0.13	0.52	nm	<0.5	16	7.6	2.9	nc	PAF
GCA5041	Fresh-Phyllite	MYC121, 54-55	5.2	0.67	3.3	0.36	3.0	nm	<0.5 (<0.5)	92	19	2.7	nc	PAF
GCA5042	Fresh-Phyllite	MYC115, 58-59	6.3	0.78	1.2	0.53	0.67	nm	1.5	20	<0.5	5.2	0.07	PAF
GCA5043	Fresh-Phyllite	MYC114, 43-44	6.6	1.4	1.8	0.37	1.5	nm	1.3	45	0.6	5.4	0	PAF

Notes:

EC = Electrical Conductivity; ANC = Acid-Neutralisation Capacity; NAPP = Net-Acid-Producing Potential; NAG = Net-Acid Generation; AFP = Acid-Formation Potential;

NAF = Non-Acid Forming; PAF = Potentially-Acid Forming; 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), EC-(1:2) and NAG-pH.

Values in parentheses represent duplicates.

**Table 7.1: Multi-Element-Analysis Results for Samples of Soil/Regolith-Materials (Trilogy Deposit)**

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)	
	Litht-Brown Clay (GCA5031)	Saprolitic-Phyllite (GCA5032)		Litht-Brown Clay (GCA5031)	Saprolitic-Phyllite (GCA5032)
Al	8.9%	7.3%	8.2%	0	0
Fe	7.4%	2.1%	4.1%	0	0
Na	0.51%	0.15%	2.3%	0	0
K	0.96%	2.9%	2.1%	0	0
Mg	1.1%	0.39%	2.3%	0	0
Ca	1.4%	0.016%	4.1%	0	0
C	0.91%	0.27%	0.048%	4	2
Ag	0.3	0.2	0.07	2	1
Cu	250	88	50	2	0
Zn	67	69	75	0	0
Cd	0.3	0.3	0.11	1	1
Pb	320	220	14	4	3
Cr	190	98	100	0	0
Ni	85	29	80	0	0
Co	24	4.3	20	0	0
Mn	160	98	950	0	0
Hg	0.01	0.03	0.05	0	0
Sn	1.9	2.7	2.2	0	0
Sr	99	68	370	0	0
Ba	340	710	500	0	0
Th	28	17	12	0	0
U	4.1	3.7	2.4	0	0
Tl	0.41	0.70	0.6	0	0
V	200	150	160	0	0
As	88	39	1.5	5	4
Bi	3.9	0.51	0.048	6	3
Sb	8.9	2.6	0.2	5	3
Se	1.5	0.33	0.05	4	2
Mo	6.4	3.2	1.5	2	1
B	160	130	10	3	3
P	98	97	1,000	0	0
F	390	860	950	0	0

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



**Table 7.2: Multi-Element-Analysis Results for Samples of Waste-Bedrocks (Trilogy Deposit)**

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)			
	Fresh-Phyllite (GCA5035)	Fresh-Phyllite (GCA5038)	Fresh-Phyllite (GCA5041)	Fresh-Phyllite (GCA5043)		Fresh-Phyllite (GCA5035)	Fresh-Phyllite (GCA5038)	Fresh-Phyllite (GCA5041)	Fresh-Phyllite (GCA5043)
Al	5.9%	6.6%	4.8%	9.7%	8.2%	0	0	0	0
Fe	2.0%	0.55%	2.3%	1.4%	4.1%	0	0	0	0
Na	0.13%	0.19%	0.093%	0.20%	2.3%	0	0	0	0
K	2.6%	2.9%	2.1%	4.3%	2.1%	0	0	0	0
Mg	0.30%	0.10%	0.23%	0.32%	2.3%	0	0	0	0
Ca	0.016%	0.064%	0.064%	0.091%	4.1%	0	0	0	0
C	1.1%	1.8%	2.1%	0.69%	0.048%	4	5	5	3
Ag	7.3	6.8	5.1	4.3	0.07	6	6	6	5
Cu	6,200	1,600	5,000	1,200	50	6	4	6	4
Zn	980	88	220	390	75	3	0	1	2
Cd	1.5	<0.1	0.2	<0.1	0.11	3	0	0	0
Pb	2,100	1,500	2,000	2,700	14	6	6	6	6
Cr	52	50	77	50	100	0	0	0	0
Ni	28	43	46	12	80	0	0	0	0
Co	16	18	24	5.3	20	0	0	0	0
Mn	73	29	62	120	950	0	0	0	0
Hg	8.2	1.2	2.4	3.8	0.05	6	4	5	6
Sn	2.9	2.5	2.9	4.7	2.2	0	0	0	1
Sr	22	61	36	130	370	0	0	0	0
Ba	640	320	330	680	500	0	0	0	0
Th	12	18	12	21	12	0	0	0	0
U	4.3	4.3	3.4	6.8	2.4	0	0	0	1
Tl	5.0	2.5	7.4	1.8	0.6	2	1	3	1
V	95	150	81	130	160	0	0	0	0
As	260	220	300	100	1.5	6	6	6	5
Bi	1.5	2.8	4.9	2.3	0.048	4	5	6	5
Sb	21	24	21	16	0.2	6	6	6	6
Se	3.5	1.8	4.0	1.7	0.05	6	5	6	5
Mo	3.3	3.0	6.5	7.7	1.5	1	0	2	2
B	160	58	150	210	10	3	2	3	4
P	81	230	220	360	1,000	0	0	0	0
F	700	390	600	980	950	0	0	0	0

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

**Table 7.3: Selected-Assay Results for Samples of Soil/Regolith-Materials and Waste-Bedrocks (Trilogy Deposit)**

GCA-SAMPLE NO.	LITHOTYPE	C (%)	Cu (mg/kg)	Pb (mg/kg)	Zn (mg/kg)	Cd (mg/kg)
<b>Sample of Soil/Regolith-Materials</b>						
GCA5033	Saprolitic-Phyllite	0.08	330	2,500	110	0.3
<b>Samples of Waste-Bedrocks</b>						
GCA5034	Fresh-Phyllite	2.6	170	750	210	0.3
GCA5036	Fresh-Phyllite	0.85	2,700	330	42	0.1
GCA5037	Fresh-Phyllite	1.9	730	620	260	0.4
GCA5039	Fresh-Phyllite	2.8	710	1,500	200	0.2
GCA5040	Fresh-Phyllite	1.7	1,600	1,400	40	<0.1
GCA5042	Fresh-Phyllite	1.5	1,200	2,200	410	0.3

**Table 7.4: Results for Water-Extraction Testwork on Samples of Waste-Bedrocks (Trilogy Deposit)**

GCA-SAMPLE NO.	LITHOTYPE	Content of Water-Extractable Solutes			
		Cu (mg/kg)	Pb (mg/kg)	Cl (mg/kg)	SO <sub>4</sub> (mg/kg)
GCA5035	Fresh-Phyllite	30	13	190	650
GCA5038	Fresh-Phyllite	61	1.1	340	580
GCA5041	Fresh-Phyllite	160	6.0	120	820
GCA5043	Fresh-Phyllite	0.7	<0.5	860	170

Note:

Water-Extraction Tests performed on crushed (nominal 2-mm) 'splints' of waste-rock samples, using deionised-water, and a solid:solution ratio of c. 1:2 (w/w). The sample-slurries were 'bottle-rolled' overnight, and the water-extracts then vacuum-filtered (0.45-µm-membrane), and preserved, as appropriate, for analysis.

**Table 7.5: Mineralogical Results for Sample of Waste-Bedrock (Trilogy Deposit)**

Fresh-Phyllite (GCA5041)	
Component	Abundance
quartz	dominant
muscovite	minor
<b>pyrite</b>	accessory
<b>marcasite</b>	trace
<b>digenite</b>	
<b>covellite</b>	
<b>chalcocite</b>	
alunite	
albite	
kaolin	

Note:

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

Refer mineralogical report in Apendix C for additional information.

**Table 8.1: Acid-Base-Analysis, Salinity and Net-Acid-Generation Results for Samples of Low-Grade-Ores (Trilogy Deposit)**

GCA-SAMPLE NO.	LITHOTYPE	DRILLHOLE & DOWN-HOLE INTERVAL (m)	pH-(1:2)	EC-(1:2) [mS/cm]	TOTAL-S (%)	SO <sub>4</sub> -S (%)	Sulphide-S (%)	ANC	NAPP	NAG	NAG-pH	ANC/MPA	AFP
								kg H <sub>2</sub> SO <sub>4</sub> /tonne				RATIO	CATEGORY
GCA5046	LG-Oxide-Ore	MYC121, 30-31	5.3 (5.2)	1.5 (1.5)	0.41	0.38	0.03	<0.5	nc	2.5	4.4	nc	NAF
GCA5045	LG-Transition-Ore	MYC115, 49-50	6.4	0.78	0.23	0.15	0.08	3.9	nc	0.7	5.4	nc	NAF
GCA5044	LG-Primary-Ore	MYC117, 73-74	6.0	1.6	4.9	0.17 (0.18)	4.8	<0.5	150	22 (22)	2.8 (2.8)	nc	PAF

Notes:

EC = Electrical Conductivity; ANC = Acid-Neutralisation Capacity; NAPP = Net-Acid-Producing Potential; NAG = Net-Acid Generation; AFP = Acid-Formation Potential;

NAF = Non-Acid Forming; PAF = Potentially-Acid Forming; 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), EC-(1:2) and NAG-pH.

