
Memorandum

To: Brad Thrall, Alexco Resource Corp.

From: Andrew Gault and Matt Corriveau, Alexco Environmental Group Inc.

CC: Kai Woloshyn, Alexco Environmental Group Inc.

Date: September 25, 2017

Re: Bermingham Waste Rock Geochemical Characterization

1 INTRODUCTION

Alexco Keno Hill Mining Corp. (AKHM) is exploring the resource potential of the Bermingham deposit, located within the historic Keno Hill Silver District (KHSD). As part of their exploration efforts, AKHM has developed a cover hole along the proposed advanced exploration decline, which will be driven through non-mineralized rock and is not intended to intercept significant metal sulphide mineralization.

Rock samples spanning the rock lithologies identified at the Bermingham site were collected from a cover hole encompassing the first 255 m of the decline. Upon the decline reaching a length of 255m an additional cover hole will be drilled to the bottom of the decline. This memorandum summarizes the results of static geochemical testing of the rock samples from the first 255 m of the decline in terms of their potential for acid rock drainage (ARD) and/or metal leaching (ML) and their relation to the proposed Bermingham mine geochemistry.

2 SITE GEOLOGY

2.1 REGIONAL AND DISTRICT GEOLOGY

The KHSD is primarily composed of Yukon Group metasedimentary rocks which are described in the Keno Hill Silver District Environmental Conditions Report (AEG, 2016a) and the NI43-101 technical report for the Birmingham Exploration Project (Roscoe Postle and Associates Inc., 2017). The mineralization of the KHSD is hosted within the Mississippian Keno Hill Quartzite Formation in the Tombstone Thrust Sheet, which conformably overlies the Devonian Earn Group to the north and is structurally overlain by the Upper Proterozoic Hyland Group Yusezyu Formation across the Robert Service Thrust Fault in the south (Roscoe Postle and Associates Inc., 2017).

The stratigraphic units in the district are mainly composed of the Earn Group and the Keno Hill Quartzite. The Earn Group comprises typically phyllitic, grey graphitic metasediments with an upper band of greenish chlorite-sericite meta-felsic volcanics, and minor interbedded quartzite proximal to the conformable transition to the overlying Keno Hill Basal Quartzite Member. The Keno Hill Quartzite is structurally approximately 1,900 m thick and contains the lower massive blocky Basal Quartzite Member (approximate structural thickness of 1,100 m) with thin to thick quartzite and graphitic schist interbeds and the Sourdough Hill Member (~800 m) with basal horizons of sericitic meta-rhyolite and graphitic schist, intermediate units of an Upper Quartzite, quartz eye grits, and chloritic schist that enter an overlying carbonate rich section containing well-defined black limestone beds. Mid-Triassic greenstone lenses up to 100 m thick are also contained within the Keno Hill sequence but only to the top of the Basal Quartzite Member (Roscoe Postle and Associates Inc., 2017).

One to two phases of deformation and chloritic grade regional metamorphism and isoclinal folding produced overturned isoclinal folds in the Keno Hill Quartzite Basal Member overlying the Earn Group. The mineralization was developed in northeast striking, southeasterly dipping normal oblique normal faults with displacement of tens to hundreds of metres formed likely during the early stages of deformation.

The KHSD mineralization is in the form of silver-rich base metal quartz-carbonate veins that are predominantly present in steep southeasterly dipping vein-filled faults with deposits hosted by thick competent Basal Quartzite of the Keno Hill Quartzite or occasionally where greenstone forms part of the Earn Group wall rock (Roscoe Postle and Associates Inc., 2017).

The Birmingham prospect is located on the northern flank of Galena Hill above the town of Elsa and about 24 km southwest of Keno City by road. The mineralization is hosted by the Keno Hill Basal Quartzite at the stratigraphic top of the unit which contains minor interbedded greenstone. The mineralization is overlain by the Keno Hill Quartzite Sourdough Hill Member with graphitic or sericite schist marker units below the Upper Quartzite (Roscoe Postle and Associates Inc., 2017).

Most of the historic mining was conducted within the upper levels of the Basal Quartzite Member. Basal Quartzite interspersed with graphitic schists compose the footwall stratigraphy to the Birmingham vein-fault structure which essentially hosts the mineralization. The two stratigraphic lithologies of interest are a massive (~50 m), pale grey, siliceous, massive quartzite and a very thick (15-25 m) graphitic schist approximately 240 m below the top of the Basal Quartzite Member. The mineralized segments in Birmingham include the Main Birmingham Vein-Fault and the Aho Vein-Fault. The Birmingham Vein-Faults are commonly 0.5-2.5 m wide

and consist of iron-magnesium-manganese carbonate (dolomite, ankerite and siderite, quartz and calcite gangue with sulphide including sphalerite, galena, pyrite and arsenopyrite with accessory chalcopyrite, argentiferous tetrahedrite, jamesonite, pyrrargyrite, stephanite and native silver. The Aho vein-fault is a multi-metre wide quartz within a halo of structurally damaged rocks with quartz being the predominant gangue mineral, with sulphides (arsenopyrite and pyrite, minor galena and sphalerite) that typically constitute less than 2% of the vein, minor calcite and less common iron-rich carbonates; although vein intercepts close to the Bermingham and Bermingham Footwall veins can host more abundant iron rich carbonates (Roscoe Postle and Associates Inc., 2017).

