IRON ORE COMPANY OF CANADA

2013 ARD Potential - Study and Analysis
Wabush 3 – EIA 2014 Supporting Documentation

LORAX ENVIRONMENTAL

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1. Introduction

Since the early 1960s the Iron Ore Company of Canada (IOC) has been operating the Carol Project in Labrador City, Labrador. IOC is the largest producer of iron ore in Canada, and a leading global supplier of iron ore pellets and concentrates. The current operations at the Carol Project consist of open pit mining, mineral processing facility (concentrator and pellet plant), tailings management facility, and transportation infrastructure. Iron pellets and concentrate are transported to its port facilities in Sept-Îles, Quebec via a 418 km railway.

The Carol Project facilities cover approximately 11,000 hectares, including five existing operating open pits:

- Luce;
- Sherwood;
- Humphrey Main;
- Humphrey South; and
- Lorraine South.

Future plans include reactivating one existing open pit (Spooks), and the proposed open pit mining of Wabush 3. IOC is in the process of assembling supporting documents to satisfy the Environmental Impact Statement (EIS) requirements for the proposed Wabush 3 mine development. As part of the supporting documents, IOC requires an evaluation of the acid rock drainage (ARD) potential of waste material from within the Wabush 3 open pit area. A total of 25 drill core samples from the Wabush 3 area were selected by IOC. These samples were selected to represent the range of lithologies with the highest acid rock drainage (ARD) potential within the Wabush 3 area. The following discussion presents the static test results for the 25 Wabush 3 samples and compares the results with existing static test results for waste rock from existing and previously operating pits within the Carol Project area.

Following this introduction, Chapter 2 provides an overview of the regional geology, Wabush 3 mine area geology, in addition to sample selection and methodology. Chapter 3 discusses the static test results for the samples obtained for the Wabush 3 drill core samples. The results are also compared with static test results for existing waste rock piles associated with existing and previous open pit operations at the Carol Project facility. Chapter 4 provides a summary of the salient results with recommendations.

2. Background

2.1 Regional Geology

The Iron Ore Company of Canada (IOC) mining property is located within the Lower Proterozoic iron formations of the Knob Lake Group. The Knob Lake Group is a continental margin meta-sedimentary sequence comprised of pelitic schists, iron formations, quartzite, dolomitic marble, semi-pelitic gneiss and subordinate, local mafic volcanics. The Knob Lake Group includes six formations: the Attikamagen; the Denault, the Mackay River; the Wishart; the Sokoman; and the Menihek Formation. These formations occur along a northeast trending belt. The sequence has experienced deformation that subjected the Knob Lake Group to metamorphism from greenshcist to upper amphibolite facies.

2.1.1 Attikamagen Formation

The Attikamagen Formation, the oldest stratigraphic unit, is a meta-sedimentary rock sequence within the Knob Lake Group. The formation unconformably overlies the Archean Ashuanipi Metamorphic Complex. The Attikamagen Formation is predominantly comprised of brownish to creamy coloured banded, medium to coarse grained quartz-feldspar-biotite-muscovite schist and minor gneiss. Accessory minerals include chlorite, garnet, kyanite and calcite.

2.1.2 Denault Formation

The Denault Formation conformably overlies the Attikamagen Formation. It consists of coarse grained, banded, dolomitic and calcitic marble up to 75m thick with minor tremolite, quartz, diopside and phlogopite as accessory minerals. The Denault Formations has been primarily identified as occurring to the east and south of Wabush Lake. This dolomitic/calcitic marble formations represents a transition between the shallow and deeper parts of the continental shelf. Within the Denault Formation stromatolites have been described to the south of Wabush Mines. The Formation can be sub-divided into three sub-units consisting of the lower siliceous horizon, the middle low silica (<5% SiO2) horizon and the upper siliceous horizon. The middle low silica horizon is mined for the purposes of producing iron pellets.

2.1.3 Mackay River Formation

The Mackay River Formation overlies the Denault Formation and is typically composed of aqueous metatuffaceous sediments and conglomerate units. The Mackay River Formation is not present in the general area of IOC's property, however it is found northeast of Shabogamo Lake.

2.1.4 Wishart Formation

The Wishart Formation overlies the Denault Formation and in some area unconformably overlies the Attikamagen Formation. The Wishart Formation consists of a 60 - 90 m thick sequence of white, massive to foliated quartzite, which is typically resistant to weathering and erosion. In the Wabush Lake Region the prominent hills are a result of the Wishart Formation resistance to weathering. The Wishart Fm. can be subdivided into the Lower, Middle and the Upper Members based on compositional and textural variations.

The Lower Member includes white to reddish brown, quartz-muscovite schist with varying percentage of garnet and kyanite.

The Middle Member is a coarsely crystalline ortho-quartzite that is generally massive to banded. Accessory minerals include carbonates, amphiboles (varying from tremolite and/or anthophyllite to grunerite and/or cummingtonite), garnets, micas (muscovite, sericite and biotite) and chlorite. Bands of iron-rich carbonates or their weathered products, limonite and goethite, may also occur.

The Upper Member exhibits a gradational contact with the overlying Sokoman Formation. It generally consists of bands of carbonate alternating with bands of quartzite with thin layers of muscovite and biotite schist (pelitic layers). Accessory minerals include grunerite, garnets, kyanite and staurolite.

2.1.5 Sokoman Formation

The Sokoman Formation, or Wabush Iron Formation, is the iron ore-bearing formation in the Wabush Lake-Mount Wright area. The formation conformably overlies the Wishart Formation, however where the Wishart Formation is not present the Sokoman shares its basal contact with the Denault, Mackay Lake, and the Attikamagen Formations. The Sokoman Formation is sub-divided into Lower, Middle and Upper Members. Hydrous iron oxides, limonite and/or goethite have been observed in all members of the Sokoman Formation. Limonite and/or goethite are present in weathered and fractured zones. Pyrolusite (MnO_2) may occur in a distinct zone at the base of the Middle Member but has also been observed in all members of the Sokoman Formation typically associated with surficial or supergene enrichment, extending to depth along and adjacent to fault and fractured zones.

The Lower Member or LIF consists of a 0 - 50 m thick sequence of fine to coarse grained banded quartz-carbonate, and/or quartz-carbonate-magnetite, and/or quartz-carbonate (*i.e.*, siderite, ankerite and ferro-dolomite)-silicate (grunerite, cummingtonite, actinolite, garnets), and/or quartz-carbonate-silicate-magnetite, and/or quartz-magnetite-specularite units. This member generally contains an oxide band up to 10 metres thick near the upper portion. This oxide zone has a typically high manganese content (>1% Mn)

The Middle Member or MIF, forms the principal iron ore unit, consists of a 45 - 110 m thick sequence of quartz-magnetite, and/or quartz-specularite-magnetite, and/or quartz-specularite-magnetite-carbonate, and/or quartz-specularite-magnetite-anthophyllite gneiss and schist units. Actinolite and grunerite rich bands can be present in this member though are generally attributed to in-folding of the upper member. A vertical zonation is typically present with finer grained quartz magnetite dominated iron formation forming the basal section. A higher manganese content (rhodochrosite and pyrolucite) ranging from 0.4 – 1.0% Mn is associated with this zone. Martite may also occur in weathered zones by supergene alteration of magnetite. The upper portion of the Middle Iron Formation horizon is predominantly comprised of coarser grained quartz hematite iron formation with low manganese content (<0.4% Mn).

The Upper Member or UIF consists of a 45 – 75 m thick sequence similar in composition to the Lower Member and can generally be differentiated through contact relationships with the overlying and underlying formations and the presence of increased grunerite or actinolite. A magnetite rich zone may be present in the lower portion of this member.

2.1.6 Menihek Formation

The Menihek Formation is the youngest formation of the Knob Lake Group. It consists of a 15-75 m thick sequence of pelitic sediments. The Menihek Formation is commonly fine grained, foliated with some interspersed quartz-feldspar-mica (biotite-muscovite)-graphite schist. Garnets, epidote, chlorite and carbonates are accessory minerals. This unit is well preserved adjacent to the craton in the southern region, and within broad synclinal regions in the north.

2.2 Wabush 3 Mine Area

The Wabush 3 mine area is situated to the south of, and adjacent to, the operating Luce Mine and to the west of, and adjacent to, the Smokey Mountain ski hill and sections of the Nordic ski trails. Economically viable mineral resources are estimated at 800 million tonnes and predicted waste rock mass of 450 million tonnes (IOC, 2013). Production is expected at the rate of approximately 23 million tonnes per year over a 40 year mine life. Based on the EA Registration (IOC, 2013) the project will consist of the following components:

- An open pit mine which contains an estimated 800 M tonnes of iron ore and has an estimated operating life of 40 years. This could vary significantly, depending on the actual mining rate;
- An overburden storage area to the south of the open pit and dissected by an existing gravel road which also dissects the open pit footprint;
- A waste rock disposal site, adjacent to and northwest of the open pit;
- A haulage road to the northeast of the open pit, linking the open pit with existing ore conveyor and concentrator facilities;
- A haulage road to the west of the open pit, connecting the open pit to the waste rock storage pile;
- A haulage road to the south of the open pit, connecting the open pit to the overburden storage area;
- A pole line to twin the haulage road to the northeast of the open pit;
- A groundwater extraction system; and
- A mine water collection, treatment and disposal system.

The overall Wabush 3 Project area encompasses approximately 464 ha, this includes the pit area, waste rock disposal area, overburden storage area and haulage roads. The Project will be developed in four phases:

- ***Phase 1 (Years 2 to 16):*** Construction of the haulage roads, clearing and use of the waste rock disposal site and overburden storage area, overburden and waste rock removal in the northern section of the pit, and mining of the northern section.
- ***Phase 2 (Years 17 to 28):*** Extension of the pit into the central section with overburden clearing, waste rock removal, and mining in the northern and central sections.
- ***Phase 3 (Year 29 to 40):*** Extension of the pit into the southern section with overburden clearing, waste rock removal, and mining in all sections.
- ***Phase 4 (after year 40):*** Site closure and rehabilitation will occur after completion of the mining activity. The IOC site Closure Plan will be amended to include the Wabush 3 operation.

2.2.1 Local Geology

The following provides an overview of the salient geology for the project area. The IOC Carol Project is located within in the Knob Lake Group, which is within the Lower

Proterozoic iron formations. The Knob Lake Group is a continental margin meta-sedimentary sequence comprised of pelitic schists, iron formations, quartzite, dolomitic marble, semi-pelitic gneiss and subordinate, local mafic volcanics. Deformation in the Knob Lake Group has resulted in a greenschist to upper amphibolite metamorphic facies. The Knob Lake Group includes six formations: the Attikamagen; the Denault, the Mackay River; the Wishart; the Sokoman; and the Menihek Formation (Table 2-1).

Table 2-1:
Bedrock geology of the Carol Lake Project, Stratigraphy Upwards

Formation		Primary Rock Types
Shabagomo		Metagabbro gneiss dykes and sills with lesser amphibolite schist
Menihek		Youngest formation of Knob Lake Group comprising mainly quartz-feldspar-mica-graphite schist
Sokomon (previously Wabush)	Upper Iron Ore Fm (UIF)	Light brown/white quartz-carbonate (siderite) gneiss with variable amounts of magnetite, hematite, grunerite, tremolite, and actinolite
	Middle Iron Ore Fm (MIF)	Quartz-magnetite, and/or quartz-specular hematite-magnetite, and/or quartz-specular hematite-magnetite-carbonate, and/or quartz-specular hematitite-magnetite-anthophyllite gneiss and schist units
	Lower Iron Ore Fm (LIF)	Light brown/white quartz-carbonate (siderite) gneiss with variable amounts of magnetite, hematite, grunerite, tremolite, and actinolite-quartz-carbonate, and/or quartz-carbonate- magnetite, and/or quartz-carbonate-silicate, and/or quartz- carbonate-silicate-magnetite, and/or quartz-magnetite- specular hematite units
Wishart (previously Carol)		White massive to foliated quartzite
Attikamagen (previously Katsao)		The oldest formation of the Knob Lake Group comprising medium to coarse grained quartz-feldspar-biotite-muscovite schist and lesser gneiss

The Wabush 3 mine area is typical of the IOC Carol Project, with the exception of that the Gabbro at Wabush 3 is present as a massive unit rather than as dykes and sill. It is located within a rugged topography with rolling hills and valleys. The topography of the area is characterized by the outcropping of quartzite from the Wishart Formation. The quartzite is particularly resistant to erosion and consequently forms much of the high ground. The Sokomon Formation is surrounded by the Wishart Formation outcrop as part of a large, kilometer-scale non-cylindrical synclinal structure with an approximate axial trace striking northeast-southwest and a hinge line that plunges towards the southwest. Consequently, most of the proposed Wabush 3 open pit is bounded by the Wishart Formation, the main exception being the southwest side of the proposed open pit towards Leg Lake

2.3 Previous Geochemical Studies

Previous geochemical studies for the Carol Lake Project have included the following reports:

- Preliminary Acid Rock Drainage / Metal Leaching Report. April 2006. Prepared by Lorax Environmental Services for Iron Ore Comapany of Canada.
- Acid Rock Drainage Characterization and Assessment. February 2007. Prepared by Lorax Environmental Services for Iron Ore Company of Canada.
- Waste Rock and Tailings Kinetic Test Results. October 2008. Prepared by Lorax Environmental Services for Iron Ore Company of Canada.
- Exploration ML/ARD Study. Samples ARD00001 to ARD00022. November 2008. Prepared by Lorax Environmental Services for Iron Ore Company of Canada.
- Exploration ML/ARD Study. Samples ARD00023 to ARD00028. November 2010. Prepared by Lorax Environmental Services for Iron Ore Company of Canada.

Previous ML/ARD studies have demonstrated that waste rock material within the Carol Lake Project area have total S, sulphate S, and sulphide S concentrations that are near or below the analytical detection limit. Neutralization potential (NP) ranged from low to high. Therefore, the bulk of the waste rock was concluded to be non-potentially acid generating (non-PAG). Of importance to note, Lorax (2008) presented samples from within the Wabush 3 mine area as part of exploration ARD sampling. These samples included ARD00013 to ARD00022.

Kinetic testing of waste rock types (Quartz Carbonate, Hornblende Schist, and Limonite) indicated these units have sufficient neutralization potential to buffer acid generating reactions, as evinced by the neutral leachate pH during testing. Sulphide oxidation rates during testing were low and generally below the method detection limit, therefore indicating the lack of acid generating reactions. In general for metal mines, metals such as Cd, Cu, Cr, Pb, Ni, and Zn can be elevated. However, with respect to the waste rock humidity cells from the Carol Lake Project area metal release rates were also typically low. Arsenic concentrations were noted as being elevated in leachate chemistry.

3. Geochemical Characterization

The following section discusses the selection of Wabush 3 samples, an overview of static testing used in developing geochemical characterization, the geochemical results for Wabush 3 samples, and a comparison with geochemical results from previous investigations.