Values in parentheses represent duplicates.

**Table 8.2: Multi-Element-Analysis Results for Samples of Low-Grade-Ores (Trilogy Deposit)**

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)		
	LG-Oxide-Ore (GCA5046)	LG-Transition-Ore (GCA5045)	LG-Primary-Ore (GCA5044)		LG-Oxide-Ore (GCA5046)	LG-Transition-Ore (GCA5045)	LG-Primary-Ore (GCA5044)
Al	6.3%	2.0%	0.98%	8.2%	0	0	0
Fe	1.3%	8.5%	4.4%	4.1%	0	0	0
Na	0.16%	0.058%	0.087%	2.3%	0	0	0
K	2.5%	0.34%	0.39%	2.1%	0	0	0
Mg	0.30%	0.061%	0.063%	2.3%	0	0	0
Ca	0.056%	0.0096%	0.011%	4.1%	0	0	0
C	0.14%	1.5%	0.80%	0.048%	1	4	3
Ag	48	170	84	0.07	6	6	6
Cu	5,900	8,800	4,800	50	6	6	6
Zn	480	1,500	160	75	2	4	1
Cd	0.3	0.3	2.0	0.11	1	1	4
Pb	11,000	4,200	4,900	14	6	6	6
Cr	85	40	32	100	0	0	0
Ni	18	31	43	80	0	0	0
Co	4.5	19	68	20	0	0	1
Mn	33	91	83	950	0	0	0
Hg	0.45	6.3	9.1	0.05	3	6	6
Sn	3.0	2.8	3.1	2.2	0	0	0
Sr	77	62	30	370	0	0	0
Ba	600	780	430	500	0	0	0
Th	12	16	8.7	12	0	0	0
U	6.2	8.6	3.5	2.4	1	1	0
Tl	4.5	0.64	6.2	0.6	2	0	3
V	90	22	17	160	0	0	0
As	260	750	1,200	1.5	6	6	6
Bi	1.4	74	17	0.048	4	6	6
Sb	36	130	220	0.2	6	6	6
Se	5.0	3.2	5.0	0.05	6	5	6
Mo	3.8	28	3.7	1.5	1	4	1
B	130	170	140	10	3	4	3
P	150	240	160	1,000	0	0	0
F	890	250	160	950	0	0	0

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

**Table 8.3: Results for Water-Extraction Testwork on Samples of Low-Grade-Ores (Trilogy Deposit)**

GCA-SAMPLE NO.	LOW-GRADE-ORE TYPE	Content of Water-Extractable Solutes			
		Cu (mg/kg)	Pb (mg/kg)	Cl (mg/kg)	SO <sub>4</sub> (mg/kg)
GCA5044	LG-Oxide-Ore	21	11	660	480
GCA5045	LG-Transition-Ore	1.0	<0.5	360	170
GCA5046	LG-Primary-Ore	74	28	1,000	290

Note:

Water-Extraction Tests performed on crushed (nominal 2-mm) 'splits' of low-grade-ore samples, using deionised-water, and a solid:solution ratio of *c.* 1:2 (w/w). The sample-slurries were 'bottle-rolled' overnight, and the water-extracts then vacuum-filtered (0.45-µm-membrane), and preserved, as appropriate, for analysis.

**Table 8.4: Mineralogical Results for Samples of Low-Grade-Ores (Trilogy Deposit)**

Low-Grade-Oxide-Ore (GCA5046)		Low-Grade-Transition-Ore (GCA5045)		Low-Grade-Primary-Ore (GCA5044)	
Component	Abundance	Component	Abundance	Component	Abundance
quartz	dominant	quartz	dominant	quartz	dominant
muscovite	minor	goethite	minor		
albite	accessory	muscovite	accessory	<b>pyrite</b> muscovite	accessory
siderite	trace	<b>pyrite</b>	trace	<b>covellite</b>	trace
alunite		<b>azurite</b>		<b>chalcocite</b>	
anglesite		Pb-Fe-Cu-arsenates/ sulphates		<b>digenite</b>	
atacamite (?)		tourmaline		<b>galena</b>	
goethite		barite		graphite	

Note:

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

Refer mineralogical report in Appendix C for additional information.