A brief descriptive overview of the major lithology types is summarized below from Boyle (1962), Altura (2008a) and (Roscoe Postle and Associates Inc., 2017).

- **Quartzite (QTZT):** The dominant lithology unit at the Bermingham deposit development rock and occurs both as thickly and thinly bedded sequences with assemblages of graphitic schist. The quartzites are variably silicified with purer quartzites a few metres thick and darker grey, impure quartzites on to four metres thick. Quartzites are comprised primarily of quartz but also contain some mica, carbonate minerals and carbonaceous materials. Accessory minerals include leucoxene, tourmaline, zircon, apatite and pyrite. Calcareous quartzite contains disseminated primary calcite that fizzes readily when subjected to dilute hydrochloric acid.
- **Schist (SCH):** The schist within the Bermingham development area are most commonly graphitic schist (GSCH), which are black or dark gray in color due to their significant carbon content, occur in beds from millimetre to many meters in scale, and can be intercalated with quartzites as well as the other lithologies. In addition to graphite; quartz, mica, carbonates, feldspar, chlorite, isotropic colloidal material and pyrite metacrysts have been identified in thin sections within these rocks. Although not anticipated to be present in significant quantities in the Bermingham development (i.e., <5%), other forms of schist are documented elsewhere in the KHSD. These include quartz sericite schist (SSCH) and chlorite schists, which are pale to dark green in colour. Thin sections of sericite schists show primarily quartz and sericite composition, with trace carbonate minerals and leucoxene. Accessory minerals include apatite, zircon, tourmaline and pyrite metacrysts. Calcareous schist contains disseminated primary calcite that fizzes readily when subjected to dilute hydrochloric acid (HCl). Interbedded carbonaceous quartzite and schist (ICQS) and thin bedded quartzite (TQTZT), the latter of which does occur in the Bermingham development area, are also included as their own lithologies, but these units are predominantly composed of schist.
- **Greenstone (GNST):** Greenstones vary from narrow (0.3 – 2 m wide) to 100 m thick and vary in color from greyish green to dark green. Greenstones occur in conformable elongated lenses and sills as a result of boudinage, particularly within the more ductile schist units. Greenstones units are generally more resistant than the quartzites and schists and appear geomorphologically as the prominent hills in the KHSD. Thin sections show significant variety in mineral composition and texture but generally show a high degree of alteration. The primary mineralogy of the greenstones includes hornblende, actinolite, saussurite (zoisite, epidote, albite, sericite, carbonate), plagioclase (oligoclase to andesine), chlorite, stilpnomelane, biotite, sericite, leucoxene, and carbonate minerals. Quartz, K-feldspar, ilmenite, magnetite, limonite and apatite are minor constituents with some pyrite. Chlorite is also generally present, which is primarily responsible for this rock's color.

Quartzite is expected to be the dominant rock lithology encountered in the Bermingham exploration decline, with minor amounts of graphitic schist and greenstone units (Table 2-1).

Table 2-1: The Relative Abundances of Lithologies Present in the Proposed Bermingham Deposit Development Areas

Lithology	Relative Abundance
Quartzite (QTZT) - including Calcareous (CQTZT) and Thin-bedded TQTZT)	70%
Graphitic Schist - GSCH (including ICQS)	20%
Greenstone – GNST	10%
Total	100%

3 METHODS

3.1 SAMPLE SELECTION

Fifty-five (55) rock samples were collected at regular intervals along the 255 m length of the Birmingham cover hole (Table 3-1). The sample selection was designed to maximize the spatial distribution in the area of the planned decline (which is located away from the mineralized vein faults structures) and represent the relative proportions of lithologies present in the Birmingham development and production area. All 55 samples used in this study were selected by Alexco personnel from the exploration decline cover hole drilled during 2017.

The spatial distribution and location of samples are shown in plan view (Figure 3-1) and cross section (Figure 3-2) with respect to the proposed exploration decline.

3.2 STATIC TESTING

3.2.1 Sample Preparation

The cover hole samples were submitted for analysis to Maxxam Analytics (Burnaby, BC, Canada). Each sample (typically 1.9 to 4.5 kg) was oven dried at 40°C and jaw-crushed to 95% passing $\frac{1}{4}$ inch (6.3 mm). This size fraction was used for the shake flask extraction (SFE) testing. A subsample (150 to 250 g) of the crushed material was obtained using a riffle splitter and was further pulverized to 85% passing 200 mesh (75 μm) for acid base accounting, elemental, and X-ray diffraction analyses.