3.1 Sample Selection

Sample selection was carried out by IOC geologists. Samples were selected based on assay results using criteria of high total S content and low calculated carbonate mineral content. The sample selection was carried out such that intervals with an expected elevated ARD potential were targeted. The result was an estimate of the acid potential (AP) and carbonate neutralization potential (NP). Intervals of approximately 16 meters in length were selected from drill core. Table 3-1 presents a list of ARD samples selected with drill hole IDs and intervals. Drill core locations are presented in Table 3-1.

3.2 Laboratory Methods

The following section describes laboratory analysis techniques for Wabush 3 waste rock material. Samples were shipped by IOC to SGS, Burnaby for sample preparation and analysis. Analyses and result for the static testing are discussed in this report.

3.2.1 Sample Preparation

At SGS, the sample portion used for acid rock drainage characterization were crushed in a jaw crusher to approximately 80% passing ¼ inch. Each sample was mixed by passing through a ½ inch splitter box and recombining. A 200 g split was then made and pulverized in a ring pulverizer to 80% passing 200 mesh. Splits of the pulverized samples were then submitted for analysis.

3.2.2 Sample Analysis

3.2.2.1 Paste pH

Paste pH was conducted according to the procedure by Sobek A., *et al*. 1978 “Field and Laboratory Methods Applicable to Overburdens and Minesoils” (Report EPA-600/2-78-054).

Table 3-1:
Wabush 3 ABA Results

Sample ID	Hole	Interval		Unit	Weight	Rock Type
		From (m)	To (m)		(kg)	
W3-ARD-001	W3-10-26	199	216	52	8.82	Quartz-magnetite-grunerite gneiss
W3-ARD-002	W3-10-27	80	91	40	6.38	Quartz-carbonate-gneiss
W3-ARD-003	W3-10-28	205	220	52	6.5	Quartz-magnetite-grunerite gneiss
W3-ARD-004	W3-10-30	4	20	62	3.32	Quartz-specularite Schist
W3-ARD-005	W3-10-30	20	37	62	3.94	Quartz-specularite Schist
W3-ARD-006	W3-10-30	55	70	81	8.06	Metagabbro
W3-ARD-007	W3-10-30	190	206	61	5.46	Quartz-magnetite-specularite
W3-ARD-008	W3010-30	206	224	61	5.52	Quartz-magnetite-specularite
W3-ARD-009	W3-10-30	259	276	80	7.18	Gabbro
W3-ARD-010	W3-10-31	3	19	81	8.66	Metagabbro
W3-ARD-011	W3-10-31	280	296	60	5.22	Quartz-magnetite
W3-ARD-012	W3-11-47	285	298	42/43	6.18	Quartz-(carbonate-grunerite)-gneiss/Quartz-grunerite-schist
W3-ARD-013	W3-11-51	164	172	43	6.7	Quartz-grunerite Schist
W3-ARD-014	W3-11-69	267	286	53	6.38	Quartz-magnetite-carbonate gneiss
W3-ARD-015	W3-12-113	43	29	60	9.8	Quartz-magnetite
W3-ARD-016	W3-12-114	18	34	61	6.04	Quartz-magnetite-specularite
W3-ARD-017	W3-12-136	2	15	80	4.8	Gabbro
W3-ARD-018	W3-12-150	59	71	62	4.54	Quartz-specularite Schist
W3-ARD-019	W3-12-152	198	214	62	5.7	Quartz-specularite Schist
W3-ARD-020	W3-12-153	21	37	62	6.34	Quartz-specularite Schist
W3-ARD-021	W3-12-153	101	120	62	5.74	Quartz-specularite Schist
W3-ARD-022	W3-12-154	239	255	82	5.76	Amphibolite: Hornblend-Biotite +/- Schist
W3-ARD-023	W3-12-155	59	72	32/40	5.7	Quartzite with accessory carbonate/Quartz-carbonate-gneiss
W3-ARD-024	W3-12-168	24	36	62	4.62	Quartz-specularite Schist
W3-ARD-025	W3-13-175	59	70	62	6.68	Quartz-specularite Schist

3.2.2.2 Acid-base Accounting

Acid base accounting (ABA) was conducting according to Method 3: Modification of Conventional EPA Neutralization Potential Determination by Addition of Hydrogen Peroxide. The procedure is outlined in MEND Project 1.16.1c, 1991.

3.2.2.3 Total Sulphur and Carbon

Total sulphur and carbon were determined by Acme Analytical Laboratories using a Leco furnace.

3.2.2.4 Inorganic Carbon

Total inorganic carbon was determined by Assayers Canada Ltd. In this procedure a known weight of sample is placed into a glass test tube and acidified with 25% hydrochloric acid.

The sample is boiled to evolve CO_2 which is measured by coulometric titration with the Carbon Dioxide Analyzer.

3.2.2.5 Sulphate-Sulphur

Sulphate-sulphur was determined by IPL Labs Ltd. by the procedure outlined in ASTM D2492-02, "Standard Test Method for Forms of Sulfur in Coal". In this procedure sulphate sulphur is dissolved with hydrochloric acid and measured gravimetrically after precipitation of barium chloride.

3.2.2.6 Sulphide-Sulphur

Sulphide-sulphur was also determined by IPL Labs Ltd. The residue from the sulphate-sulphur determination was leached with 1:7 nitric acid to water, according to the procedure by Sobek, 1978. The oxidized sulphide was then determined gravimetrically after precipitation with barium chloride.

3.2.2.7 Total Metals – Aqua Regia

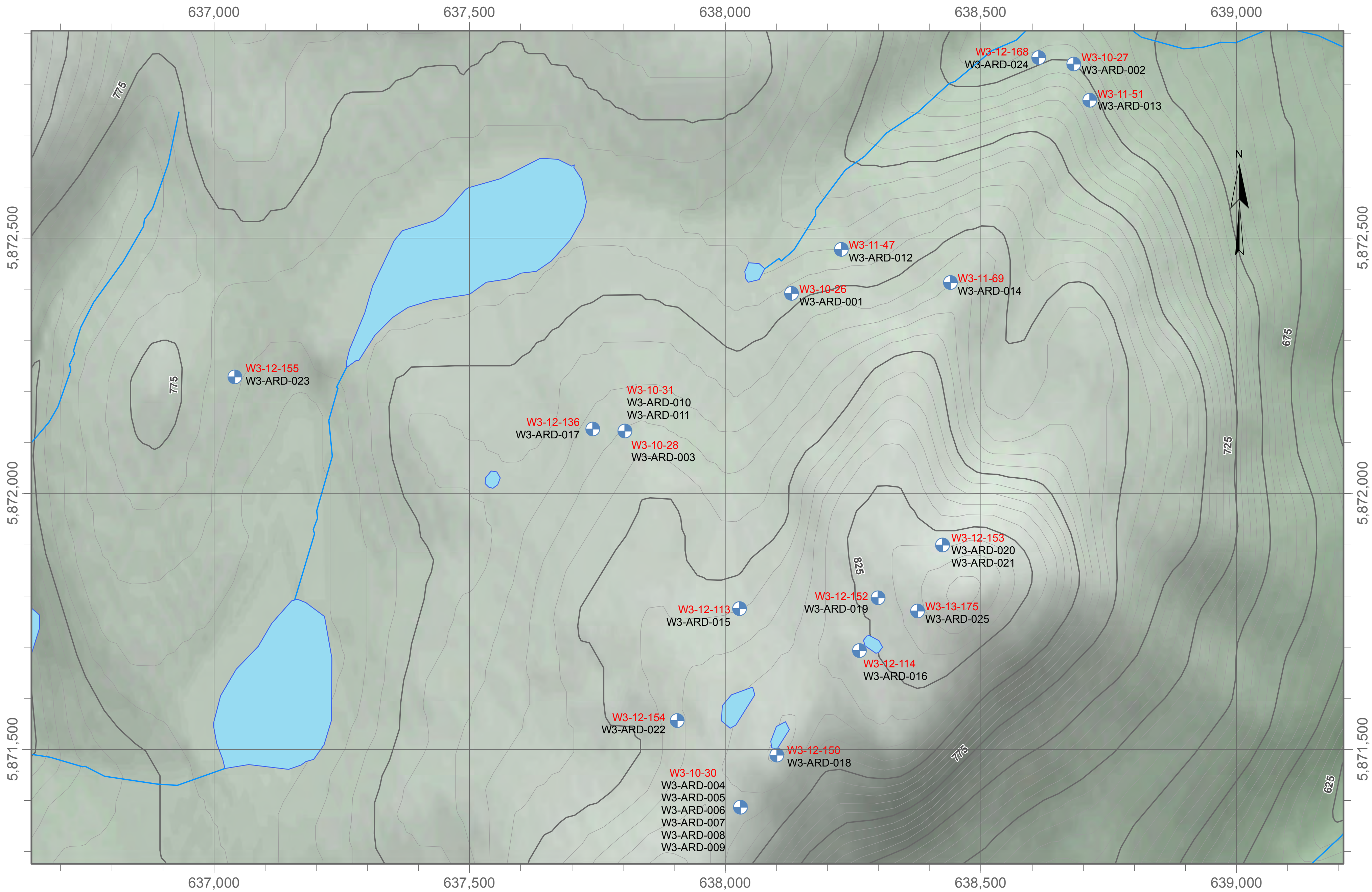
Total metals were conducted at Acme on the pulverized sample by digesting 0.500 g in aqua regia at $95^{o}C$ for one hour. The extract is then diluted to 10.0 mL and analysed for metals by ICP-MS.

3.3 Static Testing

This section provides an overview of the static test analysis completed for Wabush 3 waste rock samples, and previous waste rock samples for the Carol Project mine area. Static tests are used to develop geochemical characteristics of waste materials produced from mining activity. These tests assist in determining the nature of neutralization potential and the sulphur speciation. Consequently, the acid generation potential of waste rock materials can be determined using static test results. Static testing includes an assessment of the acid-base accounting and solid phase metals.

3.3.1 Paste pH

On its own, paste pH is not a predictor of the acid generation potential; however the paste pH can be used as a primary indicator of the presence of existing buffering capacity. The paste pH is governed by the carbonate mineral solubility and, hence, the neutralizing potential (NP) present. When the paste pH values are <5.5, the NP present is limited or non-existent. Conversely, higher paste pH values imply the presence of available NP.



Legend

- Drill Hole ID / Sample ID
- 25m elevation Contour
- 5m Elevation Contour

DATE SAVED:	Feb 19, 2014
DRAWN BY:	AL
REVIEWED:	JM
VERSION:	1

Coordinate System: NAD 1983 UTM Zone 19N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter

0 150 300 Meters

CLIENT: IOC IRON ORE COMPANY OF CANADA

LORAX ENVIRONMENTAL

PROJECT: **Wabush 3 ARD**

TITLE: Drill Hole & ARD Sample Locations

PROJECT #: A361

FIGURE: 3-1

P:\A361 (Wabush 3)\Drafting\MXD\Drill Hole and ARD Samples_20140219.mxd

3.3.2 Sulphur Species

Sulphur speciation is essential when determining the ARD potential as some sulphur species do not contribute to ARD. Sulphur may be present in mine rock as sulphide or pyritic S, sulphate S, and insoluble S. The insoluble S content is a calculated value and may represent either organic S species or incomplete digestion of sulphide S during analysis.

The potential for acid to be generated from mine rock is estimated from the acid potential (AP). Typically, ARD is the result of oxidation of sulphide bearing minerals, such as pyrite. Accordingly, the AP for mine waste material is typically calculated from the measured sulphide S content. However, when an appreciable concentration of insoluble S is present a conservative estimate of AP is calculated utilizing the total S content. This conservative approach assumes that the insoluble S estimate may represent an incomplete dissolution of sulphide minerals during the analytical process.

The sulphide oxidation reaction for pyrite is typically represented as (Equation 1):

$$Pyrite: \quad FeS_2 + {}^{15}\!/_{4}\, O_2 + {}^{7}\!/_{2}\, H_2O \Rightarrow Fe(OH)_3 + 2SO_4^{2-} + 4H^+$$

Thus, for each mole of sulphide-sulphur oxidized, 2 moles of acidity are produced. In the most simplistic scenario, when carbonate minerals are present the oxidation-neutralization reaction is pH-dependent. Assuming that calcium and sulphate are not lost to secondary mineral precipitation, two carbonate consumption reactions can describe this process. These reactions are represented below as Example 1 and Example 2:

(Example 1): at pH<6.3:

Pyrite (Equation 2)

$$FeS_2 + {}^{15}\!/_{4}\, O_2 + {}^{7}\!/_{2}\, H_2O + 2[Ca^{2+}, Mg^{2+}]CO_3 \longrightarrow Fe(OH)_3 + 2SO_4^{2-} + 2H_2CO_3^0 + 2[Ca^{2+}, Mg^{2+}]$$

(Example 2): at 6.3<pH<10.3:

Pyrite (Equation 3)

$$FeS_2 + {}^{15}\!/_{4}\, O_2 + {}^{7}\!/_{2}\, H_2O + 4[Ca^{2+}, Mg^{2+}]CO_3 \longrightarrow Fe(OH)_3 + 2SO_4^{2-} + 4HCO_3^- + 4[Ca^{2+}, Mg^{2+}]$$

3.3.3 Neutralization Potential

ML/ARD results when sulphidic mine waste material is subjected to weathering processes only if there is insufficient production of neutralizing alkalinity. The neutralization potential of weathering waste material depends on the buffering capacity of the minerals that dissolve when exposed to acidic conditions. Those minerals that act to buffer acid generating reactions are typically carbonate minerals (calcite, dolomite,.), although slower dissolving silicate and aluminosilicate minerals may also contribute to the measured neutralizing capacity. Carbonate mineral dissolution as a result of acid production reactions maintain the drainage water at circumneutral pH levels, whereas aluminosilicate and silicate mineral dissolution results maintains pH levels of drainage waters at or near a pH of 4.0. When carbonate minerals and aluminosilicate/silicate minerals are present, buffering reactions will preferentially dissolve the carbonate minerals until they are exhausted. Therefore, to maintain neutral drainage chemistry it is important that carbonate minerals are present in the waste rock.

While many carbonate dissolution reactions can be thought of as acid buffering reactions, the minerals generally responsible for acid neutralization are fast dissolving carbonates. The dissolution rate of some carbonate minerals, particularly Fe-bearing carbonate, are lower than the dissolution rates of calcite and are, therefore, less effective at buffering acid generating reactions. In addition, Fe-bearing carbonates liberate Fe^{2+} during dissolution reactions, the Fe^{2+} is oxidized to Fe^{3+}, which precipitates as $Fe(OH)_3$ liberating an H+ ion. The net capacity of a sample to neutralize acid decreases as the amount of Fe-bearing carbonate increases (Jambor *et al*., 2002).