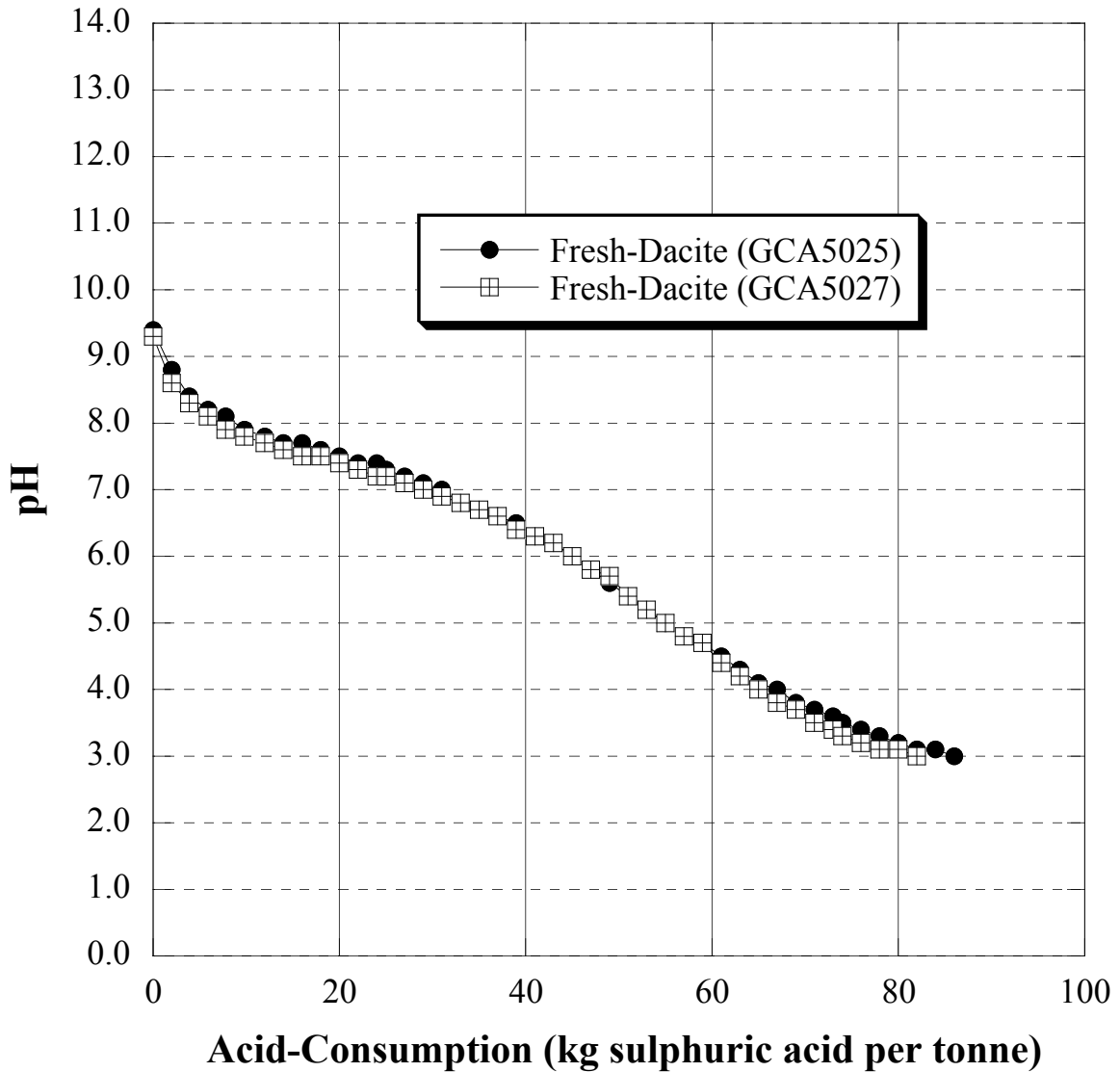


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## **FIGURES**

**Figure 1**

**pH-Buffering Curves for Samples of Waste-Bedrock  
(Kundip Deposit)**

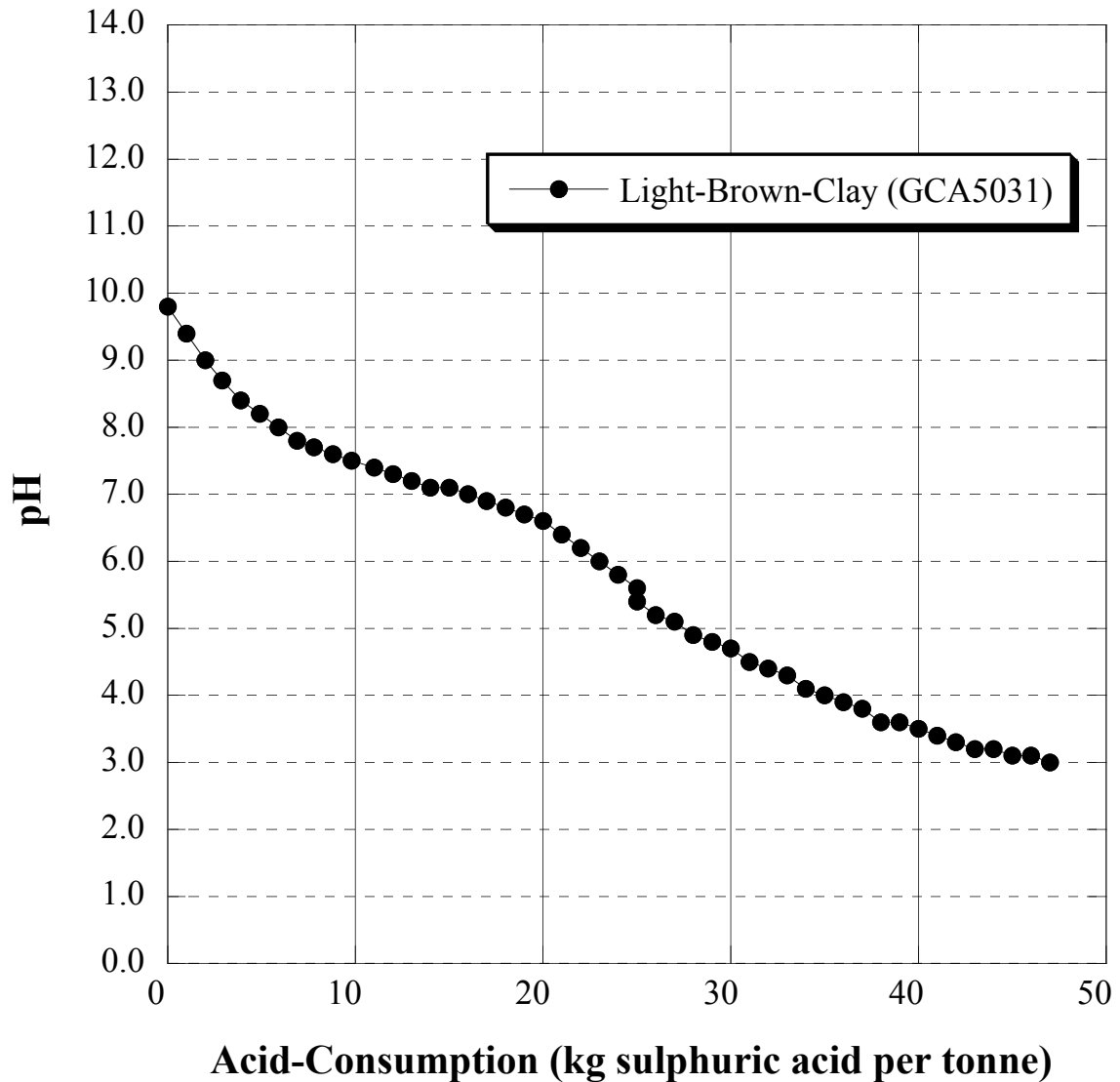


Note: The H<sub>2</sub>SO<sub>4</sub>-addition rates employed in the auto-titrations correspond to sulphide-oxidation rates (SORs) of *c.* 1-2 x 10<sup>6</sup> mg SO<sub>4</sub>/kg/week (= *c.* 5-10 x 10<sup>4</sup> kg H<sub>2</sub>SO<sub>4</sub>/tonne/year).

These SORs are therefore up to 10<sup>4</sup>-10<sup>5</sup> **faster** than those typical for the weathering (at circum-neutral-pH) of mine-waste materials that contain "trace/accessory-sulphides".

**Figure 2**

**pH-Buffering Curve for Sample of Soil/Regolith-Material  
(Trilogy Deposit)**



Note: The H<sub>2</sub>SO<sub>4</sub>-addition rate employed in the auto-titration corresponds to a sulphide-oxidation rate (SOR) of *c.* 6-7 x 10<sup>5</sup> mg SO<sub>4</sub>/kg/week (= *c.* 3-4 x 10<sup>4</sup> kg H<sub>2</sub>SO<sub>4</sub>/tonne/year).

This SOR is therefore up to 10<sup>4</sup>-10<sup>5</sup> **faster** than that typical for the weathering (at circum-neutral-pH) of mine-waste materials that contain "trace-sulphides".

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**APPENDIX A**

**DETAILS OF SAMPLING PROGRAMME**



**TECTONIC RESOURCES NL**  
ACN 004 287 790

**Suite 4, 100 Hay Street, SUBIACO WA 6008**  
**Telephone: (08) 9388 3872 Facsimile: (08) 9388 1077**

19 December 2003

Memo To: Graeme Campbell

From: Dave Jackson

**Re: Trilogy and Kundip Waste Rock Samples**

The attached spreadsheet outlines the hole number, depth, rock type, ore/waste type and available geochemistry for the samples you requested in your email of 5 November 2003.

Regards,

David G Jackson  
Exploration Manager

Deposit	Hole No	From	To	Rock Type	Sample Type
Kundip	KP053		16	17 Yellow Clay, 20% Qtz	Low Grade Oxide Ore
Kundip	KP056		62	63 Fresh Dacite, 20% Qtz, 5% Oxidised Pyrite	Low Grade Transition Ore
Kundip	KP103		77	78 Fresh Dacite, 10% Qtz, 5% Pyrite	Low Grade Primary Ore
Kundip	KP075/076		0	1 Red Brown Clay	Top Soil
Kundip	KP076		14	15 Saprolitic Dacite, Tr Qtz	Clay/Saprolite Waste
Kundip	KP076		30	31 Saprolitic Dacite	Weathered Waste
Kundip	KP076		50	51 Slightly weathered Dacite	Transition/Primary Waste
Kundip	KP056		56	57 Slightly weathered Dacite and Andesite	Transition/Primary Waste
Kundip	KP106		140	141 Fresh fg Dacite	Underground Waste
Kundip	KP106		144	145 Fresh fg Dacite, 2% Pyrite	Underground Waste
Kundip	KP110		145	146 Fresh Andesite	Underground Waste
Kundip	KP110		148	149 Fresh Dacite, 5% Pyrite	Underground Waste
Kundip	KP101		137	138 Fresh fg Dacite, Tr Pyrite	Underground Waste
Kundip	KP101		150	151 Fresh Dacite	Underground Waste
Trilogy	MYC117		73	74 Fresh Phyllite, 3% Qtz, 10% Py	Low Grade Ore Transition/Primary
Trilogy	MYC115		49	50 Slightly weathered Pyllite, 3% Qtz, 20% Oxidised Pyrite	Low Grade Ore Transition
Trilogy	MYC121		30	31 Saprolitic Phyllite, 2% Malachite and Azurite	Low Grade Ore Oxide
Trilogy	MYC114		0	2 Light Brown Clay	Top Soil
Trilogy	MYC117		10	11 Weathered saprolitic Phyllite	Clay/Shale
Trilogy	MYC117		20	21 Weathered saprolitic Phyllite, 1% Qtz	Weathered Shale
Trilogy	MYC117		40	41 Fresh Phyllite, 5% Qtz	Fresh waste
Trilogy	MYC117		45	46 Fresh Phyllite	Fresh waste
Trilogy	MYC117		50	51 Fresh Phyllite	Fresh waste
Trilogy	MYC117		55	56 Fresh Phyllite	Fresh waste
Trilogy	MYC117		60	61 Fresh Phyllite	Fresh waste
Trilogy	MYC121		45	46 Fresh Phyllite, 1% Oxidised Pyrite	Fresh waste
Trilogy	MYC121		50	51 Fresh Phyllite, 3% Qtz	Fresh waste
Trilogy	MYC121		54	55 Fresh Phyllite, 2% Qtz, 1% Pyrite	Fresh waste
Trilogy	MYC115		58	59 Fresh Phyllite	Fresh waste
Trilogy	MYC114		43	44 Fresh Phyllite, 10% Qtz, 2% Azurite	Fresh waste

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**APPENDIX B**

**TESTWORK METHODS**

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## APPENDIX B

### TESTWORK METHODS

#### B1.0 ACID-BASE-CHEMISTRY AND SALINITY TESTWORK

The acid-base chemistry and salinity of the soil/regolith-materials, waste-bedrock and low-grade-ore samples was assessed by determining:

- pH and Electrical-Conductivity (EC) on sample slurries.
- Total-Sulphur (Total-S) and Sulphate-Sulphur (SO<sub>4</sub>-S).
- Acid-Neutralisation-Capacity (ANC), Carbonate-Carbon (CO<sub>3</sub>-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.<sup>1</sup>

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



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

## **B1.2 Total-S and SO<sub>4</sub>-S Tests**

The Total-S values were measured by Leco combustion (@ 1300 °C) with detection of evolved SO<sub>2(g)</sub> by infra-red spectroscopy.

The SO<sub>4</sub>-S values were determined by the Na<sub>2</sub>CO<sub>3</sub>-Extraction Method (Lenahan and Murray-Smith 1986).<sup>3</sup> The difference between the Total-S and SO<sub>4</sub>-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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<sup>2</sup> The pH-(1:2) values approximate the "Abrasion-pH" values employed for identifying minerals in the field (Stevens and Carron 1948).

<sup>3</sup> The Na<sub>2</sub>CO<sub>3</sub>-reagent extracts SO<sub>4</sub>-S which occurs as soluble sulphates, and calcium sulphates (e.g. gypsum and anhydrite). It also extracts SO<sub>4</sub> sorbed to the surfaces of sesquioxides, clays and silicates. However, SO<sub>4</sub> present as barytes (BaSO<sub>4</sub>) is not extracted, and SO<sub>4</sub> associated with jarositic-type and alunitic-type compounds are incompletely extracted.