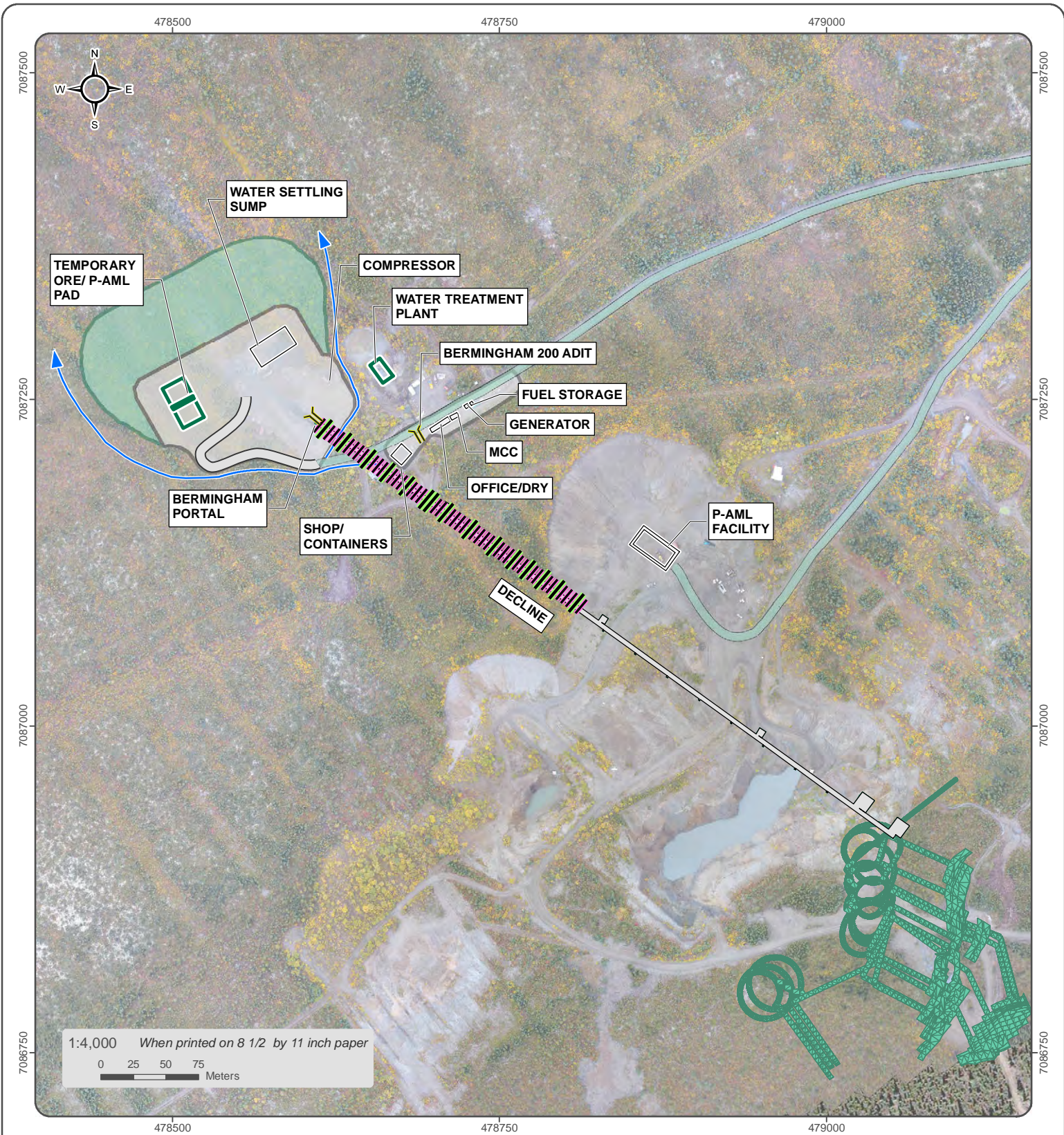
3.2.2 Acid Base Accounting

Acid base accounting (ABA) analyses were conducted on 15 of the cover hole samples that spanned the length of the cover hole and all lithologies present (Table 3-1). The ABA analysis included:

- Siderite-corrected neutralization potential (Skousen et al., 1997);
- Total Sulphur by Leco;
- Sulphate-sulphur by HCl extraction;
- Total inorganic carbon; and
- Paste pH.

Table 3-1: Waste Rock Sampling Intervals, Lithology, and Analysis

Sample ID	From (m)	To (m)	Lithology	Aqua Regia metals	ABA	SFE	XRD
M369901	0.0	4.5	QTZT	x			
M369902	4.5	9.0	QTZT	x	x	x	
M369903	9.0	13.5	QTZT	x			
M369904	13.5	18.0	QTZT	x			
M369906	18.0	22.5	GSCH	x			
M369907	22.5	27.0	GSCH	x	x	x	
M369908	27.0	31.5	GSCH	x			
M369909	31.5	36.0	GSCH	x			
M369911	40.5	45.0	GSCH	x			
M369912	45.0	49.5	QTZT 75%/GSCH 25%	x			
M369913	49.5	54.0	QTZT	X7	x	x	x
M369914	54.0	58.5	QTZT	x			
M369916	58.5	63.0	TQTZT	x			
M369917	63.0	67.5	FAULT	x			
M369918	67.5	72.0	GSCH	x	x	x	
M369919	72.0	76.5	GSCH	x			
M369920	76.5	81.0	GSCH	x			
M369921	81.0	85.5	GSCH	x			
M369922	85.5	90.0	GSCH	x	x	x	x
M369924	90.0	94.5	GSCH	x			
M369925	94.5	99.0	GSCH	x			
M369926	99.0	103.5	GSCH	x			
M369927	103.5	108.0	GSCH	x	x	x	
M369928	108.0	112.5	QTZT	x	x	x	
M369929	112.5	117.0	QTZT 70%/TQTZT 30%	x			
M369931	117.0	121.5	TQTZT	x			
M369932	121.5	126.0	TQTZT	x	x	x	
M369933	126.0	130.5	TQTZT	x			
M369934	130.5	135.0	TQTZT 75%/GSCH 25%	x			
M369936	135.0	139.5	QTZT	x			
M369937	139.5	144.0	QTZT 80%/ TQTZT 20%	x			
M369938	144.0	148.5	QTZT	x	x	x	
M369939	148.5	153.0	QTZT	x			
M369940	153.0	157.5	QTZT	x			
M369941	157.5	162.0	QTZT	x			
M369942	162.0	166.5	QTZT	x			
M369943	166.5	171.0	QTZT	x	x	x	x
M369944	171.0	175.5	QTZT	x			
M369945	175.5	180.0	QTZT	x			
M369947	180.0	184.5	TQTZT	x			
M369948	184.5	189.0	TQTZT	x	x	x	x
M369949	189.0	193.5	TQTZT	x			
M369951	193.5	198.0	QTZT	x			
M369952	198.0	202.5	QTZT	x	x	x	
M369953	202.5	207.0	QTZT	x			
M369954	207.0	211.5	QTZT	x			
M369955	211.5	216.0	QTZT	x	x	x	
M369956	216.0	220.5	QTZT	x			
M369958	220.5	225.0	QTZT	x			
M369959	225.0	229.5	QTZT	x	x	x	
M369960	229.5	234.0	QTZT	x			
M369961	234.0	238.5	QTZT 70%/TQTZT 30%	x			
M369962	238.5	243.0	TQTZT	x			
M369963	243.0	247.5	TQTZT	x	x	x	
M369964	247.5	252.0	TQTZT	x			