Samples were analyzed for siderite corrected NP and carbonate NP (CaNP). Siderite corrected NP measurements are a non-mineral specific, relatively aggressive means of determining NP. This method of NP measurement removes the artifacts from the incomplete hydrolysis of Fe during the measurement. Samples are treated with hydrogen peroxide to oxidize ferrous iron produced via the dissolution of Fe-bearing carbonates during the Sobek NP analysis. NP from both carbonate minerals, such as calcite and dolomite, as well as the NP of silicate and aluminosilicate minerals, which have slower dissolution rates than carbonate minerals, are measured. Therefore, in some cases a sample may exhibit an appreciable amount of NP, but if the NP is primarily available as the slower dissolving silicates and or aluminosilicates then not all of the NP measured by this method may be available with high sulphide content and reactivity.

The CaNP is calculated from the amount of inorganic carbon in the sample:

$$CaNP\ (kg\ CaCO_3/t) = Inorganic\ C\ (\%) \times (100.09\ g/mol\ CaCO_3\ /\ 12.01\ g/mol\ C) \times 10$$

Inorganic carbon is measured via coulometry. This measurement assumes that all the carbon in a sample that is evolved as CO_2 during analysis was originally present as calcium carbonate ($CaCO_3$). Inorganic carbon is measured via coulometry. This measurement assumes that all the carbon in a sample that is evolved as CO_2 during analysis was originally present as calcium carbonate ($CaCO_3$).

3.3.4 Net Potential Ratio

The net potential ratio (NPR) is a measure of whether a sample will be potentially acid generating. The NPR compares the proportion of NP to acid potential (AP), and can be used over a wide range of AP and NP values. The NP used in developing the NPR is the siderite corrected NP, while the AP is conservatively estimated using the total S concentration.

The NPR is compared to criteria specified in the BC MEM regulatory guidelines (Price, 1997 and Price, 2009). The BC MEM regulatory guidelines have been utilized as acceptable criteria within British Columbia and across Canada. They are generally considered a basis for development of ML/ARD predictions. These guidelines, Table 3-2, indicate that a sample with NPR of less than 1.0 can be, theoretically considered as potentially acid generating (PAG). For a sample with a NPR between 1.0 and 2.0 there is a possibility of becoming acid generating, given that the NP is depleted at faster rates than the rate of sulphide oxidation or that if the buffering minerals are partially unavailable. NPR values between 2.0 and 4.0 indicate a low risk of acid drainage, while NPR values greater than 4.0 have no potential of ARD. For the purposes of this discussion samples with an NPR ≤ 2.0 are classified as PAG, while NPR > 2.0 are non-PAG or NAG.

Table 3-2:
Acid-Base Accounting (ABA) Screening Criteria (Price, 1997 and Price, 2009)

ARD Potential	Initial Screening Criteria (NPR)	Comments
Likely	< 1	Likely to be ARD generating unless sulphide minerals are unreactive.
Possibly	1 – 2	Possibly ARD generating if NP is insufficiently reactive or is depleted at a faster rate than sulphides.
Low	2 - 4	Not potentially ARD generating unless significant preferential exposure of sulphides along fracture planes, or extremely reactive sulphides in combination with insufficiently reactive NP.
None	> 4	No further ARD testing required unless materials are to be used as a source of alkalinity.

3.3.5 Solid Phase Metals Analysis

Solid phase metals concentrations are evaluated in order to identify metals that could potentially leach from mine waste materials when exposed to atmospheric conditions and precipitation. Metal concentrations are compared to average continental crustal abundance to yield metals that may be elevated in mine drainage. While a metal may be enriched in the solid phase relative to the crustal abundance, such enrichment does not necessarily indicate that the metal will become problematic in drainage waters. The leaching rate of metals is dependent on a series of factors in addition to solid phase concentrations. These factors include: the mineralogical associations, the geochemical stability of those minerals, and the geochemistry of the infiltrating waters. Consequently, whether a metal becomes problematic in drainage waters is dependent on the interrelationship of the variables discussed above. Solid phase metal concentrations are determined via ICP-MS metal scans on leachate derived from aqua-regia digestion of samples.

For this investigation solid phase metals results are compared to the average continental crustal abundance as presented in Price (1997). For the purposes of this assessment, a metal is considered elevated or enriched if the measured concentration is greater than three times the average continental crustal abundance.

3.4 Wabush 3 Static Test Results

The following discussion presents the geochemical characterization of Wabush 3 waste rock samples. The acid generation potential is evaluated and solid phase metals results are presented in comparison to average continental crustal abundances.

3.4.1 ABA

The paste pH ranges from 6.2 to 9.5, with a median of 8.3 (Table 3-3 and Figure 3-2). The circumneutral to alkaline paste pH indicates that Wabush 3 waste rock materials currently have sufficient NP available to buffer acid generating reactions.

Sulphur speciation analysis indicates that total S concentrations are typically low, <0.50 %, ranging from <0.010 to 0.42 (median total S = 0.095 %), Table 3-3. Each of sulphide S, sulphate S and insoluble S have median concentrations of 0.010 % (Table 3-3). The species of sulphur that typically drives acid production in metal leaching / acid rock drainage/metal-leaching (ML/ARD) systems is sulphide S. Un-oxidized mine waste with paste pH greater than 5.5 and sulphide S content less than 0.30 % are considered to have little ARD potential (Price, 1998). In general, Wabush 3 waste rock material have demonstrated circumneutral to slightly alkaline paste pH and sulphide S less than 0.30 %. Therefore, the Wabush 3 waste rock is not considered to be a risk of generating acidic drainage. Figure 3-3 demonstrates a comparison of sulphide S and total S. In general, each of the samples fall below the 1:1 total S:sulphide S line. Similarly, Figure 3-4 demonstrates a comparison of sulphate S and total S, while Figure 3-5 compares insoluble S with total S. As with sulphide S, samples fall below the 1:1 line. Therefore, for the majority of Wabush 3 samples, while the total S is primarily comprised of sulphide S, sulphate S and insoluble S are present in appreciable concentrations relative to the bulk concentration. For the purposes of this investigation a conservative approach has been taken, total S concentrations are used in calculating AP.

The siderite corrected NP ranges from 5.9 to 329 kg $CaCO_3$/t, median NP of 41 kg $CaCO_3$/t (Table 3-3). CaNP ranges from 0.83 to 665 kg $CaCO_3$/t, median CaNP of 10 kg $CaCO_3$/t (Table 3-3). Figure 3-6 presents a comparison of CaNP with siderite corrected NP. For samples with siderite correct NP greater than 50 kg $CaCO_3$/t the CaNP is typical greater than the siderite corrected NP. For samples with siderite correct NP less than 50 kg $CaCO_3$/t the CaNP is typical less than the siderite corrected NP. At higher NP Fe-bearing carbonates are present and therefore CaNP overestimates the acid buffering capacity of Wabush 3 waste rock. When carbonate minerals and aluminosilicate/silicate minerals are present, buffering reactions will preferentially dissolve the carbonate minerals until they are exhausted. Therefore, to maintain neutral drainage chemistry it is important that carbonate minerals are present in the waste rock. The exception is the presence of Fe bearing carbonates, such as siderite, as Fe-carbonates do not act to buffer acid generating reactions at neutral pH. To conservatively estimate NPR for Wabush 3, the lower NP of the CaNP and siderite corrected NP is used.

The NPR for Wabush 3 waste rock is presented in Table 3-3. As discussed above, a conservative approach has been taken to estimate NPR. NPR ranges from 0.27 to 1054, with a median of 5.3. In general the bulk Wabush 3 waste rock is classified as non-PAG, having NPR > 2.0 (Table 3-3 and Figure 3-7). A single Gabbro sample (W3-ARD-009) is classified as PAG, having NPR = 0.27. The total S of W3-ARD-009 is low, 0.16 %, and therefore the long-term acid generation potential of this sample is not considered to be a concern.

Table 3-3:
Wabush 3 ABA Results

Sample ID	Paste pH	TIC	S (T)	S (S^{2-})	S (SO_4)	S (Insol.)	CaNP	NP	AP	CaNPR	NPR	NPR**
	s.u.	%	%	%	%	%	kg $CaCO_3$/t	kg $CaCO_3$/t	kg $CaCO_3$/t	CaNP/AP	NP/AP	
W3-ARD-001	8.6	2.3	<0.010	<0.010	<0.010	<0.010	188	134	0.31	603	428	428
W3-ARD-002	8.3	8.0	<0.010	<0.010	<0.010	<0.010	665	329	0.31	2128	1054	1054
W3-ARD-003	9.1	0.88	<0.010	<0.010	0.020	<0.010	73	94	0.31	235	302	235
W3-ARD-004	7.4	0.020	<0.010	<0.010	0.010	<0.010	1.7	7.2	0.31	5.3	23	5.3
W3-ARD-005	6.7	<0.010	<0.010	<0.010	0.010	<0.010	0.83	5.9	0.31	2.7	19	2.7
W3-ARD-006	8.6	0.10	0.12	0.020	<0.010	0.10	8.3	46	3.8	2.2	12	2.2
W3-ARD-007	8.9	0.26	<0.010	<0.010	<0.010	<0.010	22	52	0.31	69	166	69
W3-ARD-008	8.9	0.34	<0.010	<0.010	<0.010	<0.010	28	33	0.31	91	107	91
W3-ARD-009	9.5	0.020	0.20	0.040	<0.010	0.16	1.7	29	6.3	0.27	4.6	0.27
W3-ARD-010	9.1	0.24	0.11	0.050	<0.010	0.060	20	52	3.4	5.8	15	5.8
W3-ARD-011	8.5	1.3	<0.010	<0.010	<0.010	<0.010	104	93	0.31	333	298	298
W3-ARD-012	8.3	3.7	0.30	<0.010	<0.010	0.30	308	164	9.4	33	17	17
W3-ARD-013	7.7	1.5	0.41	0.21	<0.010	0.20	128	114	13	10.0	8.9	8.9
W3-ARD-014	8.5	2.0	0.020	<0.010	<0.010	0.020	166	138	0.63	265	220	220
W3-ARD-015	8.6	0.35	<0.010	<0.010	0.010	<0.010	29	32	0.31	93	101	93
W3-ARD-016	7.4	0.050	<0.010	<0.010	0.010	<0.010	4.2	9.2	0.31	13	29	13
W3-ARD-017	9.2	0.11	0.11	<0.010	<0.010	0.11	9.2	48	3.4	2.7	14	2.7
W3-ARD-018	6.9	<0.010	<0.010	<0.010	<0.010	<0.010	0.83	5.9	0.31	2.7	19	2.7
W3-ARD-019	6.4	<0.010	<0.010	<0.010	0.010	<0.010	0.83	8.4	0.31	2.7	27	2.7
W3-ARD-020	6.2	<0.010	<0.010	<0.010	<0.010	<0.010	0.83	6.6	0.31	2.7	21	2.7
W3-ARD-021	6.4	<0.010	<0.010	<0.010	<0.010	<0.010	0.83	6.6	0.31	2.7	21	2.7
W3-ARD-022	9.4	0.12	0.080	0.060	<0.010	0.020	10	41	2.5	4.0	16	4.0
W3-ARD-023	8.3	0.71	0.42	0.32	<0.010	0.10	59	55	13	4.5	4.2	4.2
W3-ARD-024	7.1	<0.010	<0.010	<0.010	<0.010	<0.010	0.83	6.2	0.31	2.7	20	2.7
W3-ARD-025	6.5	<0.010	<0.010	<0.010	0.010	<0.010	0.83	8.0	0.31	2.7	26	2.7
MIN	6.2	<0.010	<0.010	<0.010	<0.010	<0.010	0.83	5.9	0.31	0.27	4.2	0.27
MAX	9.5	8.0	0.42	0.32	0.020	0.30	665	329	13	2128	1054	1054
MEDIAN	8.3	0.12	0.010	0.010	0.010	0.010	10	41	0.31	5.3	21	5.3

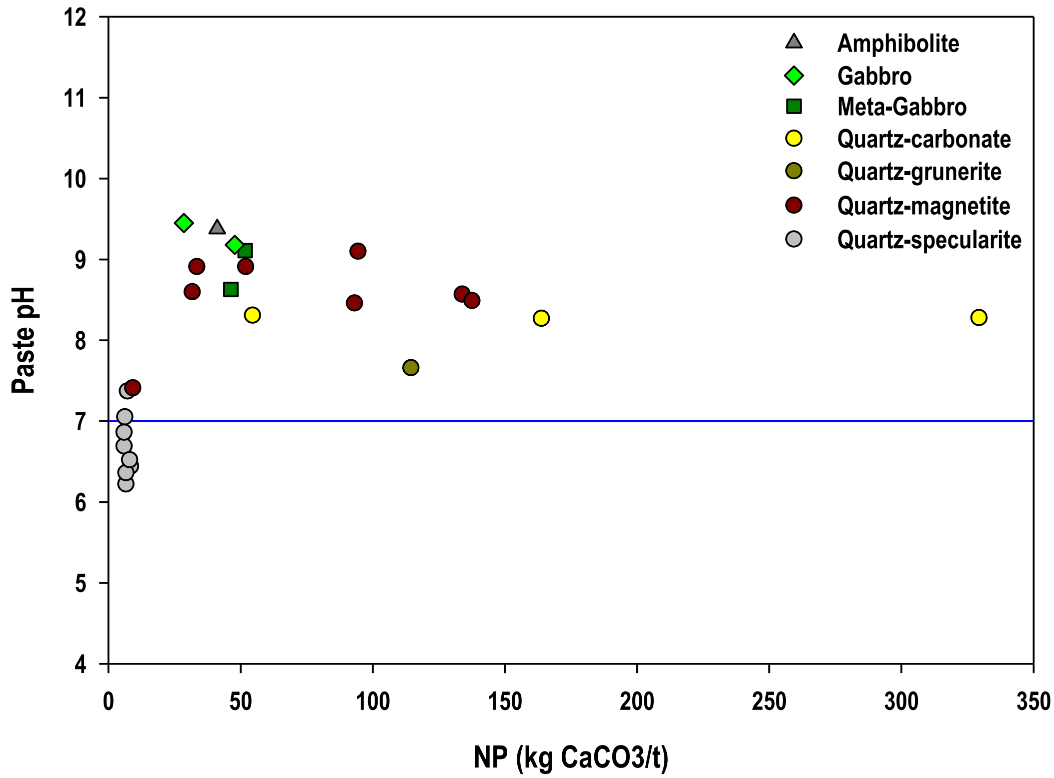


Figure 3-2: Paste pH vs NP for Wabush 3 waste rock samples.