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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.<sup>4</sup> 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 manganous 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<sub>2</sub>SO<sub>4</sub>-consumption rates 'of-the-order' 10<sup>-11</sup>/10<sup>-12</sup> moles/m<sup>2</sup>/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<sub>4</sub>/kg/week (= *c.* 0.1-1.0 kg H<sub>2</sub>SO<sub>4</sub>/tonne/year).<sup>5</sup> Maintenance of circum-neutral-pH through dissolution/hydrolysis of primary-silicates is therefore restricted to both "mineral-fines", and slow rates of pyrite weathering.

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<sup>4</sup> Two drops of 30 % (w/w) H<sub>2</sub>O<sub>2</sub> 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)<sub>3</sub>"). 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<sub>2</sub>O<sub>2</sub> reagent is not part of the methodology described by Sobek *et al.* (1978).

<sup>5</sup> 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 %).

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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 CO<sub>3</sub>-C Values

The CO<sub>3</sub>-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<sub>2(g)</sub> 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 selected samples were determined via a Metrohm® 736 Titrino auto-titrator, and 0.05 M-H<sub>2</sub>SO<sub>4</sub>.

The auto-titrations comprised regular addition of the H<sub>2</sub>SO<sub>4</sub> reagent to monotonically decrease the pH values of the test-suspensions to 3.0.<sup>6</sup> The Start-pH values of the suspensions were *c.* 9-10. Under the testwork conditions employed, the H<sub>2</sub>SO<sub>4</sub>-addition

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<sup>6</sup> 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<sub>2</sub>SO<sub>4</sub>/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<sub>2</sub>SO<sub>4</sub> titrant.

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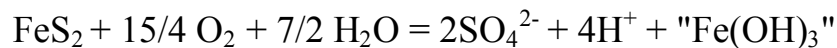
rates correspond to SORs 'of-the-order'  $10^5$ - $10^6$  mg SO<sub>4</sub>/kg/week (i.e. 'of-the-order'  $10^4$  kg H<sub>2</sub>SO<sub>4</sub>/tonne/year) , and so represent very-rapid rates of acid addition.

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<sub>4</sub>-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 either 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 H<sub>2</sub>SO<sub>4</sub>/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<sub>2</sub>' 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).

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In this test, the sample is reacted with H<sub>2</sub>O<sub>2</sub> 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<sub>2</sub>O<sub>2</sub> solution (prepared from A.R.-grade H<sub>2</sub>O<sub>2</sub>) was adjusted to pH=4.5 using dilute NaOH. In addition, the boiling treatment to decompose residual, unreacted-H<sub>2</sub>O<sub>2</sub> 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<sub>4</sub> to the test mixtures, followed by boiling again for *c.* 2 hours). The addition of Cu(II) salts catalyses the decomposition of residual H<sub>2</sub>O<sub>2</sub>, and thereby prevents "positive-blank" values being obtained (O'Shay *et al.* 1990).<sup>7</sup> 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<sub>2</sub>O<sub>2</sub>. 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<sub>2</sub>SO<sub>4</sub>/tonne (as typically recorded for a felsic/mafic-gangue that is void of carbonates). Furthermore, oxidation by H<sub>2</sub>O<sub>2</sub> is generally at least 10<sup>3</sup> 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

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

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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)*.<sup>8</sup>

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

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.

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

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

where:

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

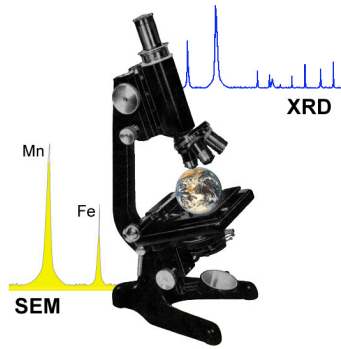
$B_n$  = "background" content of the n-th element in the sample.

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

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**APPENDIX C**

**LABORATORY REPORTS**



*Roger Townend and  
Associates  
Consulting Mineralogists*

G CAMPBELL AND ASSOC,

5-1-2004

PO BOX 247,

BRIDGETOWN

WA

OUR REF. 20858

YOUR REF.

XRD/SEM/PLM ANALYSIS OF EIGHT SAMPLES.

R TOWNEND

**RESULTS.**

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

ACN 069 920 476 ABN 92 076 109 663



GCA	5025	5028	5029	5030
quartz	25-30%	25-35%	45-55%	25-35%
chlorite	15-25%	15-25%	45-55%	35-45%
muscovite		20-25%	<5%	10-15%
biotite	15-25%	5-10%		
plagioclase	10-15%	10-15%		15-20%
epidote	1%			
calcite	1-2%			
siderite				1-2%
pyrite	2-3%		<1%	1-2%
digenite			<1%	
covellite			<1%	
chalcopyrite				<1%
galena				<<1%
sphalerite				<<1%
goethite		1-2%	<1	
rutile	1%	1%	<1%	
magnetite	2-3%			

GCA	5041	5044	5045	5046
quartz	70%+	85%	75%	70%
chlorite				
muscovite	20%	5%	5%	25%
kaolin	<1%			
albite	<1%			2-3%
tourmaline			<1%	
siderite				<1%
pyrite	3-4%	5-6%	<<1%	
marcasite	<<1%			
digenite	<<1%	<<1%		
covellite	<1%	<1%		
chalcocite	<<1%	<<1%		
galena		<1%		
alunite	1-2%			<1%
anglesite				<1%
Pb >Fe >Cu Arsenate/ Sulphates?			<1%	?
atacamite?				<1%
goethite			10-15%	<1%
azurite			1-2%	
barite			<1%	
graphite	2%	1%		

The analysed chlorites in most samples were iron-rich. The plagioclases are albite. In GCA 5028, the SEM detected Cu with the goethite. In GCA 5046, there was evidence of Pb and Cu with some of the alunite. Determination of the meta sulphate/arsenates is best done by heavy liquid concentration.



27 November, 2003

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

Our Reference: 76735 NATA Accreditation: 2562(1705)  
Your Reference: GCA0333

Dear Sir

On the 17<sup>th</sup> of November 2003 you forwarded testwork instructions for thirty(30) mine waste materials which were received earlier that day at our laboratory. The samples were received “damp” and all were dried at 45°C prior to being crushed to a nominal 2mm particle size with a subsample of this then pulped to a nominal -75µm particle size. Sub samples of each pulp were forwarded to the GCA Testing Laboratory and Genalysis Laboratory Services as requested.

Results of all testwork performed follow:

Sample Number	pH (pH Units)	Conductivity @ 25°C (µS/cm)	Total Sulphur S (% w/w)	Sulphate Sulphur SO <sub>4</sub> -S (% w/w)
GCA5017	8.4	3100	0.05	-
GCA5018	8.4	2400	0.02	-
GCA5019	8.6	1100	0.02	-
GCA5020	8.6	580	0.03	-
GCA5021	8.5	540	0.04	-
GCA5022	8.3	1100	0.10	0.02
GCA5023	8.2	2200	0.20	0.02
GCA5024	8.4	2000	0.16	0.03
GCA5025	8.4	440	1.6	0.03
GCA5026	8.9	260	0.27	0.02
GCA5027	9.2(9.1)	210(220)	0.04	-
GCA5028	9.0	700	0.02	-
GCA5029	8.7	840	0.28	0.03
GCA5030	8.3	720	1.5	0.04
GCA5031	8.9	2200	0.04	-
GCA5032	8.0	1500	0.20	0.18
GCA5033	7.8	1900	0.15	0.17
GCA5034	9.8	400	0.12	0.10(0.09)
GCA5035	6.4	770	1.9	0.10
GCA5036	6.7	230	0.56	0.05
GCA5037	8.4(8.8)	200	0.28	0.12
GCA5038	5.8	1000	1.2	0.45
GCA5039	8.0	460	0.26	0.17
GCA5040	5.7	1100	0.65	0.13
GCA5041	5.2	670	3.3	0.36
GCA5042	6.3	780	1.2	0.53
GCA5043	6.6	1400	1.8	0.37

**CLIENT: Graeme Campbell & Associates Pty Ltd      OUR REFERENCE: 76735**  
**PROJECT NO: GCA0333**

GCA5044	6.0	1600	4.9	0.17(0.18)
GCA5045	6.4	780	0.23	0.15
GCA5046	5.3(5.2)	1500(1500)	0.41	0.38

**NOTES:**

- pH and conductivity were determined on a 1:2 w/w as received (45°C dried) crushed sample to deionised water extract after 24 hours ambient aging.*
- Total sulphur was determined on as received (45°C dried) pulped sample by LECO induction furnace, IR detection, and is reported on that basis. This testwork was performed by SGS Analabs, Welshpool, report number WM074591.*
- Sulphate sulphur was determined on an as received (45°C dried) crushed sample by Na<sub>2</sub>CO<sub>3</sub> extraction, BaSO<sub>4</sub> precipitation with results reported on that basis.*
- Bracketed results from duplicate analysis.*