**ALEXCO KENO HILL MINING CORP.
BERMINGHAM**

**FIGURE 3-1
SAMPLE LOCATION
PLAN VIEW**

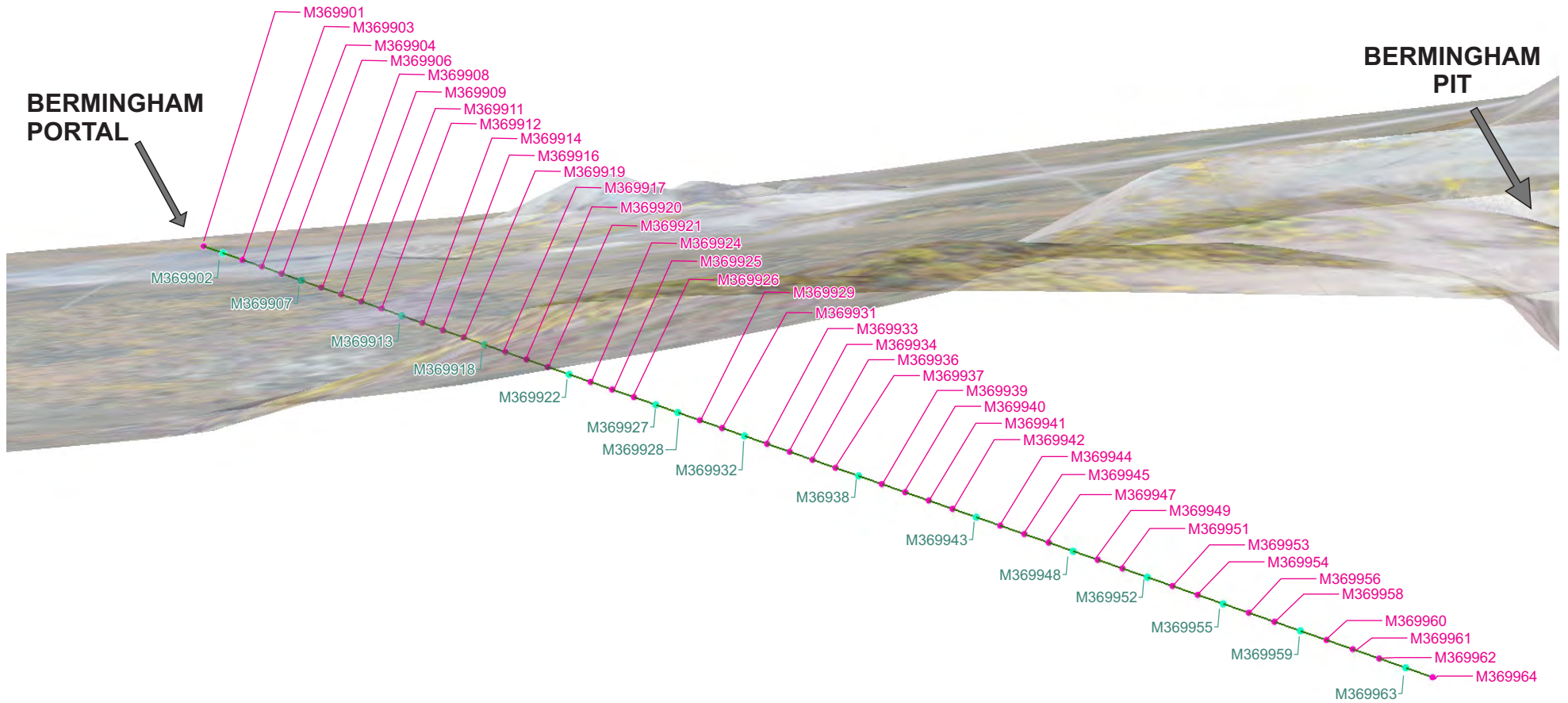
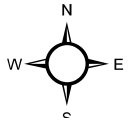
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National topographic Data Base (NTDB) compiled by Natural Resources Canada at a scale of 1:50,000. Reproduced under license from Her Majesty the Queen, as represented by the Minister of Natural Resources Canada. All rights reserved. Datum: NAD 83; Projection: UTM Zone 8N