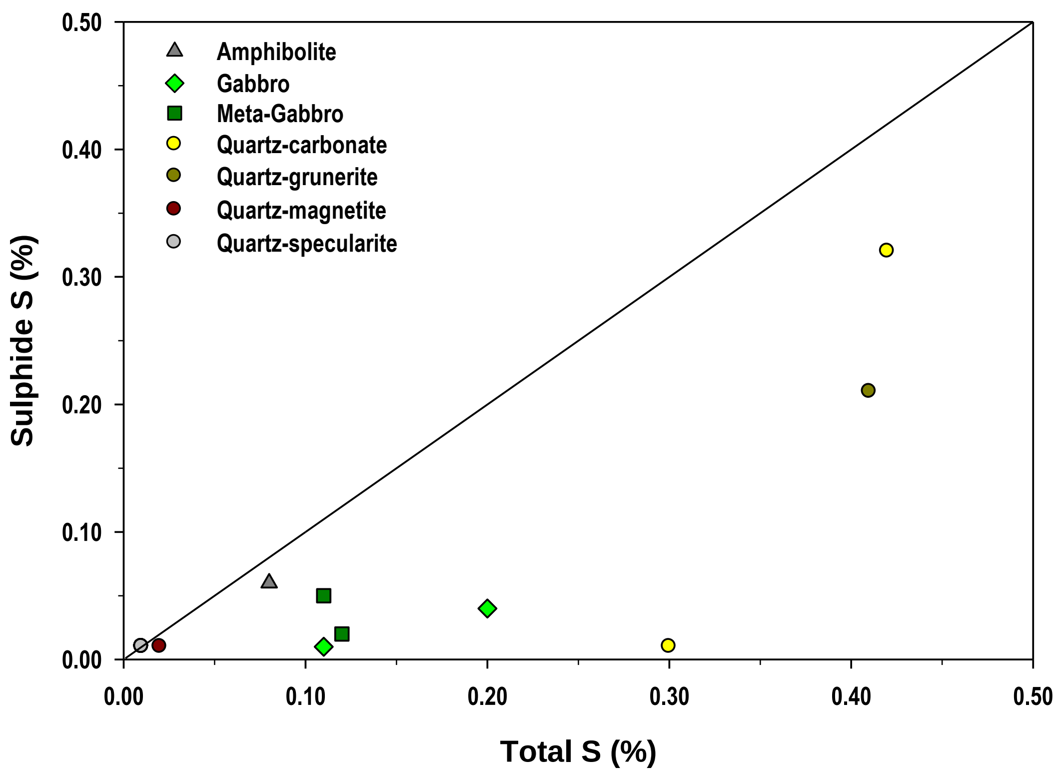


Figure 3-3: Sulphide S vs Total S for Wabush 3 waste rock samples.

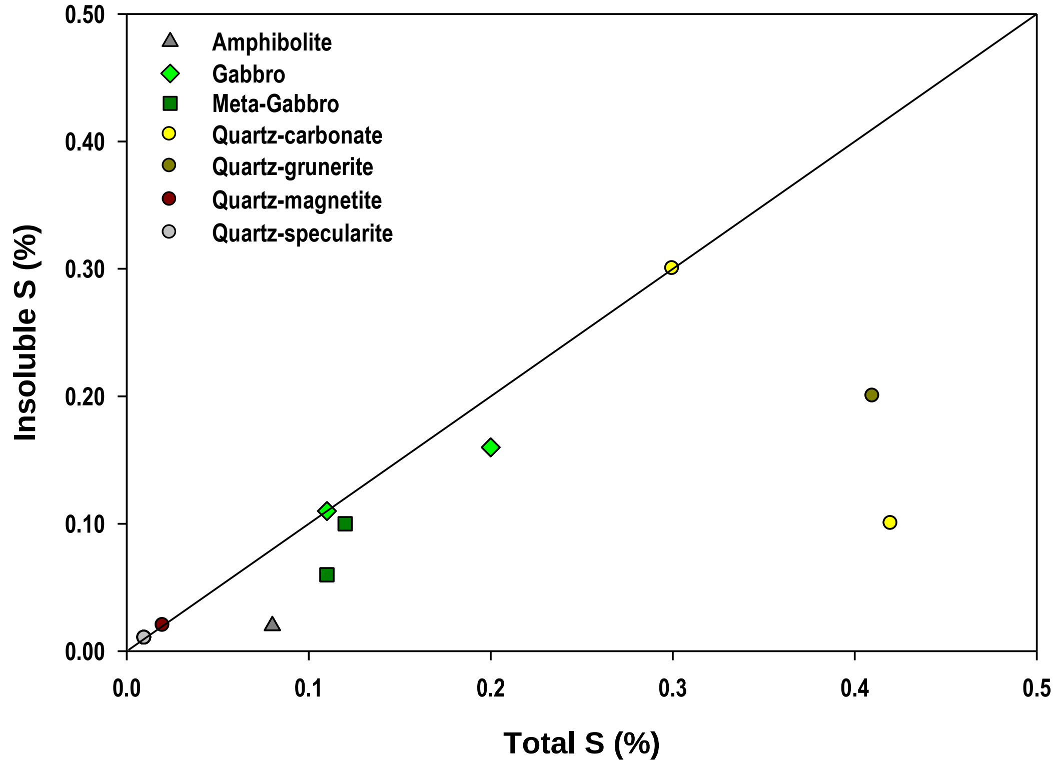


Figure 3-4: Sulphate S vs Total S for Wabush 3 waste rock samples.

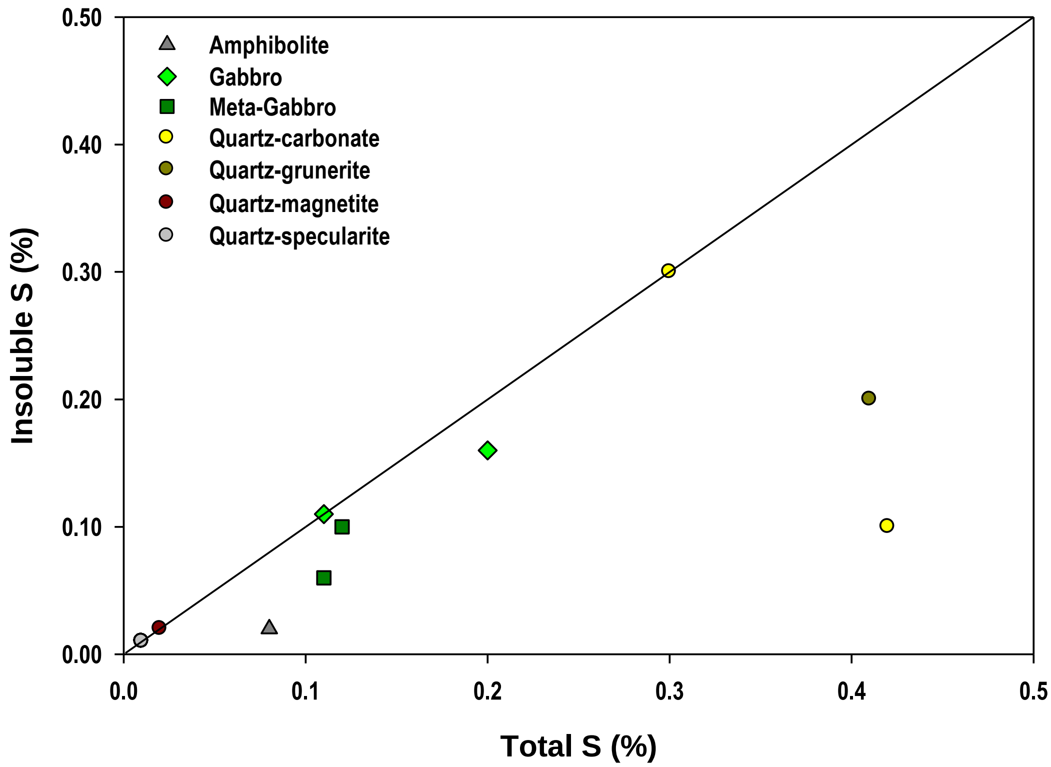


Figure 3-5: Insoluble S vs Total S for Wabush 3 waste rock samples.

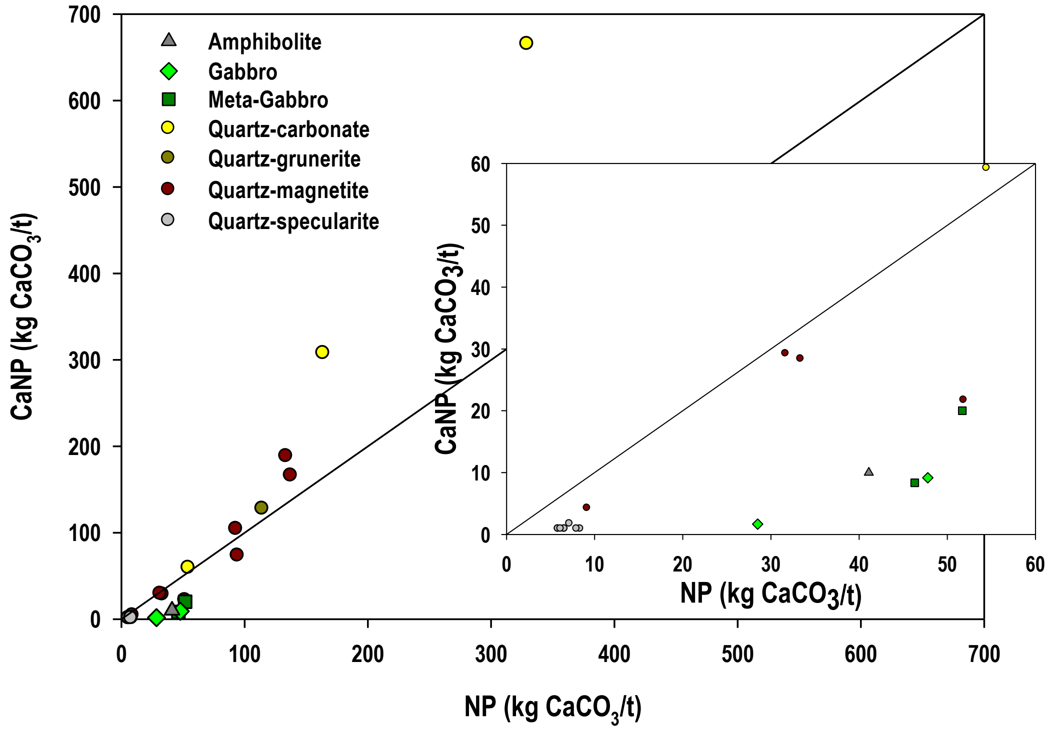


Figure 3-6: CaNP vs Siderite Corrected NP for Wabush 3 waste rock samples.

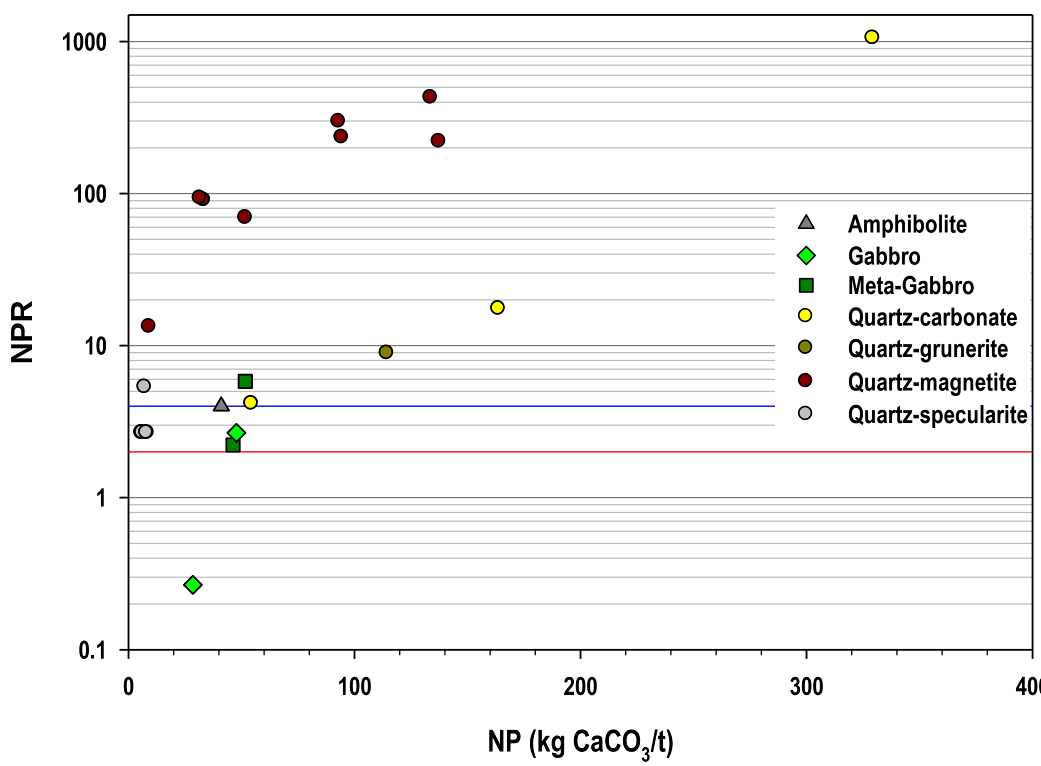


Figure 3-7: Net Potential Ratio (NPR) vs Siderite Corrected NP for Wabush 3 waste rock samples.

3.4.2 Solid Phase Metals

Solid phase metal concentrations for Wabush 3 waste rock are practical in identifying metals that could potentially leach should acid generation occur. Table 3-4 presents the complete listing of sample and bulk minimum, maximum, and median solid phase metal concentrations for selected metals. Included are metals that are typically observed in elevated concentrations in drainages from metal mines, such as Cd, Co, Cu, Cr, Ni, Pb, and Zn. A complete listing of solid phase metals results is presented in Appendix B.

Solid phase metals results presented in Table 3-4 are compared with the average crustal abundance and, hence, the enrichment factor of metals concentrations over the average crustal abundance. Those results that are enriched by a factor of three times the average crustal abundance are shaded in grey. The enrichment factor is a practical parameter as it allows for determining which elements are present in elevated levels, and therefore may be of potential concern in waste rock runoff. As discussed previously, although an element may be present at elevated concentrations in the solid phase, this does not necessarily indicate that the element will become problematic in drainage waters. The leaching rates are dependent on a number of other factors in addition to solid phase concentrations, including: the mineralogical associations, the geochemical stability of those minerals, and the geochemistry of the infiltrating waters. Accordingly, a metal may be present at high concentrations relative to the average crustal abundance. Whether this metal becomes problematic in drainage waters is dependent on the interrelationship of the variables discussed above.

Waste rock samples exhibit enrichment of Ag, As, B, Bi, Mn, and Mo, Table 3-4. Metals typically observed in drainage from metal mines (Cd, Co, Cu, Cr, Ni, Pb, and Zn) were generally less than the enrichment factor. Of note are Fe and Mn, the majority of samples tested exhibit concentrations that are greater than the analytical detection limit. Given the nature of the deposit and the lithologies present the elevated Fe and Mn concentrations are expected.

Table 3-4:
Wabush 3 Solid Phase Metals Results Compared with Average Crustal Abundance.