**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 <sub>2</sub> SO <sub>4</sub> /tonne)
GCA5017	0	5.0024	13.7	0.1	Nil	Nil	1.9	11
GCA5018	0	5.0170	19.3	0.1	Nil	Nil	1.6	5.8
GCA45019	0	4.9993	19.5	0.1	Nil	Nil	1.5	5.6
GCA5020	0	5.0443	21.5	0.1	Nil	Nil	1.4	3.6
GCA5021	0	4.9962	22.0	0.1	Nil	Nil	1.5	3.2
GCA5021 Rpt	0	5.0060	22.4	0.1	Nil	Nil	1.5	2.8
GCA5022	2	1.9971	16.6	0.1	Moderate	Nil	1.6	21
GCA5023	1	4.9934	15.7	0.1	Slight	Nil	1.6	9.3
GCA5024	1	5.0347	12.8	0.1	Slight	Nil	1.9	12
GCA5025	3	0.9992	21.1	0.5	Strong	Nil	0.8	93
GCA5026	1	4.9931	9.7	0.1	Slight	Nil	2.4	15
GCA5026 Rpt	1	4.9918	9.9	0.1	Slight	Nil	2.4	15
GCA5027	4	2.0016	20.0	0.5	Strong	Nil	0.8	60*
GCA5028	0	4.9986	21.5	0.1	Nil	Nil	1.5	3.7
GCA5029	0	5.0490	21.6	0.1	Nil	Nil	1.8	3.5
GCA5030	0	5.0257	7.8	0.1	Nil	Nil	3.9	17
GCA5031	4	2.9962	20.0	0.5	Strong	Nil	0.7	40
GCA5031 Rpt	4	3.0028	20.1	0.5	Strong	Nil	0.7	39
GCA5032	0	5.0377	25.0	0.1	Nil	Nil	1.4	<0.5
GCA5033	0	5.0282	24.6	0.1	Nil	Nil	1.5	0.7
GCA5034	0	4.9989	23.7	0.1	Nil	Nil	1.4	1.5
GCA5035	0	4.9821	24.5	0.1	Nil	Nil	1.4	0.8
GCA5036	0	5.0293	24.4	0.1	Nil	Nil	1.4	0.9
GCA5036 Rpt	0	4.9928	24.6	0.1	Nil	Nil	1.4	0.7
GCA5037	0	4.9933	24.1	0.1	Nil	Nil	1.4	1.2
GCA5038	0	5.0055	24.9	0.1	Nil	Nil	1.3	<0.5
GCA5039	0	4.9940	24.0	0.1	Nil	Nil	1.4	1.3
GCA5040	0	4.9987	24.9	0.1	Nil	Nil	1.3	<0.5
GCA5041	0	5.0109	25.3	0.1	Nil	Nil	1.4	<0.5
GCA5041 Rpt	0	5.0085	25.2	0.1	Nil	Nil	1.4	<0.5
GCA5042	0	4.9922	23.8	0.1	Nil	Nil	1.3	1.5
GCA5043	0	4.9732	24.0	0.1	Nil	Nil	1.4	1.3

**CLIENT:** Graeme Campbell & Associates Pty Ltd      **OUR REFERENCE:** 76735  
**PROJECT NO:** GCA0333

GCA5044	0	4.9968	24.8	0.1	Nil	Nil	1.4	<0.5
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**CLIENT:** Graeme Campbell & Associates Pty Ltd      **OUR REFERENCE:** 76735  
**PROJECT NO:** GCA0333

Sample Number	Fizz Rating	Sample Weight (g)	Titre NaOH (mL)	Normality HCl/NaOH (N)	Initial Effervescence	Effervescence on Warming	ANC Solution pH	ANC (kg H2SO4/tonne)
GCA5045	0	5.0199	21.3	0.1	Nil	Nil	1.7	3.9
GCA5046	0	4.9880	25.4	0.1	Nil	Nil	1.4	<0.5
GCA5046 Rpt	0	5.0351	25.9	0.1	Nil	Nil	1.4	-0.6
ANC Std20	-	1.9905	17.1	0.1	-	-	1.5	19.9
ANC Std200	-	1.0045	17.3	0.5	-	-	0.8	185

**NOTES:**

1. *Acid neutralisation capacity was determined on as received (45°C dried) crushed sample with results reported on that basis. Unless otherwise stated, 25mL of HCl is used. Reagent blank titre of 0.1N NaOH and 0.5N NaOH were 25.3mL and 24.9mL respectively.*
2. *\*Indicates the pH dropped to 3-4 on the addition of the hydrogen peroxide. Two drops of hydrogen peroxide are added to all samples as the pH=7 endpoint is approached to oxidise any ferrous iron.*
4. *ANC Std20 and Std200 are internally produced standards of CaCO<sub>3</sub> and quartz pulped to a nominal 75µm which have a nominal ANC of 20kg and 200kg H<sub>2</sub>SO<sub>4</sub>/tonne respectively.*
5. *This procedure is based on the method of Sobek et al 1978.*

The pH and EC extraction procedure is not covered by our terms of NATA accreditation.

Yours faithfully,

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PETER BAMFORD  
Manager Laboratory Services

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JANICE VENNING  
Manager, Perth

*This report supersedes our preliminary results sent by facsimile on the 26 November 2003.*



12 December, 2003

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

Our Reference: 77091  
Your Reference: GCA0333  
NATA Accreditation: 2562(1705)

Dear Sir

On the 1st of December 2003 you forwarded testwork instructions for thirty(30) waste rock samples which were already held at our laboratory under our job reference 76735. Approximately 100g of the crushed split for all 30 samples was forwarded to the GCA Testing Laboratory as requested. Approximately 50g of the same crushed split for samples GCA5025, GCA5028 to GCA5030, GCA5041 and GCA5044 to GCA5046 were forwarded to Dr Roger Townend in Malaga also as requested.

Results of all testwork performed follow:

Sample Number	Total Carbon, C (%w/w)	Total Organic Carbon (%w/w)	Carbonate Carbon, CO <sub>3</sub> -C (%w/w)
GCA5022	0.21	0.03	0.17
GCA5024	0.14	0.04	0.09
GCA5025	0.82	0.03	0.80
GCA5026	0.22	0.02	0.20
GCA 5027	0.71	0.02	0.69
GCA 5031	0.82	0.36	0.47
GCA 5034	2.3	-	-
GCA 5035	0.95	-	-
GCA 5036	0.83	-	-
GCA 5037	1.7	-	-
GCA 5038	1.6	-	-
GCA 5039	2.3	-	-
GCA 5040	1.4	-	-
GCA 5041	1.8	-	-
GCA 5042	1.4	-	-
GCA 5043	0.62	-	-
GCA 5044	0.66	-	-
GCA 5045	1.3	-	-
GCA 5046	0.13	-	-

**CLIENT:** Graeme Campbell & Associates Pty Ltd      **OUR REFERENCE:** 77091  
**PROJECT NO:** GCA0333

*NOTES:*

1. *Total carbon and total organic carbon (acid insoluble or non carbonate carbon) were determined on as received pulped sample by LECO induction furnace, IR detection, and is reported on that basis. This testwork was performed by SGS Analabs, Welshpool, report number WM074974.*

Yours faithfully,

---

PETER BAMFORD  
Manager Laboratory Services

---

JANICE VENNING  
Manager, Perth

*This report supersedes our preliminary results sent by facsimile on the 10 December 2003.*



27 January, 2004

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

Our Reference: 77771  
Your Reference: GCA0333  
NATA Accreditation: 2562(1705)

Dear Sir

On the 5<sup>th</sup> of January 2004 you forwarded testwork instructions for ten (10) mine waste material samples which were already held at our laboratory under our reference numbers 76735 and 77091. All testwork requested was performed on the 2mm crushed splits as requested.

Results of all testwork performed follow:

Sample Number	Water Soluble Copper, Cu (mg/kg)	Water Soluble Lead, Pb (mg/kg)	Water Soluble Chloride, Cl (mg/kg)	Water Soluble Sulphate SO <sub>4</sub> (mg/kg)
GCA5028	<0.5	-	-	-
GCA5029	<0.5	-	-	-
GCA5030	<0.5	-	-	-
GCA45035	30	13	190	650
GCA45038	61	1.1	340	580
GCA5041	160	6.0	120	820
GCA5043	0.7	<0.5	860	170
GCA5044	21	11	660	480
GCA5045	1.0	<0.5	360	170
GCA5046	74	28	1000	290
Method	PEM-001	PEM-001	PEI-020	PEI-020

**NOTES:**

- All testwork was performed on the crushed sample from a 1:2w/w crushed sample to deionised water extract after overnight bottle rolling with results reported back to the crushed sample basis.*

The 1:2w/w extraction procedure is not covered by our terms of NATA accreditation.