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CONCEPTUAL DRAWING; FEATURES ARE NOT TO SCALE

- ICP Aqua Regia, ABA and SFE Samples
- ICP Aqua Regia Samples



ALEXCO KENO HILL MINING CORP.
FIGURE 3-2
CROSS SECTION LOOKING NORTH OF
BERMINGHAM COVER HOLE SAMPLES

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The neutralization potential (NP) was determined using the Sobek method with siderite-correction (Skousen et al., 1997). The siderite-corrected method was preferred since:

- Ferrous carbonate including siderite was anticipated to represent a significant portion of the carbonate mineralogy in a number of samples based on ABA data collected on waste rock samples elsewhere in the KHSD; and
- The siderite-corrected NP method has been used in the majority of ABA characterization work on waste rock from proposed production units elsewhere in the KHSD, which facilitates the comparison of the Birmingham ABA data with the wider KHSD dataset.

Total sulphur was measured by LECO, sulphate was determined with HCl leach and sulphide sulphur calculated as the difference between total sulphur and sulphate sulphur. Total inorganic carbon was measured with the direct HCl method.

3.2.3 Elemental Analysis

The trace element composition of each sample was determined using aqua regia digestion followed by ICP-MS analysis. The pulped sample (0.5 g) was leached in hot (95°C) aqua regia (3:1 ratio of concentrated hydrochloric acid: nitric acid). Following digestion, the filtered digestate was analyzed by inductively coupled plasma-mass spectrometry (ICP-MS) to determine the trace and major element content of the sample. This method is considered as a pseudo-total digestion; although the majority of minerals in the sample will be dissolved (e.g., carbonates, sulphides, hydroxides, and most oxides), some refractory silicate phases may be only partially digested. Nevertheless, dissolution of those minerals that are most environmentally significant from an ARD/ML perspective (i.e., sulphides and carbonates) is accomplished by aqua regia digestion.

3.2.4 X-Ray Diffraction

Rietveld X-ray diffraction (XRD) analysis was conducted on four waste rock sample (Table 3-1) at the University of British Columbia via Maxxam Analytics (Burnaby, BC). The sample was reduced to the optimum grain-size range for quantitative X-ray analysis (<10 µm) by grinding under ethanol in a vibratory McCrone Micronising Mill for 10 minutes. Step-scan X-ray powder-diffraction data were collected over a range 3-80° 2θ with Co Kα radiation on a Bruker D8 Advance Bragg-Brentano diffractometer equipped with an Fe monochromator foil, 0.6 mm (0.3°) divergence slit, incident- and diffracted-beam Soller slits and a LynxEye-XE detector. The long fine-focus Co X-ray tube was operated at 35 kV and 40 mA, using a take-off angle of 6°.

The resulting X-ray diffractogram was analyzed using the International Centre for Diffraction Database PDF-4 and Search-Match software by Bruker. X-ray powder-diffraction data of the samples were refined with Rietveld program Topas 4.2 (Bruker AXS). The results of quantitative phase analysis represent the relative amounts of crystalline phases normalized to 100%. The detection limit is approximately 0.1 wt.%, dependent on the phase in question.

3.2.5 Shake Flask Extraction

A standard 24-hour shake flask extraction (Price, 2009) test was conducted on the same 15 sample intervals that were subjected to ABA analysis (Table 3-1). The tests were performed using rock ground to less than 6.3 mm and deionized water as the extraction fluid at a 3:1 water to solids ratio, by weight. Following 24 hours of gyratory shaking, the sample was filtered (0.45 µm) and the concentrations of major and trace elements in the leachate was measured by ICP-MS.

3.3 DATA ANALYSIS

Data were compiled for statistical analyses and geochemical characterization. Static data that were reported below the detection limit were assigned values one half of that detection limit.

3.3.1 Quality Assurance / Quality Control

The laboratory testing included the analysis of replicates, blanks, certified reference materials (CRMs), spiked blanks, and spiked samples, depending on the nature of the analysis.

The precision of replicate analyses was assessed by the relative percent difference (RPD) between the two sets of analyses, defined as:

$$\%RPD = 100 \times ABS(A-B) / MEAN(A,B)$$

Where: A is the first analysis of the sample;

B is the second analysis of the sample;

ABS (A-B) is the absolute value of the difference between the two analyses; and

MEAN (A,B) is the average of the analysis A and analysis B results

The accuracy of the CRM, blank spikes and matrix spikes analyses was assessed by percent recovery, defined as:

$$\% \text{ recovery} = 100 \times A/B$$

Where: A is the measured value; and

B is the certified value (CRM) or known spiked concentration (blank and matrix spikes).

For the ABA analyses, approximately one duplicate was analyzed for every five samples. Six CRM and three blanks were included for the 15 ABA sample analyses. An RPD of ≤15% was considered acceptable for the ABA parameters where the value is present at >10x the reporting detection limit (RDL). All the ABA duplicates that returned values >10x the RDL had acceptable RPDs (i.e., ≤15%). A CRM recovery of 85 to 115% was deemed acceptable where the analyte was present at 10x the RDL. The ABA CRMs employed included ARD-Paste pH

(8732871, pH 8.29), ARD REF MAT GS311-1 (8732837), ARD Spike 2.37% CO₂ (8732871) and ARD-GS910-4 CS (8732871) for total sulphur, and two SO₄²⁻ spikes (RS10 STF and ARD Ref Mat DBOHC). Analysis of ABA CRMs indicated excellent agreement with the certified values (recoveries of 91 to 102%). All the ABA blanks returned values that were below the detection limit indicating that there were no significant sources of laboratory-based contamination.