Sample ID	Ag	Al	As	B	Ba	Bi	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Sb	Zn
	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm
W3-ARD-001	0.040	0.040	1.0	60	139	<0.020	0.060	8.8	95	22	>15	6790	3.9	5.3	1.2	0.050	9.0
W3-ARD-002	0.020	0.030	<1.0	50	104	<0.020	0.11	12	86	8.8	>15	>10000	3.4	3.4	0.80	<0.050	10
W3-ARD-003	0.020	0.020	2.0	70	616	0.030	0.030	5.2	141	8.1	>15	1470	4.6	4.1	1.2	0.060	3.0
W3-ARD-004	0.080	0.030	<1.0	50	119	<0.020	0.040	7.7	180	6.6	>15	>10000	5.9	4.4	1.1	0.060	6.0
W3-ARD-005	0.080	0.050	3.0	80	177	<0.020	0.040	10	147	9.5	>15	9130	4.6	4.1	1.3	<0.050	5.0
W3-ARD-006	<0.010	1.5	<1.0	20	619	<0.020	0.030	22	128	42	6.2	761	4.7	28	0.90	<0.050	75
W3-ARD-007	0.020	0.020	13	60	115	<0.020	0.030	8.1	142	5.8	>15	1470	4.2	3.8	0.80	0.20	5.0
W3-ARD-008	0.010	0.020	9.0	60	111	<0.020	0.030	8.0	143	5.5	>15	1740	4.1	3.4	0.50	0.21	4.0
W3-ARD-009	0.030	1.5	7.0	<10	548	<0.020	0.060	23	88	36	3.1	299	3.2	40	2.6	0.22	54
W3-ARD-010	0.010	1.5	<1.0	<10	424	<0.020	0.050	27	115	62	2.5	208	3.1	51	1.5	<0.050	41
W3-ARD-011	0.030	0.060	2.0	80	156	<0.020	0.040	8.3	93	7.9	>15	2950	3.3	3.4	0.50	<0.050	2.0
W3-ARD-012	0.060	0.21	<1.0	40	97	0.020	0.050	7.1	67	20	13	7700	3.1	7.8	1.8	<0.050	6.0
W3-ARD-013	0.10	0.47	<1.0	20	119	0.040	0.090	5.9	63	25	7.5	2820	3.8	12	3.0	<0.050	11
W3-ARD-014	0.020	0.15	<1.0	60	162	<0.020	0.030	6.9	100	8.6	>15	7250	4.4	4.7	0.70	<0.050	10
W3-ARD-015	0.040	0.010	3.0	90	189	0.040	0.040	5.0	107	8.3	>15	1480	3.5	3.5	0.70	0.11	18
W3-ARD-016	0.020	0.020	2.0	70	140	<0.020	0.020	14	129	6.0	>15	4850	4.9	4.5	0.80	0.090	5.0
W3-ARD-017	0.040	2.0	8.0	10	300	<0.020	0.080	25	168	30	3.2	250	3.5	60	3.0	<0.050	45
W3-ARD-018	0.070	0.040	2.0	50	130	<0.020	0.050	10	154	5.9	>15	>10000	5.6	5.8	0.80	0.080	7.0
W3-ARD-019	0.030	0.060	<1.0	70	155	<0.020	0.050	9.8	139	7.7	>15	>10000	4.9	5.0	0.90	<0.050	9.0
W3-ARD-020	0.020	0.020	<1.0	50	98	<0.020	0.020	5.9	168	4.6	>15	>10000	5.1	3.6	0.70	0.070	4.0
W3-ARD-021	0.030	0.040	<1.0	50	119	<0.020	0.060	11	168	5.5	>15	>10000	5.8	6.1	0.70	0.060	8.0
W3-ARD-022	0.030	1.3	1.0	40	475	<0.020	0.040	21	111	31	12	848	3.8	21	2.9	0.11	50
W3-ARD-023	0.27	0.020	18	<10	13	0.040	0.020	20	237	17	1.2	391	10	25	0.70	<0.050	1.0
W3-ARD-024	0.050	0.020	2.0	50	104	<0.020	0.020	7.8	150	8.3	>15	1680	4.6	5.2	0.90	0.080	3.0
W3-ARD-025	0.040	0.030	1.0	60	126	<0.020	0.020	8.6	162	6.1	>15	>10000	5.4	4.8	0.80	<0.050	5.0
MIN	<0.010	0.010	<1.0	<10	13	<0.020	0.020	5.0	63	4.6	1.2	208	3.1	3.4	0.50	<0.050	1.0
MAX	0.27	2.0	18	90	619	0.040	0.11	27	237	62	>15	>10000	10	60	3.0	0.22	75
MEDIAN	0.030	0.040	1.0	50	139	0.020	0.040	8.8	139	8.3	15	2950	4.4	5.0	0.90	0.050	7.0
Crustal Abundance	0.075	8.2	1.8	10	425	0.0085	0.15	25	102	60	5.6	950	1.2	84	14	0.20	70

3.5 Comparison of Wabush 3 with Carol Lake Waste Rock

The following provides comparison of Wabush 3 waste rock sample geochemical results with results compiled in the '*Acid Rock Drainage Characterization and Assessment*' (Lorax, 2007). Summary Carol Lake waste rock results are presented, providing minimum, maximum, and median values.

Figure 3-8 Figure 3-14 compare the geochemical characteristics of Wabush 3 waste rock samples with the range of geochemical results for waste rock samples collected waste rock piles during the 2006 survey of each of the Carol Lake pits. While the range of paste pH measured exhibits a lower paste pH for Wabush 3, the median paste pH value (pH = 8.3) is within the range observed for Carol Lake waste rock, Figure 3-8.

In general, the sulphur concentrations, including total S, sulphide S, and sulphate S, observed for Wabush 3 are typically greater than those observed for Carol Lake waste rock (Figure 3-9 to Figure 3-12). However, the median sulphur concentration for each of total S, sulphide S, and sulphate S of 0.010 %, Table 3-3, is equivalent to the median concentrations observed from waste rock sampled at the Carol Lake project area, Figure 3-9 to Figure 3-12.

The Wabush 3 siderite corrected NP is within the range of NP observed for waste rock that exists currently at Carol Lake, Figure 3-13. The median NP for Wabush 3 waste rock of 41 kg $CaCO_3$/t, Table 3-3, is slightly lower than the median NP observed for waste rock from existing pits within the Carol Lake area.

As a result of the slightly elevated sulphur content and similar NP of the Wabush 3 samples, relative to waste rock from other Carol Lake open pit operations, the NPR ranges from lower than that observed at other locations, Figure 3-14. However, the median NPR for Wabush 3 material is 5.3, therefore the bulk waste is classified as non-PAG. This NPR is within the range observed for Spooks and Luce-Hakim waste rock.

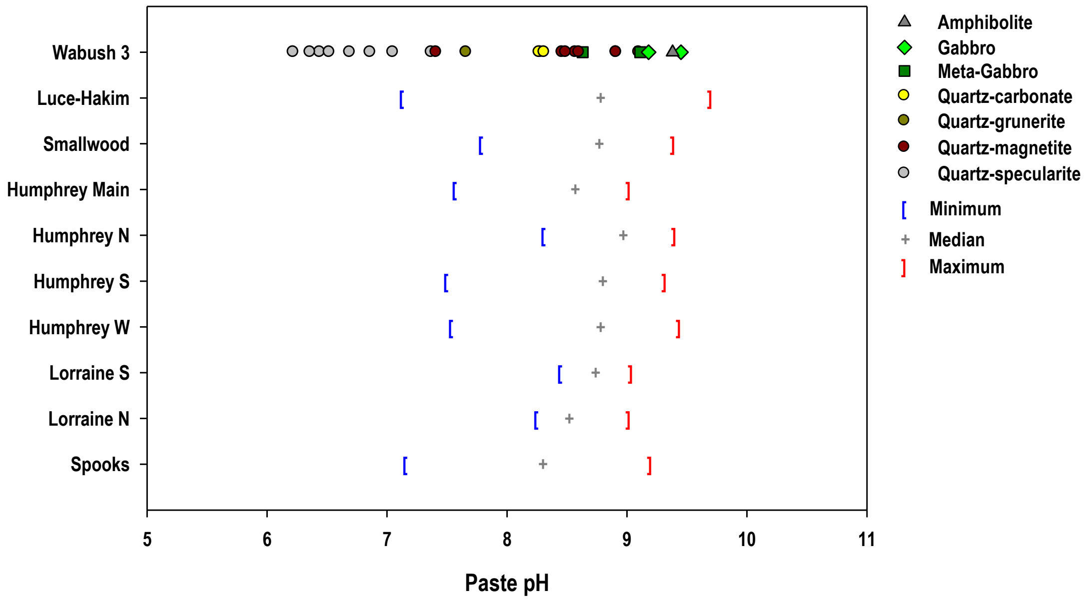


Figure 3-8: Comparison of Paste pH for Wabush 3 and Waste Rock from the Carol Project Site.

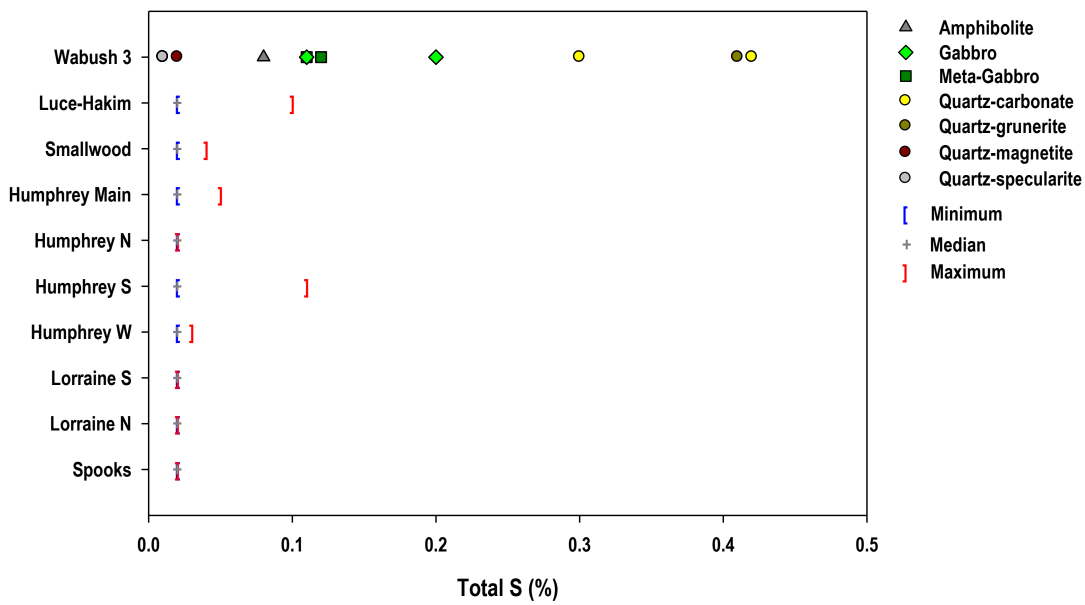


Figure 3-9: Comparison of Total S for Wabush 3 and Waste Rock from the Carol Project Site.

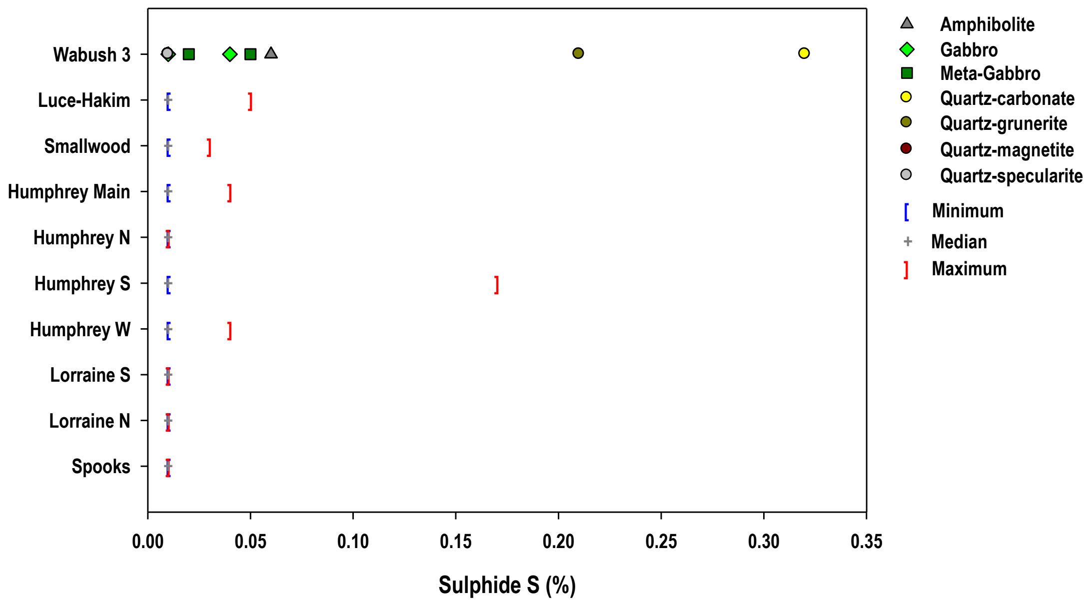


Figure 3-10: Comparison of Sulphide S for Wabush 3 and Waste Rock from the Carol Project Site.

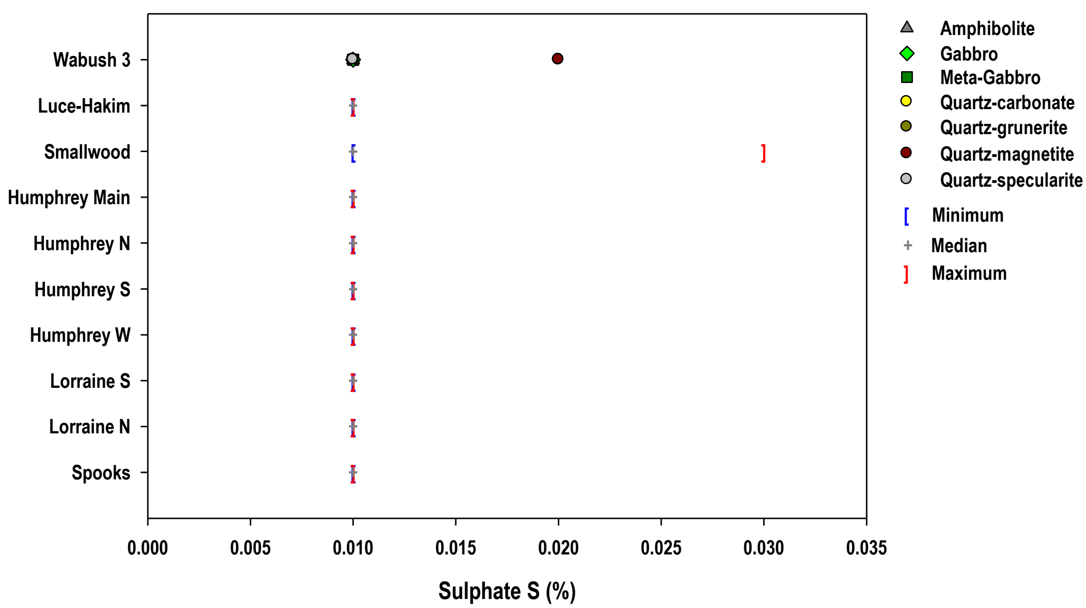


Figure 3-11: Comparison of Sulphate S for Wabush 3 and Waste Rock from the Carol Project Site.