Yours faithfully,

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PETER BAMFORD  
Manager Laboratory Services

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JANICE VENNING  
Manager, Perth



**CLIENT:** Graeme Campbell & Associates Pty Ltd      **OUR REFERENCE:** 69619  
**PROJECT NO:** GCA0301

*This report supersedes our preliminary results sent by facsimile on the 22 January 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 <sub>2</sub> SO <sub>4</sub> /tonne)
				pH	EC (µS/cm)		
GCA5023	4.8		6.7	7.1	230	-	<0.5
GCA5024	5.3		6.8	7.0	220	-	<0.5
GCA5025	4.8		7.0	7.0	380	-	<0.5
GCA5026	4.8		6.7	7.2	220	-	<0.5
GCA5029	4.4		4.4	4.3	180	2.00	2.3
GCA5030	5.2	Reaction peaked overnight	5.4	6.1	510	0.40	<0.5
GCA5035	4.1	Reaction peaked within 1 hour	3.0	2.8	910	14.40	18
GCA5036	4.3	Reaction peaked within 3 hours	3.2	3.1	370	6.30	7.2
GCA5037	4.7		5.1	5.2	75	0.30	<0.5
GCA5038	4.1	Reaction peaked within 1.5 hours	3.1	2.9	680	8.80	11
GCA5040	4.4	Reaction peaked within 1.5 hours	3.1	2.9	540	6.80	7.6
GCA5041	5.0	Reaction peaked within 0.5 hours	2.8	2.7	1,300	19.20	19
GCA5042	4.6		5.4	5.2	96	0.30	<0.5
GCA5043	4.7		5.6	5.4	120	0.50	0.6
GCA5044	5.3	Reaction peaked within 1 hour	2.8	2.8	1,400	23.40	22
GCA5044 (Repeat)	5.9	Reaction peaked within 1 hour	2.8	2.8	1,400	25.30	22
Blank	4.2		5.6	7.1	61	-	<0.5

**Notes:** Test conditions based on those described by Miller *et al.* (1997). The pH of the 15 % (v/v) H<sub>2</sub>O<sub>2</sub> 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<sub>2</sub>O<sub>2</sub>. Then, after allowing the test mixtures to cool, 1.0 mL of 0.016 M-CuSO<sub>4</sub> 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<sub>2</sub>O<sub>2</sub> 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**  
**5<sup>th</sup> December 2003**

**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 <sub>2</sub> SO <sub>4</sub> /tonne)
				pH	EC (µS/cm)		
GCA5017	4.1		6.0	7.1	170	-	<0.5
GCA5018	3.5		5.5	6.8	130	-	<0.5
GCA5019	3.8		5.7	7.2	83	-	<0.5
GCA5020	4.1		5.4	6.3	51	0.30	<0.5
GCA5021	3.4		5.3	6.3	48	0.30	<0.5
GCA5022	4.3		6.5	7.6	130	-	<0.5
GCA5027	4.6		6.8	8.3	120	-	<0.5
GCA5028	4.6		5.7	7.1	74	-	<0.5
GCA5028 (Repeat)	4.4		5.7	7.2	68	-	<0.5
GCA5031	4.3	Reaction peaked overnight	6.7	8.4	240	-	<0.5
GCA5032	4.0		5.4	7.1	98	-	<0.5
GCA5033	5.0	Reaction peaked within 20 minutes	6.4	6.5	120	0.30	<0.5
GCA5034	4.0		5.4	6.6	54	0.30	<0.5
GCA5039	4.4		4.9	5.8	68	0.40	<0.5
GCA5045	4.3	Reaction peaked overnight	4.5	5.4	73	0.60	0.7
GCA5046	5.9		3.2	4.4	180	2.90	2.5
Blank	4.1		5.4	7.7	61	-	<0.5

**Notes:** Test conditions based on those described by Miller *et al.* (1997). The pH of the 15 % (v/v) H<sub>2</sub>O<sub>2</sub> 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<sub>2</sub>O<sub>2</sub>. Then, after allowing the test mixtures to cool, 1.0 mL of 0.016 M-CuSO<sub>4</sub> 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<sub>2</sub>O<sub>2</sub> 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**  
**5<sup>th</sup> December 2003**

## 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 <sub>2</sub> SO <sub>4</sub> /tonne)
				pH	EC (µS/cm)		
GCA5030	4.9	Reaction peaked within 4 hrs	4.3	6.1	490	0.40	<0.5
GCA5030 (Repeat)	6.0	Reaction peaked within 4 hrs	4.5	6.2	570	0.50	<0.5
Blank	3.2		5.6	7.3	71	-	<0.5

**Notes:** Test conditions based on those described by Miller *et al.* (1997). The pH of the 15 % (v/v) H<sub>2</sub>O<sub>2</sub> 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<sub>2</sub>O<sub>2</sub>. Then, after allowing the test mixtures to cool, 1.0 mL of 0.016 M-CuSO<sub>4</sub> 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<sub>2</sub>O<sub>2</sub> 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**  
**22nd January 2004**

pH-BUFFERING TESTWORK (GCA5025)

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H <sub>2</sub> SO <sub>4</sub> /tonne)	pH
0.00	0.0	9.4
0.40	2.0	8.8
0.80	3.9	8.4
1.20	5.9	8.2
1.60	7.8	8.1
2.00	9.8	7.9
2.40	12	7.8
2.80	14	7.7
3.20	16	7.7
3.60	18	7.6
4.00	20	7.5
4.40	22	7.4
4.80	24	7.4
5.20	25	7.3
5.60	27	7.2
6.00	29	7.1
6.40	31	7.0
6.80	33	6.8
7.20	35	6.7
7.60	37	6.6
8.00	39	6.5
8.40	41	6.3
8.80	43	6.2
9.20	45	6.0
9.60	47	5.8
10.00	49	5.6
10.40	51	5.4
10.80	53	5.2
11.20	55	5.0
11.60	57	4.8
12.00	59	4.7
12.40	61	4.5
12.80	63	4.3
13.20	65	4.1
13.60	67	4.0
14.00	69	3.8
14.40	71	3.7
14.80	73	3.6
15.20	74	3.5
15.60	76	3.4
16.00	78	3.3
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<sup>®</sup> 736 Titrino auto-titrator, and 0.05 M-H<sub>2</sub>SO<sub>4</sub>. 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 = -18 mV (pH=7.00); slope-point = 154 mV (pH=4.00); 96.4 % of Nernstian response for 25 °C.

Immediately following titration: pH=7.00 buffer read pH=7.02 and pH=4.00 buffer read pH=4.02. These discrepancies represent drift in pH-Glass electrode response during course of auto-titration.

**Dr GD Campbell**  
**20 November 2003**

pH-BUFFERING TESTWORK (GCA5027)

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H <sub>2</sub> SO <sub>4</sub> /tonne)	pH	Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H <sub>2</sub> SO <sub>4</sub> /tonne)	pH
0.00	0.0	9.3	14.40	71	3.5
0.40	2.0	8.6	14.80	73	3.4
0.80	3.9	8.3	15.20	74	3.3
1.20	5.9	8.1	15.60	76	3.2
1.60	7.8	7.9	16.00	78	3.1
2.00	9.8	7.8	16.40	80	3.1
2.40	12	7.7	16.80	82	3.0
2.80	14	7.6			
3.20	16	7.5			
3.60	18	7.5			
4.00	20	7.4			
4.40	22	7.3			
4.80	24	7.2			
5.20	25	7.2			
5.60	27	7.1			
6.00	29	7.0			
6.40	31	6.9			
6.80	33	6.8			
7.20	35	6.7			
7.60	37	6.6			
8.00	39	6.4			
8.40	41	6.3			
8.80	43	6.2			
9.20	45	6.0			
9.60	47	5.8			
10.00	49	5.7			
10.40	51	5.4			
10.80	53	5.2			
11.20	55	5.0			
11.60	57	4.8			
12.00	59	4.7			
12.40	61	4.4			
12.80	63	4.2			
13.20	65	4.0			
13.60	67	3.8			
14.00	69	3.7			

**Note:** Titration performed using a Metrohm<sup>®</sup> 736 Titrino auto-titrator, and 0.05 M-H<sub>2</sub>SO<sub>4</sub>. 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 = -20 mV (pH=7.00); slope-point = 152 mV (pH=4.00); 97.0 % of Nernstian response for 25 °C.

Immediately following titration: pH=7.00 buffer read pH=7.02 and pH=4.00 buffer read pH=4.04. These discrepancies represent drift in pH-Glass electrode response during course of auto-titration.

**Dr GD Campbell**  
**10 December 2003**

**pH-BUFFERING TESTWORK (GCA5031)**

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H <sub>2</sub> SO <sub>4</sub> /tonne)	pH	Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H <sub>2</sub> SO <sub>4</sub> /tonne)	pH
0.00	0.0	9.8	14.40	35	4.0
0.40	1.0	9.4	14.80	36	3.9
0.80	2.0	9.0	15.20	37	3.8
1.20	2.9	8.7	15.60	38	3.6
1.60	3.9	8.4	16.00	39	3.6
2.00	4.9	8.2	16.40	40	3.5
2.40	5.9	8.0	16.80	41	3.4
2.80	6.9	7.8	17.20	42	3.3
3.20	7.8	7.7	17.60	43	3.2
3.60	8.8	7.6	18.00	44	3.2
4.00	9.8	7.5	18.40	45	3.1
4.40	11	7.4	18.80	46	3.1
4.80	12	7.3	19.20	47	3.0
5.20	13	7.2			
5.60	14	7.1			
6.00	15	7.1			
6.40	16	7.0			
6.80	17	6.9			
7.20	18	6.8			
7.60	19	6.7			
8.00	20	6.6			
8.40	21	6.4			
8.80	22	6.2			
9.20	23	6.0			
9.60	24	5.8			
10.00	25	5.6			
10.40	25	5.4			
10.80	26	5.2			
11.20	27	5.1			
11.60	28	4.9			
12.00	29	4.8			
12.40	30	4.7			
12.80	31	4.5			
13.20	32	4.4			
13.60	33	4.3			
14.00	34	4.1			

**Note:** Titration performed using a Metrohm<sup>®</sup> 736 Titrino auto-titrator, and 0.05 M-H<sub>2</sub>SO<sub>4</sub>. Equilibration time between titrant additions was 15 minutes. 2.00 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 = -13 mV (pH=7.00); slope-point = 158 mV (pH=4.00); 96.5 % of Nernstian response for 25 °C.