For the aqua regia ICP-MS analyses, two CRM, one duplicate digestion, and two method blanks were included for the 55 samples. An RPD tolerance of 20% is employed for the aqua regia ICP-MS duplicates where the value is >10x the RDL. All other duplicate analyses returned RPDs ≤20% where the value was >10x the RDL. Aqua regia ICP-MS analysis of the OREAS 905 and OREAS 920 CRMs returned a recovery within the 85 to 115% window for those analytes that were present at >10x the RDL. All the aqua regia ICP-MS method blanks returned values that were below the detection limit indicating that there were no significant sources of laboratory-based contamination.

For the SFE work, four replicates (analysis of the same shake flask extract aliquot) and two duplicates (analysis of second shake flask extract produced by processing a second split of the original pulped sample) were included for the 15 samples analyzed. An RPD tolerance of 20% is employed for the replicate analysis and 35% for the duplicate analysis where the value is >10x the RDL. All of the replicate SFE analyses that were >10x their respective detection limits returned a satisfactory RPD of <20%. The majority of duplicate analyses also satisfied the ≤35% RPD criterion, although the cobalt, iron, manganese, and nickel concentrations in one duplicate sample (M369938) returned >35% RPD and barium in the other duplicate sample (M369963) returned >35% RPD.

A method blank was included with each batch of SFE testing. Laboratory blanks, spiked blanks, and spiked samples were also run by the analytical laboratory with each batch of samples to evaluate laboratory-based contamination and analytical accuracy. The SFE method blanks typically returned below detection values for the majority of parameters. The concentration of some parameters was sporadically detected, but only at levels that were marginally above their detection limit (typically <3x the detection limit). The laboratory reference materials returned below detection data for all parameters and the blank and matrix spikes were all within 85 to 115% of the known spiked concentration.

Overall, the QA/QC results indicate that the data produced by Maxxam are acceptable for use.

4 RESULTS

4.1 XRD

The purpose of XRD is to quantitatively determine the crystalline mineralogy of samples and identify the minerals that may influence the acid rock drainage and/or metal leaching (ARD/ML) properties of the rock material. Carbonate minerals (primarily calcite and dolomite) are typically the principal contributors to neutralization potential (NP) whereas sulphide minerals (primarily ferrous sulphide minerals, generally pyrite) are usually the major sources of acid potential (AP).

The Rietveld XRD results from the analysis of four cover hole samples are shown in Table 4-1. Quartz (SiO_2) comprised the bulk of all four samples, particularly in the QTZT lithology samples M369913 and M369943 (98.1 and 96.8%, respectively). The GSCH sample (M369922) contained the largest non-quartz proportion of minerals with phyllosilicates illite ($\text{K}_{0.65}\text{Al}_{2.0}\text{Al}_{0.65}\text{Si}_{3.35}\text{O}_{10}(\text{OH})_2$), muscovite ($\text{KAl}_2\text{AlSi}_3\text{O}_{10}(\text{OH})_2$), chloritoid ($(\text{Fe}^{2+}, \text{Mg}, \text{Mn}^{2+})\text{Al}_2(\text{SiO}_4)\text{O}(\text{OH})_2$), paragonite ($\text{NaAl}_2\text{AlSi}_3\text{O}_{10}(\text{OH})_2$) and chlinochlore ($(\text{Mg}, \text{Fe}^{2+})_5\text{Al}(\text{Si}_3\text{Al})\text{O}_{10}(\text{OH})_8$) making up the majority of the sample (52.5%). Calcite (CaCO_3) – the mineral which most readily contributes to acid neutralization – was not identified in any of the analyzed samples; however, carbonate minerals such as ankerite ($\text{Ca}(\text{Fe}^{2+}, \text{Mg}, \text{Mn})(\text{CO}_3)_2$) or dolomite ($\text{CaMg}(\text{CO}_3)_2$) (M369913-QTZT and M369922-GSCH) and siderite ($\text{Fe}^{2+}\text{CO}_3$) were identified in (M369922-GSCH). It is challenging to distinguish dolomite from ankerite using quantitative XRD alone (Day, 2009) and the certainty of the distribution between dolomite and ankerite by XRD is unclear. Dolomite contributes to acid neutralization as does a portion of ankerite, however, the ferrous (and to a lesser extent, manganous) carbonate component of ankerite – like siderite - is not a net contributor to acid neutralization since an equivalent amount of acidity that is consumed by carbonate neutralization is released upon the oxidation and hydrolysis of ferrous iron. However, ankerite with higher magnesium content relative to iron may contribute to acid neutralization, but it is generally less reactive than dolomite.

Pyrite (FeS_2) was identified in the two QTZT samples analyzed by XRD at trace levels (0.1 and 0.2 wt.%) and is the primary source of acid potential in these samples. No metal sulphide minerals were detected by XRD in the GSCH and TQTZT samples.