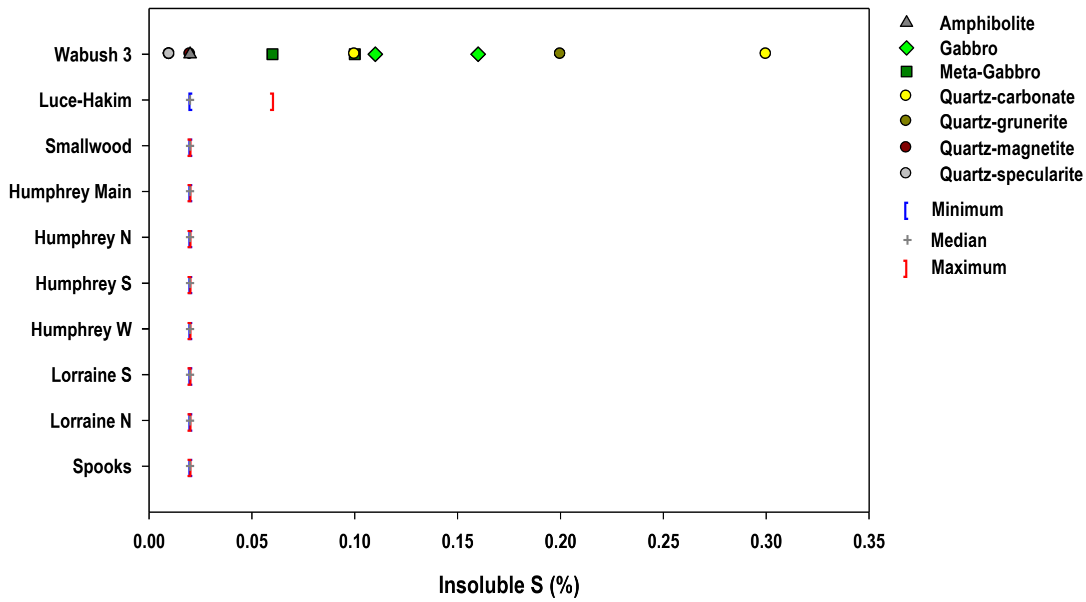


Figure 3-12: Comparison of Insoluble S for Wabush 3 and Waste Rock from the Carol Project Site.

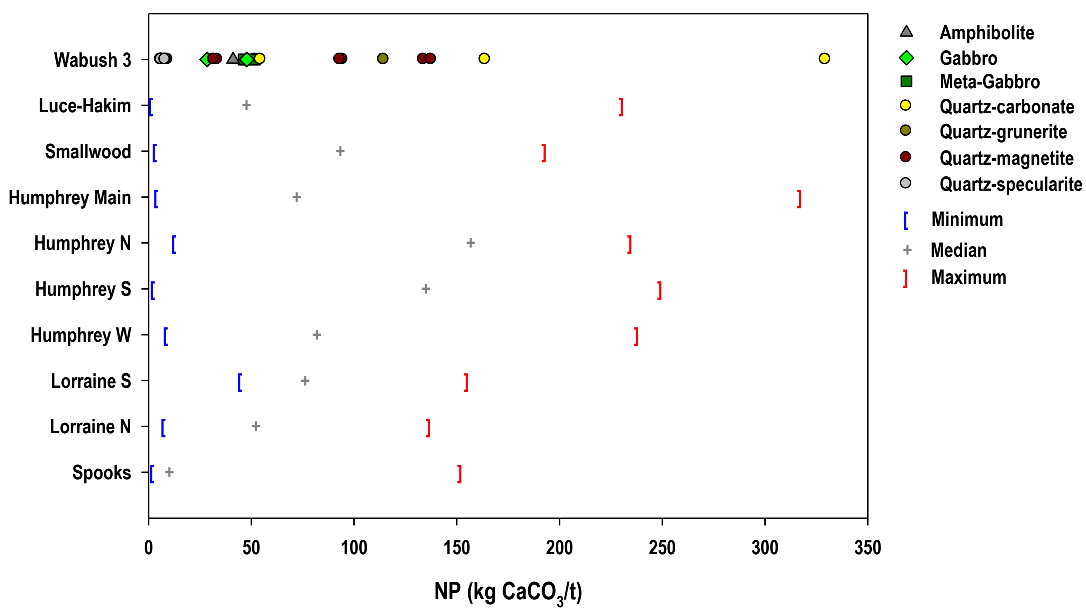


Figure 3-13: Comparison of NP for Wabush 3 and Waste Rock from the Carol Project Site.

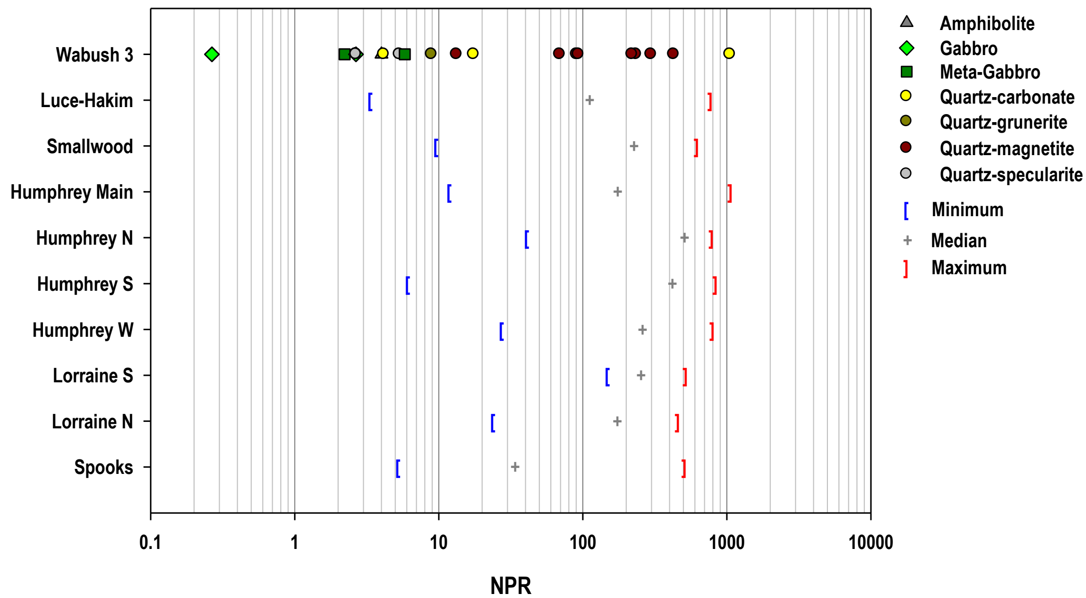


Figure 3-14: Comparison of NPR for Wabush 3 and Waste Rock from the Carol Project Site.

4. Summary and Recommendation

The following section provides the salient static geochemical results for Wabush 3 waste rock samples W3-ARD-001 to W3-ARD-025. Samples were selected by IOC site geologists to represent highest ARD potential waste rock material expected to be extracted during the development of the Wabush 3 pit area. Samples include elevated ARD potential intervals, based on initial assay results.

The geochemical results Wabush 3 waste rock material are as follows:

- Paste pH is circumneutral to slightly alkaline, ranging from 6.2 to 9.5.
- Total S concentrations are considered low, ranging from <0.010 to 0.42 % (median total S = 0.095 %).
- Each of sulphide S, sulphate S, and insoluble S have median concentrations slightly above the detection limit, median = 0.010 %.
- A comparsion sulphide S, sulphate S, and insoluble S with total S indicates the primary sulphur species is sulphide S. However, some samples demonatrate an appreciable concentration of insoluble S. This is believed to be sulphide minerals that have not been completely digested during the analytical testing.
- A conservative estimate of AP has been taken such that AP is calculated from total S content.
- Siderite correct NP ranges from relatively low to high, with a range of 5.9 to 329 kg $CaCO_3$/t. Median NP is considered moderate, 41 kg $CaCO_3$/t
- CaNP ranges from relatively low to high, with a range of 5.9 to 329 kg $CaCO_3$/t. Median CaNP is considered moderate, 10 kg $CaCO_3$/t
- A comparison of siderite corrected NP and CaNP inidicates in general for samples with siderite correct NP less than 50 kg $CaCO_3$/t the CaNP is typical less than the siderite corrected NP. Therefore siderite is not considered an issue at NP <50 kg $CaCO_3$/t. However at NP > 50 kg $CaCO_3$/t siderite appears to be present.
- To conservatively estimate NPR for Wabush 3, the lower NP of the CaNP and siderite corrected NP is used.
- NPR ranges from 0.27 to 1054, with a median of 5.3. In general the bulk Wabush 3 waste rock is classified as non-PAG, having NPR > 2.0

- A single Gabbro sample (W3-ARD-009) is classified as PAG, having NPR = 0.27. The total S of W3-ARD-009 is low, 0.16 %, and therefore the long-term acid generation potential of this sample is not considered to be a concern.
- Wabush 3 samples exhibited enrichment of Ag, As, B, Bi, Mn, and Mo.
- Metals typically observed in drainage from metal mines (Cd, Co, Cu, Cr, Ni, Pb, and Zn) were generally less than the enrichment factor.

To that end the bulk Wabush 3 material is not considered to be a risk of acid generation based on the 25 drill core samples tested. Further testing of the Gabbro material is recommended to ensure the geochemistry of the unit. It is noted that while sample the gabbro sample W3-ARD-009 indicated a potential concern with respect to acid generation, another gabbro sample, W3-ARD-017, has a sufficiently higher NPR and is not considered to be an acid generation concern.

References

Iron Ore Company of Canada (IOC). 2013. Iron Ore Company of Canada Wabush 3. Open Pit Mine Project Labrador West. Environmental Assessment Registration. May 2013.

Lorax Environmental Services Ltd. (Lorax). 2006. Preliminary Acid Rock Drainage / Metal Leaching Report. April 2006. Prepared by Lorax Environmental Services for Iron Ore Comapany of Canada.

Lorax Environmental Services Ltd. (Lorax). 2007. Acid Rock Drainage Characterization and Assessment. February 2007. Prepared by Lorax Environmental Services for Iron Ore Company of Canada.

Lorax Environmental Services Ltd. (Lorax). 2008. Waste Rock and Tailings Kinetic Test Results. October 2008. Prepared by Lorax Environmental Services for Iron Ore Company of Canada.

Lorax Environmental Services Ltd. (Lorax). 2008. Exploration ML/ARD Study. Samples ARD00001 to ARD00022. November 2008. Prepared by Lorax Environmental Services for Iron Ore Company of Canada.

Lorax Environmental Services Ltd. (Lorax). 2010. Exploration ML/ARD Study. Samples ARD00023 to ARD00028. November 2010. Prepared by Lorax Environmental Services for Iron Ore Company of Canada.

Jambor, J.L., Dutrizac, J.E., Groat, L.A. and Raudsepp, M. 2002. Static tests of neutralization potentials of silicate and aluminosilicate minerals. Environmental Geologist 43:1–17

Jambor, J., Dutriazac, J., Raudsepp, M., and Groat, L., 2003. Effect of Peroxide on Neutralization-Potential Values of Siderite and Other Carbonate Minerals. Journal of Environmental Quality **32** pp. 2373-2378.

Mattson, B. (2005) Evaluating Depletion of Carbonate Neutralization Potential from Laboratory Kinetic Tests: Proceedings of Securing the Future International Conference on Mining and Environment, Metals and Energy Recovery, Skelleftea, Sweden June 27-July 1, 2005 p. 659-672.

Price, W.A., 1997. Draft Guidelines and Recommended Methods for the Prediction of Metal Leaching and Acid Rock Drainage at Minesites in British Columbia. Reclamation Section, Energy and Minerals Division, British Columbia Ministry of Employment and Investment. Smithers, B.C., Canada. 160 p.

Price, W.A. and Errington, J.C., British Columbia Ministry of Energy and Mines (BCMEM) 1998. Guidelines For Metal Leaching and Acid Rock Drainage at Minesites in British Columbia. B.C., Canada.

Price, W.A. 2009. Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials. MEND Report 1.20.1

Sobek, A.A., Schuller, W.A., Freeman, J.R., and Smith, R.M., 1978. Field and Laboratory Methods Applicable to Overburdens and Minesoils. EPA Report 600/2-78-054, U.S. National Technical Information Report PB-280 495. 403 p.