Immediately following titration: pH=7.00 buffer read pH=7.01 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**  
**22 November 2003**

# ANALYTICAL REPORT

**Graeme CAMPBELL**  
**CAMPBELL, GRAEME and ASSOCIATES**  
 PO Box 247  
 BRIDGETOWN, W.A. 6255  
 AUSTRALIA

## JOB INFORMATION

JOB CODE : 143.0/0307353  
 No. of SAMPLES : 30  
 No. of ELEMENTS : 1  
 CLIENT O/N : GCA0333  
 SAMPLE SUBMISSION No. :  
 PROJECT :  
 STATE : Solid  
 DATE RECEIVED : 03/12/2003  
 DATE COMPLETED : 11/12/2003  
 DATE PRINTED : 11/12/2003

## 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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 PO Box 144, Gosnells 6990, Western Australia  
 Tel: +61 8 9459 9011 Fax: +61 8 9459 5343  
 Email: [genalysis@genalysis.com.au](mailto:genalysis@genalysis.com.au)  
 Web Page: [www.genalysis.com.au](http://www.genalysis.com.au)

## KALGOORLIE SAMPLE PREPARATION DIVISION

12 Keogh Way, Kalgoorlie 6430, Western Australia  
 Tel: +61 8 9021 6057 Fax: +61 8 9021 3476

## ADELAIDE SAMPLE PREPARATION DIVISION

124 Mooringe Avenue, North Plympton 5037, South Australia  
 Tel: +61 8 8376 7122 Fax: +61 8 8376 7144



## 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.

# ANALYSIS

ELEMENTS C  
UNITS %  
DETECTION 0.01  
DIGEST  
ANALYTICAL FINISH /LECO

## SAMPLE NUMBERS

---

0001 GCA5017	0.44
0002 GCA5018	0.03
0003 GCA5019	0.04
0004 GCA5020	0.04
0005 GCA5021	0.05

---

0006 GCA5022	0.25
0007 GCA5023	0.15
0008 GCA5024	0.16
0009 GCA5025	0.86
0010 GCA5026	0.22

---

0011 GCA5027	0.79
0012 GCA5028	0.11
0013 GCA5029	0.04
0014 GCA5030	0.67
0015 GCA5031	0.91

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0016 GCA5032	0.27
0017 GCA5033	0.08
0018 GCA5034	2.55
0019 GCA5035	1.06
0020 GCA5036	0.85

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0021 GCA5037	1.82
0022 GCA5038	1.78
0023 GCA5039	2.76
0024 GCA5040	1.69
0025 GCA5041	2.06

---

0026 GCA5042	1.50
0027 GCA5043	0.69
0028 GCA5044	0.80
0029 GCA5045	1.46
0030 GCA5046	0.14

---

## CHECKS

---

0001 GCA5017	0.44
0002 GCA5043	0.70

---

## STANDARDS

---

0001 LECO8	1.22
0002 MA-1b	2.44

---

# ANALYSIS

ELEMENTS	C
UNITS	%
DETECTION	0.01
DIGEST	
ANALYTICAL FINISH	/LECO
BLANKS	
0001 Control Blank	0.02

---

## METHOD CODE DESCRIPTION

### /LECO

No digestion or other pre-treatment undertaken. Analysed by LECO furnace.

# ANALYTICAL REPORT

**Graeme CAMPBELL**  
**CAMPBELL, GRAEME and ASSOCIATES**  
 PO Box 247  
 BRIDGETOWN, W.A. 6255  
 AUSTRALIA

## JOB INFORMATION

JOB CODE : 143.0/0307485  
 No. of SAMPLES : 12  
 No. of ELEMENTS : 32  
 CLIENT O/N : GCA0333  
 SAMPLE SUBMISSION No. :  
 PROJECT :  
 STATE : Ex-Pulp  
 DATE RECEIVED : 10/12/2003  
 DATE COMPLETED : 24/12/2003  
 DATE PRINTED : 24/12/2003

## 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

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## SAMPLE STORAGE DETAILS

### **GENERAL CONDITIONS**

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#### **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 Registration 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 12 samples, as listed in the report, were received as being waste rock materials.

The sample required drying at 45 degrees Celcius prior to being mixed and split to a 100g portion and then fine pulverised in a zirconia bowl.

Due to the presence of Carbon in the sample the material was roasted prior to determination according to standard methods of analysis.

The results included the assay of blanks and international reference standard SO-2 and Genalysis in-house standards TKC3, AE11 and HgSTD.

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

NATA Signatory: P Edmondson

Date: 24th December 2003

**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	RA/	RA/	RA/	RD/	RA/	RA/	RA/	RA/	RA/	RA/
ANALYTICAL FINISH	MS	OES	MS	OES	MS	MS	OES	MS	MS	OES
<b>SAMPLE NUMBERS</b>										
0001 GCA5034								0.3		
0002 GCA5035	7.3	5.82%	258	151	634.7	1.45	153	1.5	15.7	52
0003 GCA5036								0.1		
0004 GCA5037								0.4		
0005 GCA5038	6.8	6.55%	220	58	318.7	2.74	64	X	17.9	50
0006 GCA5039								0.2		
0007 GCA5040								X		
0008 GCA5041	5.1	4.74%	299	148	324.8	4.88	64	0.2	23.3	77
0009 GCA5042								0.3		
0010 GCA5043	4.3	9.69%	100	208	672.5	2.22	91	X	5.3	50
0011 GCA5044	83.1	9798	747	137	426.4	73.77	103	0.3	67.4	32
0012 GCA5045	163.1	2.00%	1132	165	775.5	16.64	96	2.0	19.0	40
<b>CHECKS</b>										
0001 GCA5034								0.3		
<b>STANDARDS</b>										
0001 AE11										
0002 HgSTD-3										
0003 SO-2										
0004 TKC3	13.9	6.07%	620		522.1	36.22	1.59%	6.2	159.8	1174
0005 TKC3				912						
<b>BLANKS</b>										
0001 Control Blank	X	X	X	X	0.1	0.01	X	X	X	2



# 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	RA/	DH/	RD/	AC/	RA/	RA/	RA/	RA/	RA/	RA/
ANALYTICAL FINISH	OES	SIE	OES	CVAP	OES	OES	OES	MS	OES	OES
<b>SAMPLE NUMBERS</b>										
0001 GCA5034	163									
0002 GCA5035	6150	700	1.94	8.15	2.53%	2929	73	3.3	1271	28
0003 GCA5036	2675									
0004 GCA5037	724									
0005 GCA5038	1570	388	0.55	1.18	2.90%	998	29	3.0	1872	43
0006 GCA5039	707									
0007 GCA5040	1520									
0008 GCA5041	4914	600	2.24	2.34	2.10%	2250	62	6.5	921	46
0009 GCA5042	1197									
0010 GCA5043	1192	980	1.32	3.74	4.22%	3101	113	7.7	1933	12
0011 GCA5044	4795	160	4.32	9.03	3849	629	83	3.7	869	43
0012 GCA5045	8767	250	8.43	6.22	3375	601	91	27.5	580	31

**CHECKS**

0001 GCA5034	163									
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**STANDARDS**

0001 AE11										
0002 HgSTD-3				0.28						
0003 SO-2		498								
0004 TKC3	2495				1.26%	1.60%	1956	57.4	1.62%	2092
0005 TKC3			9.22							

**BLANKS**

0001 Control Blank	1	X	0.01	X	X	X	X	X	X	2
--------------------	---	---	------	---	---	---	---	---	---	---

**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	RA/	RA/	RA/	RA/	BP/	RA/	RA/	RA/	RA/	RA/
ANALYTICAL FINISH	OES	MS	OES	MS	MS	MS	MS	MS	MS	MS
<b>SAMPLE NUMBERS</b>										
0001 GCA5034		747								
0002 GCA5035	81	2037	4041	20.93	3.49	2.9	21.14	11.71	4.97	4.25
0003 GCA5036		328								
0004 GCA5037		620								
0005 GCA5038	223	1473	7066	23.67	1.77	2.5	60.13	17.24	2.50	4.30
0006 GCA5039		1448								
0007 GCA5040		1395								
0008 GCA5041	217	1907	6782	20.16	3.91	2.9	35.80	11.10	7.36	3.39
0009 GCA5042		2161								
0010 GCA5043	358	2610	1.39%	15.90	1.67	4.7	126.85	20.41	1.74	6.78
0011 GCA5044	152	4895	5826	121.57	5.00	3.1	29.79	8.70	6.19	3.49
0012 GCA5045	231	4169	2986	216.39	3.18	2.8	61.98	15.77	0.64	8.54

**CHECKS**

0001 GCA5034		803								
--------------	--	-----	--	--	--	--	--	--	--	--

**STANDARDS**

0001 AE11					0.55					
0002 HgSTD-3										
0003 SO-2										
0004 TKC3	1353	2646	1.17%	190.27		5.7	490.98	122.01	24.63	18.89
0005 TKC3										