Table 4-1: X-Ray Diffraction Analysis of Waste Rock Samples

Mineral	Ideal Formula	Units	Sample ID			
			M369913	M369922	M369943	M369948
Lithology			QTZT	GSCH	QTZT	TQZT
Ankerite - Dolomite	$\text{Ca}(\text{Fe}^{2+}, \text{Mg}, \text{Mn})(\text{CO}_3)_2 - \text{CaMg}(\text{CO}_3)_2$	wt.%	0.4	1.4		
Chloritoid	$(\text{Fe}^{2+}, \text{Mg}, \text{Mn}^{2+})\text{Al}_2(\text{SiO}_4)\text{O}(\text{OH})_2$	wt.%		10.5	1.2	
Clinocllore	$(\text{Mg}, \text{Fe}^{2+})_5\text{Al}(\text{Si}_3\text{Al})\text{O}_{10}(\text{OH})_8$	wt.%	0.5	3.3		0.9
Illite-Muscovite 2M1	$\text{K}_{0.65}\text{Al}_{2.0}\text{Al}_{0.65}\text{Si}_{3.35}\text{O}_{10}(\text{OH})_2 - \text{KAl}_2\text{AlSi}_3\text{O}_{10}(\text{OH})_2$	wt.%	0.9	30.4	1.2	27.4
Kaolinite	$\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$	wt.%			0.5	
Paragonite	$\text{NaAl}_2\text{AlSi}_3\text{O}_{10}(\text{OH})_2$	wt.%		8.3		
Plagioclase	$\text{NaAlSi}_3\text{O}_8 - \text{CaCl}_2\text{Si}_2\text{O}_8$	wt.%				0.7
Pyrite	FeS_2	wt.%	0.1		0.2	
Quartz	SiO_2	wt.%	98.1	44.1	96.8	70.1
Rutile	TiO_2	wt.%		1.5	0.1	0.9
Siderite	$\text{Fe}^{2+}\text{CO}_3$	wt.%		0.5		
Total		wt.%	100	100	100	100

4.2 ACID BASE ACCOUNTING

The purpose of ABA is to quantify the content and ratio of potentially acid producing and potentially acid consuming minerals in each sample. This is an indication of the acid generation potential of geologic materials. A summary of the ABA data is presented in Table 4-2.

4.2.1 Paste pH

The paste pH of all samples ranged from 7.2 to 8.7 with a median of pH 8.3. All samples were net neutralizing (defined as a paste pH > 5.5) at the time of analysis, which is consistent with the majority non-detectable sulphate-sulphur content of the samples (< 0.01 to 0.01 wt.%; Table 4-2). Comparison of paste pH with NP and AP showed no clear correlation, although lower paste pH values were generally associated with samples that had low NP (< 10 kg CaCO₃/t) and a neutralization potential ratio (NPR = NP/AP) of two or less (Figure 4-1).

Table 4-2: Acid Base Accounting Results Summary

Sample ID	Simplified Lithology	Paste pH	Inorganic Carbon (as CO ₂)	Carbonate NP	Total Sulphur	Sulphate Sulphur	Sulphide Sulphur	AP	Siderite-corrected NP	Fizz Rating	Siderite-corrected NPR
Units		pH Units	wt.%	kg CaCO ₃ /t	wt.%	wt.%	wt.%	kg CaCO ₃ /t	kg CaCO ₃ /t		
Detection Limit:			0.02	0.5	0.02	0.01	0.02	0.6	0.1		
M369902	QTZT	7.62	<0.08	<1.8	0.02	<0.01	0.02	0.6	2.8	NONE	4.7
M369907	GSCH	7.24	<0.08	<1.8	0.09	0.01	0.08	2.5	5.0	NONE	2.0
M369913	QTZT	8.12	0.08	1.8	0.04	<0.01	0.04	1.3	2.5	NONE	1.9
M369918	GSCH	8.35	0.12	2.7	0.09	<0.01	0.09	2.8	10.5	NONE	3.8
M369922	GSCH	8.32	0.20	4.6	0.07	<0.01	0.07	2.2	11.3	NONE	5.1
M369927	GSCH	8.29	0.14	3.2	0.08	<0.01	0.08	2.5	11.3	NONE	4.5
M369928	QTZT	8.08	<0.08	<1.8	0.03	<0.01	0.03	0.9	5.8	NONE	6.4
M369932	TQTZT	8.63	4.51	102.5	0.16	<0.01	0.16	5.0	118	STRONG	23.5
M369938	QTZT	8.09	0.61	13.9	0.20	<0.01	0.20	6.3	15.8	SLIGHT	2.5
M369943	QTZT	7.21	<0.08	<1.8	0.06	<0.01	0.06	1.9	2.3	NONE	1.2
M369948	TQTZT	8.02	<0.08	<1.8	0.02	<0.01	0.02	0.6	3.0	NONE	5.0
M369952	QTZT	8.32	<0.08	<1.8	0.04	<0.01	0.04	1.3	3.5	NONE	2.7
M369955	QTZT	8.65	0.91	20.7	0.08	<0.01	0.08	2.5	33.8	MODERATE	13.5
M369959	QTZT	8.59	0.65	14.8	0.03	<0.01	0.03	0.9	19.8	SLIGHT	22.0
M369963	TQTZT	8.36	0.80	18.2	0.03	<0.01	0.03	0.9	25.0	SLIGHT	27.8