Appendix A

Appendix A1: Acid-base Accounting Results

Sample ID	Hole	Meter Interval (m)	Unit	Weight (Kg)	Rock Type	Paste	TIC	CaCO3	Total S	S(SO4)	S(S-2)	Insoluble S	AP	NP	Net	Fizz Test
						pH	%	NP	%	%	%	%			NP	
						Sobek	CSB02V	Calc.	CSA06V	CSA07V	CSA08D	Calc.	Calc.	Siderite Corr.	Calc.	Sobek
						0.20	0.01	#N/A	0.01	0.01	0.01	#N/A	#N/A	0.5	#N/A	#N/A
W3-ARD-001	W3-10-26	199-216	52	8.82	Quartz-magnetite-grunerite gneiss	8.57	2.26	188.3	<0.01	<0.01	<0.01	<0.01	<0.3	133.8	133.8	Moderate
W3-ARD-002	W3-10-27	80-91	40	6.38	Quartz-carbonate-gneiss	8.28	7.98	665.0	<0.01	<0.01	<0.01	<0.01	<0.3	329.4	329.4	Moderate
W3-ARD-003	W3-10-28	205-220	52	6.5	Quartz-magnetite-grunerite gneiss	9.10	0.88	73.3	<0.01	0.02	<0.01	<0.01	<0.3	94.4	94.4	Moderate
W3-ARD-004	W3-10-30	4.-20	62	3.32	Quartz-specularite Schist	7.37	0.02	1.7	<0.01	0.01	<0.01	<0.01	<0.3	7.2	7.2	None
W3-ARD-005	W3-10-30	20-37	62	3.94	Quartz-specularite Schist	6.69	<0.01	<0.8	<0.01	0.01	<0.01	<0.01	<0.3	5.9	5.9	None
W3-ARD-006	W3-10-30	55-70	81	8.06	Metagabbro	8.63	0.1	8.3	0.12	<0.01	0.02	0.1	0.6	46.3	45.7	Slight
W3-ARD-007	W3-10-30	190-206	61	5.46	Quartz-magnetite-specularite	8.91	0.26	21.7	<0.01	<0.01	<0.01	<0.01	<0.3	51.9	51.9	Moderate
W3-ARD-008	W3010-30	206-224	61	5.52	Quartz-magnetite-specularite	8.91	0.34	28.3	<0.01	<0.01	<0.01	<0.01	<0.3	33.4	33.4	Slight
W3-ARD-009	W3-10-30	259.2-276	80	7.18	Gabbro	9.45	0.02	1.7	0.2	<0.01	0.04	0.16	1.3	28.5	27.3	None
W3-ARD-010	W3-10-31	3.-19	81	8.66	Metagabbro	9.11	0.24	20.0	0.11	<0.01	0.05	0.06	1.6	51.7	50.1	Slight
W3-ARD-011	W3-10-31	280-296	60	5.22	Quartz-magnetite	8.46	1.25	104.2	<0.01	<0.01	<0.01	<0.01	<0.3	93.1	93.1	Moderate
W3-ARD-012	W3-11-47	285.2-298.2	42/43	6.18	Quartz-(carbonate-grunerite)-gneiss/Quartz-grunerite-schist	8.27	3.69	307.5	0.3	<0.01	<0.01	0.3	<0.3	163.8	163.8	Moderate
W3-ARD-013	W3-11-51	164-172	43	6.7	Quartz-grunerite Schist	7.66	1.53	127.5	0.41	<0.01	0.21	0.2	6.6	114.4	107.8	Moderate
W3-ARD-014	W3-11-69	267-286	53	6.38	Quartz-magnetite-carbonate gneiss	8.49	1.99	165.8	0.02	<0.01	<0.01	0.02	<0.3	137.5	137.5	Moderate
W3-ARD-015	W3-12-113	43.3-59	60	9.8	Quartz-magnetite	8.60	0.35	29.2	<0.01	0.01	<0.01	<0.01	<0.3	31.7	31.7	Slight
W3-ARD-016	W3-12-114	18-34	61	6.04	Quartz-magnetite-specularite	7.41	0.05	4.2	<0.01	0.01	<0.01	<0.01	<0.3	9.2	9.2	None
W3-ARD-017	W3-12-136	2.1-15	80	4.8	Gabbro	9.18	0.11	9.2	0.11	<0.01	<0.01	0.11	<0.3	47.8	47.8	Slight
W3-ARD-018	W3-12-150	59-71	62	4.54	Quartz-specularite Schist	6.86	<0.01	<0.8	<0.01	<0.01	<0.01	<0.01	<0.3	5.9	5.9	None
W3-ARD-019	W3-12-152	198-214	62	5.7	Quartz-specularite Schist	6.44	<0.01	<0.8	<0.01	0.01	<0.01	<0.01	<0.3	8.4	8.4	None
W3-ARD-020	W3-12-153	21-37	62	6.34	Quartz-specularite Schist	6.22	<0.01	<0.8	<0.01	<0.01	<0.01	<0.01	<0.3	6.6	6.6	None
W3-ARD-021	W3-12-153	101-120	62	5.74	Quartz-specularite Schist	6.36	<0.01	<0.8	<0.01	<0.01	<0.01	<0.01	<0.3	6.6	6.6	None
W3-ARD-022	W3-12-154	239-255	82	5.76	Amphibolite: Hornblend-Biotite +/- Schist	9.38	0.12	10.0	0.08	<0.01	0.06	0.02	1.9	41.1	39.2	Slight
W3-ARD-023	W3-12-155	59-72	32/40	5.7	Quartzite with accessory carbonate/Quartz-carbonate-gneiss	8.31	0.71	59.2	0.42	<0.01	0.32	0.1	10.0	54.5	44.5	Slight
W3-ARD-024	W3-12-168	24-36	62	4.62	Quartz-specularite Schist	7.05	<0.01	<0.8	<0.01	<0.01	<0.01	<0.01	<0.3	6.2	6.2	None
W3-ARD-025	W3-13-175	59.7-70	62	6.68	Quartz-specularite Schist	6.52	<0.01	<0.8	<0.01	0.01	<0.01	<0.01	<0.3	8.0	8.0	None
Duplicates																
W3-ARD-001						8.51			<0.01					121.9		Moderate
W3-ARD-003										0.02						
W3-ARD-012							3.66									
W3-ARD-016											<0.01					
W3-ARD-020						6.20								8.9		None
W3-ARD-021						6.38								6.2		None
QC																
GTS-2A									0.33							
PD-1										4.33						
RTS-3A											2.45					
SY-4							0.92									
NBM-1														56.9		Slight
Expected Values							0.95		0.35	4.27	2.34			57.1		Slight
Tolerance +/-							0.06		0.03	0.3	0.23			5.2		

Note:

AP = Acid potential in tonnes CaCO3 equivalent per 1000 tonnes of material. AP is determined from the measured sulphide sulphur content.

NP = Neutralization potential in tonnes CaCO3 equivalent per 1000 tonnes of material.

NET NP = NP - AP

Carbonate NP is calculated from TIC originating from carbonate minerals and is expressed in kg CaCO3/tonne.

Sulphate Sulphur determined by 25% HCl with S by ICP Finish

Sulphide Sulphur determined by Sobek 1:7 Nitric Acid with S by ICP Finish

Insoluble S is acid insoluble S (Total S - (Sulphate S + Sulphide S)).

Appendix A2: Solid Phase and Whole Rock Metals

Sample ID	Hole	Meter Interval (m)	Unit	Weight (Kg)	Rock Type	Ag ppm	Al %	B ppm	Ba ppm	Ca %	Cr ppm	Cu ppm	Fe %	K %	Li ppm	Mg %	Mn ppm
						ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B
						0.01	0.01	10.0	5	0.01	1	0.5	0.0	0.01	1.0	0.01	2
W3-ARD-001	W3-10-26	199-216	52	8.82	Quartz-magnetite-grunerite gneiss	0.04	0.04	60.0	139	1.57	95	22.2	>15	<0.01	<1	1.4	6790
W3-ARD-002	W3-10-27	80-91	40	6.38	Quartz-carbonate-gneiss	0.02	0.03	50.0	104	7.43	86	8.8	>15	<0.01	<1	4.16	>10000
W3-ARD-003	W3-10-28	205-220	52	6.5	Quartz-magnetite-grunerite gneiss	0.02	0.02	70.0	616	1.51	141	8.1	>15	<0.01	3.0	0.64	1470
W3-ARD-004	W3-10-30	4.-20	62	3.32	Quartz-specularite Schist	0.08	0.03	50.0	119	0.02	180	6.6	>15	<0.01	<1	0.02	>10000
W3-ARD-005	W3-10-30	20-37	62	3.94	Quartz-specularite Schist	0.08	0.05	80.0	177	<0.01	147	9.5	>15	<0.01	<1	0.01	9130
W3-ARD-006	W3-10-30	55-70	81	8.06	Metagabbro	<0.01	1.49	20.0	619	1.72	128	42.1	6.2	0.74	9.0	1.1	761
W3-ARD-007	W3-10-30	190-206	61	5.46	Quartz-magnetite-specularite	0.02	0.02	60.0	115	0.77	142	5.8	>15	<0.01	1.0	0.11	1470
W3-ARD-008	W3010-30	206-224	61	5.52	Quartz-magnetite-specularite	0.01	0.02	60.0	111	0.89	143	5.5	>15	<0.01	1.0	0.17	1740
W3-ARD-009	W3-10-30	259.2-276	80	7.18	Gabbro	0.03	1.54	<10	548	1.6	88	36.2	3.1	0.8	13.0	1.22	299
W3-ARD-010	W3-10-31	3.-19	81	8.66	Metagabbro	0.01	1.5	<10	424	1.63	115	61.7	2.5	0.6	10.0	1.35	208
W3-ARD-011	W3-10-31	280-296	60	5.22	Quartz-magnetite	0.03	0.06	80.0	156	1.45	93	7.9	>15	<0.01	<1	0.66	2950
W3-ARD-012	W3-11-47	285.2-298.2	42/43	6.18	Quartz-(carbonate-grunerite)-gneiss/Quartz-grunerite-schist	0.06	0.21	40.0	97	2.26	67	20.2	13.4	0.2	<1	1.73	7700
W3-ARD-013	W3-11-51	164-172	43	6.7	Quartz-grunerite Schist	0.10	0.47	20.0	119	1.9	63	25.3	7.5	0.5	3.0	0.85	2820
W3-ARD-014	W3-11-69	267-286	53	6.38	Quartz-magnetite-carbonate gneiss	0.02	0.15	60.0	162	1.89	100	8.6	>15	0.1	<1	1.35	7250
W3-ARD-015	W3-12-113	43.3-59	60	9.8	Quartz-magnetite	0.04	0.01	90.0	189	0.79	107	8.3	>15	<0.01	6.0	0.15	1480
W3-ARD-016	W3-12-114	18-34	61	6.04	Quartz-magnetite-specularite	0.02	0.02	70.0	140	0.15	129	6	>15	<0.01	<1	0.01	4850
W3-ARD-017	W3-12-136	2.1-15	80	4.8	Gabbro	0.04	1.99	10.0	300	1.74	168	29.6	3.2	0.6	6.0	1.2	250
W3-ARD-018	W3-12-150	59-71	62	4.54	Quartz-specularite Schist	0.07	0.04	50.0	130	0.02	154	5.9	>15	0.0	<1	0.01	>10000
W3-ARD-019	W3-12-152	198-214	62	5.7	Quartz-specularite Schist	0.03	0.06	70.0	155	<0.01	139	7.7	>15	0.1	<1	<0.01	>10000
W3-ARD-020	W3-12-153	21-37	62	6.34	Quartz-specularite Schist	0.02	0.02	50.0	98	0.02	168	4.6	>15	0.0	<1	0.02	>10000
W3-ARD-021	W3-12-153	101-120	62	5.74	Quartz-specularite Schist	0.03	0.04	50.0	119	0.02	168	5.5	>15	0.0	<1	0.03	>10000
W3-ARD-022	W3-12-154	239-255	82	5.76	Amphibolite: Hornblend-Biotite +/- Schist	0.03	1.34	40.0	475	1.36	111	31.3	11.8	0.7	10.0	1.04	848
W3-ARD-023	W3-12-155	59-72	32/40	5.7	Quartzite with accessory carbonate/Quartz-carbonate-gneiss	0.27	0.02	<10	13	1.25	237	16.5	1.2	<0.01	<1	0.53	391
W3-ARD-024	W3-12-168	24-36	62	4.62	Quartz-specularite Schist	0.05	0.02	50.0	104	0.01	150	8.3	>15	<0.01	<1	<0.01	1680
W3-ARD-025	W3-13-175	59.7-70	62	6.68	Quartz-specularite Schist	0.04	0.03	60.0	126	<0.01	162	6.1	>15	<0.01	<1	<0.01	>10000
Duplicate																	
W3-ARD-024						0.03	0.02	50	107	0.01	158	8.4	>15	<0.01	<1	<0.01	1690
QC																	
CH4						2.05	1.84	10	303	0.6	109	2060	4.65	1.43	13	1.2	306
Certified Values						2.13	1.85	#N/A	293	0.61	103.80	2000	4.79	1.43	12.6	1.18	324
Tolerance (%)						10.9	11.35	#N/A	14.3	14.1	12.4	10.1	10.52	11.74	29.84	12.3	11.5

Appendix A2:

Sample ID	Na	Ni	P	S	Sr	Ti	V	Zn	Zr	As	Be	Bi	Cd	Ce	Co	Cs	Ga	Ge	Hf	Hg	In	La
	%	ppm	ppm	%	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B
	0.01	0.5	50	0.01	0.5	0.01	1	1	0.5	1	0.1	0.02	0.01	0.05	0.1	0.05	0.1	0.1	0.05	0.01	0.02	0.1
W3-ARD-001	<0.01	5.3	0.027	<0.01	6.6	<0.01	9	9	2.9	1	0.2	<0.02	0.06	4.4	8.8	<0.05	0.7	1.9	0.06	0.05	<0.02	2.3
W3-ARD-002	<0.01	3.4	0.019	<0.01	30.6	<0.01	<1	10	2.6	<1	<0.1	<0.02	0.11	11.9	12.2	<0.05	0.6	0.1	<0.05	0.04	<0.02	7.2
W3-ARD-003	<0.01	4.1	0.018	0.01	14.4	<0.01	4	3	3.4	2	0.2	0.03	0.03	2.69	5.2	<0.05	0.8	0.7	<0.05	0.04	<0.02	1.7
W3-ARD-004	<0.01	4.4	0.01	<0.01	3.1	<0.01	<1	6	3.1	<1	0.3	<0.02	0.04	7.78	7.7	<0.05	0.9	2	<0.05	0.01	<0.02	5.9
W3-ARD-005	<0.01	4.1	0.02	<0.01	1.8	<0.01	<1	5	3.5	3	0.4	<0.02	0.04	9.55	10.4	<0.05	0.8	2.2	<0.05	0.02	<0.02	4.7
W3-ARD-006	0.14	27.9	0.398	0.12	34.4	0.24	57	75	4.1	<1	0.6	<0.02	0.03	79.9	21.8	0.56	6.9	0.5	0.12	0.02	0.03	35.5
W3-ARD-007	<0.01	3.8	0.02	<0.01	3.7	<0.01	1	5	3.7	13	0.2	<0.02	0.03	2.82	8.1	<0.05	0.6	1.2	<0.05	0.01	<0.02	2
W3-ARD-008	<0.01	3.4	0.011	<0.01	4.5	<0.01	<1	4	3.7	9	0.3	<0.02	0.03	2.19	8	<0.05	0.6	1.1	<0.05	<0.01	<0.02	1.6
W3-ARD-009	0.21	39.5	0.385	0.15	38.4	0.24	48	54	2.7	7	0.2	<0.02	0.06	80.8	22.7	1.18	6.9	0.2	0.11	<0.01	0.02	38.5
W3-ARD-010	0.13	50.7	0.237	0.11	30.5	0.13	54	41	1.5	<1	0.2	<0.02	0.05	43.9	27	0.69	6	0.1	<0.05	0.02	<0.02	20.7
W3-ARD-011	<0.01	3.4	0.014	<0.01	5.6	<0.01	<1	2	3.7	2	0.1	<0.02	0.04	2.09	8.3	<0.05	0.9	1.7	<0.05	<0.01	<0.02	1.2
W3-ARD-012	0.01	7.8	0.061	0.29	13.5	0.04	21	6	3.4	<1	0.2	0.02	0.05	14.2	7.1	0.15	1.4	0.2	<0.05	<0.01	<0.02	7.5
W3-ARD-013	0.02	12.1	0.098	0.43	22.6	0.09	68	11	7.3	<1	0.4	0.04	0.09	17.1	5.9	0.47	3	0.4	0.14	<0.01	<0.02	8
W3-ARD-014	<0.01	4.7	0.05	0.02	15.6	0.02	5	10	3.2	<1	0.1	<0.02	0.03	8.87	6.9	0.08	1.1	0.9	<0.05	<0.01	<0.02	4.3
W3-ARD-015	0.01	3.5	0.013	<0.01	20.5	<0.01	2	18	3.7	3	0.3	0.04	0.04	2.96	5	<0.05	0.6	0.7	<0.05	<0.01	<0.02	2.2
W3-ARD-016	<0.01	4.5	0.005	<0.01	8.3	<0.01	<1	5	3.9	2	0.2	<0.02	0.02	13.8	14.3	<0.05	0.7	2.9	<0.05	<0.01	<0.02	8
W3-ARD-017	0.28	60	0.308	0.12	67.2	0.17	78	45	4.8	8	0.2	<0.02	0.08	45.6	25.4	0.34	7.1	0.1	0.14	0.16	0.02	19.6
W3-ARD-018	<0.01	5.8	0.008	<0.01	3.1	<0.01	<1	7	3.4	2	0.4	<0.02	0.05	12.6	10	<0.05	0.7	2.9	<0.05	<0.01	<0.02	8.3
W3-ARD-019	<0.01	5	0.014	<0.01	15	<0.01	<1	9	3.6	<1	0.5	<0.02	0.05	4.4	9.8	<0.05	1	3.3	<0.05	<0.01	<0.02	2.9
W3-ARD-020	<0.01	3.6	0.006	<0.01	12.3	<0.01	<1	4	5.1	<1	0.5	<0.02	0.02	9.54	5.9	<0.05	0.5	2.6	<0.05	0.03	<0.02	5.8
W3-ARD-021	<0.01	6.1	<0.005	<0.01	8.6	<0.01	<1	8	3.3	<1	0.3	<0.02	0.06	7.05	11.4	0.18	0.7	2.2	<0.05	<0.01	<0.02	7.2
W3-ARD-022	0.11	20.6	0.308	0.1	22.9	0.16	49	50	3.1	1	0.3	<0.02	0.04	15.7	20.8	0.36	6.1	0.5	<0.05	<0.01	<0.02	7.4
W3-ARD-023	<0.01	25.1	<0.005	0.43	3.8	<0.01	3	1	<0.5	18	<0.1	0.04	0.02	1	20.1	<0.05	0.4	<0.1	<0.05	<0.01	<0.02	0.4
W3-ARD-024	<0.01	5.2	0.006	<0.01	2	<0.01	2	3	4.3	2	0.4	<0.02	0.02	3.22	7.8	<0.05	0.7	1	<0.05	<0.01	<0.02	1.8
W3-ARD-025	<0.01	4.8	0.009	<0.01	1.6	<0.01	<1	5	5.4	1	0.4	<0.02	0.02	9.68	8.6	<0.05	0.7	3	<0.05	<0.01	<0.02	6.5
Duplicate																						
W3-ARD-024	<0.01	5.2	0.005	<0.01	2	<0.01	2	5	4.4	2	0.5	<0.02	0.03	3.33	8	<0.05	0.7	1.1	<0.05	<0.01	<0.02	1.8
QC																						
CH4	0.05	48.6	0.067	0.68	9.4	0.21	71	209	11.1	7	<0.1	0.72	1.15	27.3	23.8	2.79	9.3	0.3	0.28	<0.01	0.1	14.7
Certified Values	0.06	49.6	719	0.73	9.38	0.21	79.27	189.4	9	8.14	0.11	0.51	1.17	28.18	22.8	2.6	8.72	0.21	0.29	#N/A	0.1	14
Tolerance (%)	50.3	12.5	27.4	13.4	23.3	23.3	13.2	11.3	17.7	13.1	241.3	19.7	12.1	10.4	11.1	14.8	12.9	127.4	52.8	#N/A	62.1	11.8