**BLANKS**

0001 Control Blank	X	X	X	X	X	0.2	X	X	X	X
--------------------	---	---	---	---	---	-----	---	---	---	---

## ANALYSIS

ELEMENTS	V	Zn
UNITS	ppm	ppm
DETECTION	2	1
DIGEST	RA/	RA/
ANALYTICAL FINISH	OES	OES

### SAMPLE NUMBERS

---

0001 GCA5034		208
0002 GCA5035	95	980
0003 GCA5036		42
0004 GCA5037		260
0005 GCA5038	147	88

---

0006 GCA5039		181
0007 GCA5040		40
0008 GCA5041	81	218
0009 GCA5042		402
0010 GCA5043	128	388

---

0011 GCA5044	17	159
0012 GCA5045	22	1491

---

### CHECKS

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0001 GCA5034		207
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---

### STANDARDS

---

0001 AE11		
0002 HgSTD-3		
0003 SO-2		
0004 TKC3	269	1456
0005 TKC3		

---

### BLANKS

---

0001 Control Blank	X	X
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## METHOD CODE DESCRIPTION

### **BP/MS**

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

### **RA/MS**

Pre-Roast(Ashing) followed by a multi-acid digest including Hydrofluoric, Nitric, Perchloric and Hydrochloric acids. Analysed by Inductively Coupled Plasma Mass Spectrometry.

### **DH/SIE**

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

### **RA/OES**

Pre-Roast(Ashing) followed by a multi-acid digest including Hydrofluoric, Nitric, Perchloric and Hydrochloric acids. Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.

### **RD/OES**

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

### **AC/CVAP**

Mixed acid digest specific for Mercury in plant material and soils. Analysed by Cold Vapour Generation Atomic Absorption Spectrometry.

# ANALYTICAL REPORT

**Graeme CAMPBELL**  
**CAMPBELL, GRAEME and ASSOCIATES**  
 PO Box 247  
 BRIDGETOWN, W.A. 6255  
 AUSTRALIA

## JOB INFORMATION

JOB CODE : 143.0/0307487  
 No. of SAMPLES : 18  
 No. of ELEMENTS : 32  
 CLIENT O/N : GCA0333  
 SAMPLE SUBMISSION No. :  
 PROJECT :  
 STATE : Ex-Pulp  
 DATE RECEIVED : 10/12/2003  
 DATE COMPLETED : 24/12/2003  
 DATE PRINTED : 24/12/2003

## 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

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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 Registration 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 18 samples, as listed in the report, were received as being waste rock materials.

The sample required drying at 45 degrees Celcius prior to being mixed and split to a 100g portion and then fine pulverised in a zirconia bowl.

The results were determined according to standard methods of analysis.

The results included the assay of blanks and international reference standards SY-4 and SO-2 and Genalysis in-house standards TKC3, AE11 and HgSTD.

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

NATA Signatory: P Edmondson

Date: 24th December 2003

# 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
<b>SAMPLE NUMBERS</b>										
0001 GCA5017	0.2	8.47%	8	59	195.0	0.61	5434	0.3	46.8	209
0002 GCA5018	0.2	9.90%	7	X	118.5	0.10	1.36%	0.4	37.3	265
0003 GCA5019								0.3		
0004 GCA5020								0.3		
0005 GCA5021								0.3		
0006 GCA5022								0.2		
0007 GCA5023								0.5		
0008 GCA5024								0.6		
0009 GCA5025	0.4	6.58%	4	X	48.5	0.53	3.65%	0.6	111.5	83
0010 GCA5026								0.3		
0011 GCA5027								0.3		
0012 GCA5028	0.1	7.79%	5	53	241.8	0.59	1095	0.3	56.8	32
0013 GCA5029	0.5	6.86%	3	X	40.8	0.16	452	0.3	83.1	212
0014 GCA5030	1.4	7.53%	16	X	182.4	1.07	7348	3.8	85.1	85
0015 GCA5031	0.3	8.90%	88	154	333.1	3.86	1.36%	0.3	23.9	190
0016 GCA5032	0.2	7.22%	39	124	709.7	0.51	156	0.3	4.3	98
0017 GCA5033								0.3		
0018 GCA5046	47.5	6.26%	260	121	595.5	1.39	56	0.3	4.5	85
<b>CHECKS</b>										
0001 GCA5017	1.1	8.53%	6	X	187.2	0.58	5558	0.4	42.8	205
<b>STANDARDS</b>										
0001 AE11										
0002 HgSTD-3										
0003 SO-3										
0004 SY-4	0.5	10.16%	X		333.1	0.18	5.49%	1.3	3.0	8
0005 WGB-1				257						
<b>BLANKS</b>										
0001 Control Blank	X	X	X	X	0.1	X	X	0.1	X	2



# 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
<b>SAMPLE NUMBERS</b>										
0001 GCA5017	834	199	7.28	0.05	1.10%	1.70%	262	2.8	9311	196
0002 GCA5018	22	200	5.69	0.02	9933	3.22%	606	2.0	1.13%	221
0003 GCA5019	32									
0004 GCA5020	225									
0005 GCA5021	961									
0006 GCA5022	37									
0007 GCA5023	852									
0008 GCA5024	819									
0009 GCA5025	604	250	16.88	X	3523	3.41%	1068	0.8	4419	133
0010 GCA5026	630									
0011 GCA5027	78									
0012 GCA5028	837	200	5.35	X	1.92%	1.52%	398	1.1	1.05%	50
0013 GCA5029	2935	150	13.20	0.02	2000	4.94%	803	0.5	585	155
0014 GCA5030	3186	270	10.13	0.18	1.08%	3.92%	1827	2.7	1.26%	145
0015 GCA5031	250	386	7.40	0.01	9539	1.07%	155	6.4	5077	85
0016 GCA5032	88	860	2.06	0.03	2.89%	3898	98	3.2	1416	29
0017 GCA5033	324									
0018 GCA5046	5815	887	1.22	0.45	2.48%	2926	33	3.8	1534	18
<b>CHECKS</b>										
0001 GCA5017	824	218	7.44	0.05	1.12%	1.68%	258	2.4	9427	192
<b>STANDARDS</b>										
0001 AE11										
0002 HgSTD-3				0.31						
0003 SO-3		338								
0004 SY-4	8				1.37%	3149	798	1.3	5.09%	10
0005 WGB-1			4.81							
<b>BLANKS</b>										
0001 Control Blank	X	X	0.02	X	X	X	X	0.1	X	2

**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
<b>SAMPLE NUMBERS</b>										
0001 GCA5017	177	101	670	0.63	1.10	1.5	46.20	5.47	0.19	1.25
0002 GCA5018	427	3	111	0.43	0.04	1.1	62.05	4.16	0.13	1.24
0003 GCA5019		4								
0004 GCA5020		6								
0005 GCA5021		15								
0006 GCA5022		4								
0007 GCA5023		35								
0008 GCA5024		38								
0009 GCA5025	309	13	1.68%	0.31	0.70	9.1	53.47	1.89	0.18	0.96
0010 GCA5026		6								
0011 GCA5027		3								
0012 GCA5028	262	27	85	0.18	0.23	1.3	33.70	2.94	0.14	0.93
0013 GCA5029	111	25	2376	0.18	0.24	0.8	33.67	2.37	X	0.95
0014 GCA5030	428	554	1.60%	0.33	0.33	1.8	17.01	3.14	0.40	1.51
0015 GCA5031	98	312	436	8.81	1.42	1.9	98.68	27.79	0.41	4.01
0016 GCA5032	97	216	2047	2.51	0.33	2.7	67.59	16.07	0.70	3.69
0017 GCA5033		2407								
0018 GCA5046	148	1.05%	4461	35.88	4.94	3.0	76.97	11.41	4.48	6.12
<b>CHECKS</b>										
0001 GCA5017	184	99	639	0.50	0.97	1.4	41.93	5.16	0.19	1.15
<b>STANDARDS</b>										
0001 AE11					0.54					
0002 HgSTD-3										
0003 SO-3										
0004 SY-4	609	14	146	0.10		8.0	1202.94	1.29	1.27	0.80
0005 WGB-1										
<b>BLANKS</b>										
0001 Control Blank	X	X	X	X	X	0.1	0.07	0.02	X	X

## ANALYSIS

ELEMENTS	V	Zn
UNITS	ppm	ppm
DETECTION	2	1
DIGEST	A/	A/
ANALYTICAL FINISH	OES	OES

### SAMPLE NUMBERS

0001 GCA5017	136	56
0002 GCA5018	149	44
0003 GCA5019		33
0004 GCA5020		62
0005 GCA5021		29
0006 GCA5022		19
0007 GCA5023		99
0008 GCA5024		104
0009 GCA5025	77	101
0010 GCA5026		53
0011 GCA5027		37
0012 GCA5028	69	35
0013 GCA5029	120	39
0014 GCA5030	77	815
0015 GCA5031	200	67
0016 GCA5032	143	69
0017 GCA5033		103
0018 GCA5046	90	478

### CHECKS

0001 GCA5017	137	55
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### STANDARDS

0001 AE11		
0002 HgSTD-3		
0003 SO-3		
0004 SY-4	6	95
0005 WGB-1		

### BLANKS

0001 Control Blank	X	2
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## 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.