Appendix A2:

Sample ID	Lu	Mo	Nb	Pb	Rb	Sb	Sc	Se	Sn	Ta	Tb	Te	Th	Tl	U	W	Y	Yb
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B	ICM14B
	0.01	0.05	0.05	0.2	0.2	0.05	0.1	1	0.3	0.05	0.02	0.05	0.1	0.02	0.05	0.1	0.05	0.1
W3-ARD-001	0.06	3.92	0.51	1.2	<0.2	0.05	0.2	<1	<0.3	0.27	0.11	<0.05	<0.1	<0.02	0.11	1.4	4.65	0.4
W3-ARD-002	0.06	3.39	0.19	0.8	<0.2	<0.05	0.2	<1	<0.3	0.07	0.2	<0.05	<0.1	<0.02	0.07	0.2	6.9	0.4
W3-ARD-003	0.06	4.57	0.24	1.2	<0.2	0.06	<0.1	<1	<0.3	<0.05	0.08	<0.05	<0.1	<0.02	0.13	0.5	4.33	0.4
W3-ARD-004	0.08	5.89	0.52	1.1	0.3	0.06	<0.1	<1	<0.3	<0.05	0.15	<0.05	<0.1	<0.02	0.05	1	7.05	0.6
W3-ARD-005	0.06	4.56	0.63	1.3	0.2	<0.05	0.1	<1	<0.3	<0.05	0.13	<0.05	<0.1	<0.02	0.07	0.8	5.84	0.4
W3-ARD-006	0.16	4.74	0.26	0.9	27.8	<0.05	6.4	<1	0.5	<0.05	0.86	<0.05	4.3	0.19	0.44	0.2	15.8	1
W3-ARD-007	0.05	4.16	0.17	0.8	<0.2	0.2	<0.1	<1	<0.3	<0.05	0.07	<0.05	<0.1	<0.02	<0.05	0.9	4.3	0.3
W3-ARD-008	0.05	4.09	0.22	0.5	<0.2	0.21	<0.1	<1	<0.3	<0.05	0.06	<0.05	<0.1	<0.02	<0.05	0.9	3.64	0.3
W3-ARD-009	0.15	3.15	0.2	2.6	34.5	0.22	5.6	<1	0.4	<0.05	0.7	<0.05	4	0.24	0.35	3.2	13.9	0.9
W3-ARD-010	0.06	3.14	<0.05	1.5	19.9	<0.05	3.8	<1	<0.3	<0.05	0.36	<0.05	2.2	0.14	0.22	<0.1	5.73	0.4
W3-ARD-011	0.04	3.26	0.43	0.5	<0.2	<0.05	0.2	<1	<0.3	<0.05	0.05	<0.05	<0.1	<0.02	<0.05	0.8	3.03	0.3
W3-ARD-012	0.05	3.1	0.9	1.8	8.6	<0.05	0.4	<1	<0.3	<0.05	0.18	0.19	0.5	0.08	0.3	0.4	5.83	0.3
W3-ARD-013	0.07	3.8	0.83	3	19.7	<0.05	0.7	<1	0.3	<0.05	0.29	0.13	0.6	0.16	0.98	0.9	8.21	0.5
W3-ARD-014	0.07	4.4	0.17	0.7	3.5	<0.05	0.7	<1	<0.3	<0.05	0.17	<0.05	0.2	0.02	0.06	0.1	6.84	0.4
W3-ARD-015	0.06	3.49	0.2	0.7	<0.2	0.11	<0.1	<1	<0.3	<0.05	0.08	<0.05	<0.1	<0.02	0.08	0.3	4.87	0.4
W3-ARD-016	0.09	4.85	0.44	0.8	0.3	0.09	<0.1	<1	<0.3	<0.05	0.18	<0.05	<0.1	<0.02	<0.05	2.7	7.8	0.6
W3-ARD-017	0.22	3.45	0.19	3	22	<0.05	3.3	<1	0.6	<0.05	0.81	<0.05	2.8	0.15	0.24	0.1	19.3	1.4
W3-ARD-018	0.11	5.57	0.47	0.8	0.7	0.08	<0.1	<1	<0.3	<0.05	0.22	0.06	<0.1	0.07	<0.05	2.8	9.13	0.8
W3-ARD-019	0.05	4.87	0.31	0.9	1.2	<0.05	0.2	<1	<0.3	<0.05	0.1	<0.05	<0.1	<0.02	0.07	0.8	5.75	0.3
W3-ARD-020	0.08	5.08	0.9	0.7	1.3	0.07	<0.1	<1	<0.3	<0.05	0.15	0.15	<0.1	<0.02	<0.05	1.2	6.58	0.5
W3-ARD-021	0.13	5.82	0.41	0.7	2	0.06	<0.1	<1	<0.3	<0.05	0.23	<0.05	<0.1	<0.02	<0.05	1.1	13.8	0.9
W3-ARD-022	0.13	3.77	0.14	2.9	24.4	0.11	4.7	<1	0.5	<0.05	0.27	<0.05	0.8	0.14	0.11	0.3	9.05	0.8
W3-ARD-023	<0.01	10.3	<0.05	0.7	<0.2	<0.05	0.5	<1	<0.3	<0.05	<0.02	0.07	<0.1	0.04	0.19	1.1	0.76	<0.1
W3-ARD-024	0.05	4.6	0.47	0.9	0.2	0.08	0.2	<1	<0.3	<0.05	0.08	0.06	<0.1	<0.02	<0.05	1.1	3.84	0.3
W3-ARD-025	0.1	5.42	0.75	0.8	<0.2	<0.05	<0.1	<1	<0.3	<0.05	0.17	0.11	<0.1	<0.02	0.06	1.1	7.54	0.7
Duplicate																		
W3-ARD-024	0.05	4.74	0.47	0.8	0.2	0.09	0.2	<1	<0.3	<0.05	0.08	0.07	<0.1	<0.02	<0.05	1.1	3.84	0.3
QC																		
CH4	0.06	3.25	0.15	8.3	70.8	0.34	7.9	2	0.6	<0.05	0.29	0.55	2.3	0.44	0.27	3.2	6.08	0.4
Certified Values	#N/A	3.05	0.19	8.24	67	0.34	7.99	1.57	0.6	0.3	0.27	0.42	2.2	0.4	0.29	2.15	5.66	#N/A
Tolerance (%)	#N/A	14.1	75	16.1	10.7	47.3	13.1	169.6	134.5	51.7	28.4	39.6	21.2	22.6	52.9	21.6	12.2	#N/A

Appendix A2:

Sample ID	SiO2 %	Al2O3 %	Fe2O3 %	CaO %	MgO %	Na2O %	K2O %	MnO %	TiO2 %	P2O5 %	Cr2O3 %	Ba %	LOI %	SUM %
	0.01 4X	0.01 4X	0.01 4X	0.01 4X	0.01 4X	0.01 4X	0.01 4X	0.01 4X	0.01 4X	0.01 4X	0.00 4X	0.01 4X	-5.11 4X	0.01 4X
W3-ARD-001	36.28	0.17	48.94	2.45	4.42	0.02	<0.01	1.35	<0.01	0.06	0.02	<0.01	6.64	100.38
W3-ARD-002	25.04	0.17	26.23	10.9	7.02	0.01	<0.01	2.55	<0.01	0.04	0.02	<0.01	28.22	100.21
W3-ARD-003	45.11	0.11	47.74	2.73	2.42	0.14	0.01	0.25	<0.01	0.04	0.029	0.05	1.78	100.42
W3-ARD-004	59.08	0.1	37.84	0.04	0.03	0.02	0.01	2.22	<0.01	0.02	0.04	<0.01	0.85	100.26
W3-ARD-005	42.55	0.19	54.59	0.01	0.02	0.02	0.01	1.25	0.05	0.05	0.03	<0.01	1.15	99.95
W3-ARD-006	45.32	13.28	20.17	7.13	4.72	2.83	1.26	0.52	3.58	0.87	0.034	0.08	0.54	100.33
W3-ARD-007	39.07	0.11	57.31	1.8	1.23	0.13	<0.01	0.28	<0.01	0.04	0.027	<0.01	0.38	100.39
W3-ARD-008	39.79	0.13	55.91	1.91	1.07	0.13	<0.01	0.31	<0.01	0.03	0.029	<0.01	0.79	100.09
W3-ARD-009	45.41	15.05	15.96	8.26	5.68	3.57	1.56	0.27	3.41	0.86	0.024	0.08	0.17	100.31
W3-ARD-010	44.69	17.04	14.65	8	6.56	3.19	0.94	0.22	3.13	0.51	0.035	0.05	0.98	100.01
W3-ARD-011	40.49	0.17	52.1	2.11	1.17	0.02	<0.01	0.4	<0.01	0.03	0.017	<0.01	3.01	99.54
W3-ARD-012	35.95	1.05	40.48	3.31	5.58	0.04	0.2	1.61	0.17	0.14	0.011	<0.01	11.3	99.84
W3-ARD-013	42.86	1.79	40.88	2.85	5.09	0.13	0.53	1.23	0.37	0.22	0.018	0.01	3.92	99.88
W3-ARD-014	51.26	1	35.06	2.72	2.4	0.19	0.14	1.04	0.27	0.11	0.022	0.01	5.93	100.16
W3-ARD-015	38.86	0.05	59.1	1.52	0.8	0.17	<0.01	0.24	<0.01	0.03	0.024	<0.01	-0.56	100.26
W3-ARD-016	39.42	0.05	60.22	0.23	0.01	0.02	<0.01	0.68	<0.01	0.01	0.03	<0.01	-0.14	100.53
W3-ARD-017	46.25	16.86	14.11	8.63	6.2	3.09	1.1	0.17	2.79	0.66	0.038	0.06	0.14	100.11
W3-ARD-018	45.5	0.1	50.74	0.03	0.01	0.03	0.03	2.56	<0.01	0.01	0.033	<0.01	0.58	99.64
W3-ARD-019	48.72	0.17	48.54	0.02	0.01	0.01	0.06	1.57	<0.01	0.03	0.028	0.01	0.58	99.74
W3-ARD-020	45.29	0.07	52.2	0.05	0.22	0.02	0.03	1.63	<0.01	0.01	0.033	<0.01	0.55	100.11
W3-ARD-021	47.13	0.23	50.71	0.04	0.23	0.04	0.04	1.8	<0.01	0.01	0.035	<0.01	0.43	100.69
W3-ARD-022	41.18	9.8	33.22	5.44	4.06	1.63	1.01	0.36	2.68	0.68	0.024	0.05	0.02	100.18
W3-ARD-023	92.7	0.05	1.65	1.68	0.89	<0.01	<0.01	0.05	0.01	<0.01	0.049	<0.01	2.28	99.4
W3-ARD-024	45.72	0.09	53.53	0.02	<0.01	<0.01	<0.01	0.23	<0.01	0.01	0.028	<0.01	-0.04	99.61
W3-ARD-025	42.22	0.07	55.13	0.01	0.02	0.02	<0.01	1.39	<0.01	0.02	0.031	<0.01	0.47	99.39
Duplicate														
W3-ARD-024	42.43	0.06	55.39	0.01	0.01	0.02	<0.01	1.41	<0.01	0.02	0.034	<0.01	0.54	99.92
QC														
CH4	50.45	20.78	6.25	7.95	0.52	7.13	1.66	0.11	0.28	0.13	<0.001	0.04	4.56	99.87
Certified Values	49.9	20.69	6.21	8.05	0.54	7.1	1.66	0.108	0.287	0.131	0.002	0.03	4.56	-
Tolerance (%)														