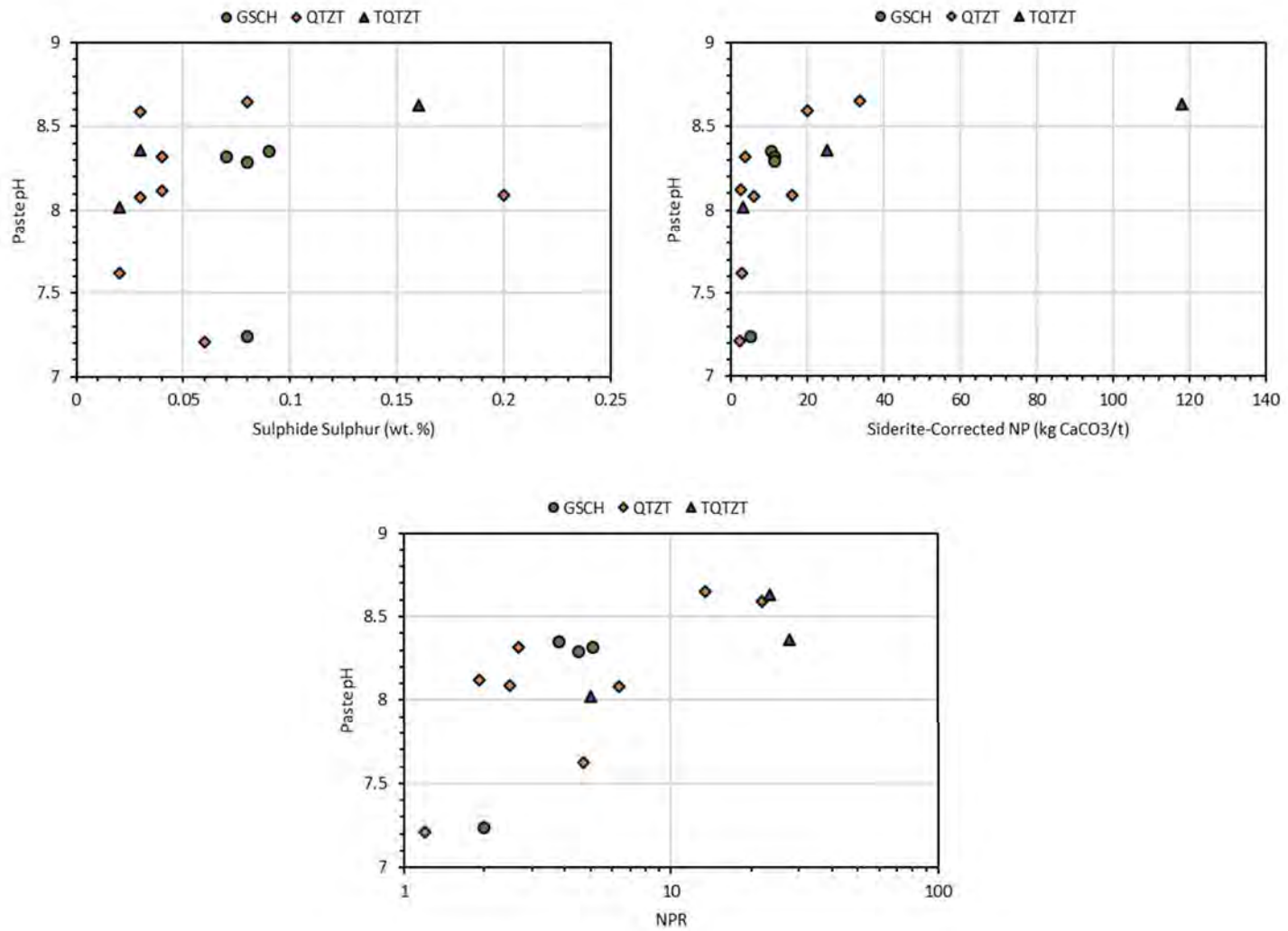


Figure 4-1: Comparison of Paste pH with Sulphide Sulphur (top left), NP (top right) and NPR (bottom)

4.2.2 Neutralization Potential

The acid neutralizing potential (NP) describes the total amount of acid that a material can neutralize and is an important factor in the prediction and mitigation of acidic drainage from waste rock material. Carbonate minerals such as calcite (CaCO_3) typically provide the bulk of NP in a sample; however, not all carbonate phases are net neutralizing under the oxidizing conditions encountered at the surface. Ferrous carbonate-bearing phases such as siderite (FeCO_3) have been identified as common gangue minerals associated with mineralization in the KHSO (Cathro, 2006). Ferrous carbonate phases do not contribute any net neutralizing potential under the well oxygenated weathering conditions present in most waste rock piles since the acid neutralized by the carbonate portion of the mineral is counterbalanced by the acid produced from the oxidation of ferrous iron.

The siderite-corrected NP (Skousen et al., 1997) procedure is capable of correcting for the presence of ferrous carbonates by promoting the oxidation of the liberated ferrous iron during the procedure. The Skousen method has also been adopted for other ABA testwork of waste rock from proposed production units elsewhere in the KHSO and thus was used to determine NP for these samples.

The NP distribution by sample lithology is displayed in Figure 4-2. The dataset NP ranged from 2.3 kg CaCO_3/t to 118 kg CaCO_3/t with a median of 10.5 kg CaCO_3/t . The highest NP was observed in a TQTZT sample (n=3). The two lowest NP samples were from the QTZT lithology (n=8). The median NP of QTZT and GSCH lithologies were 4.6 kg CaCO_3/t and 10.9 kg CaCO_3/t , respectively.

The siderite corrected NP and the carbonate NP (determined from the total inorganic carbon content) were broadly correlated confirming that carbonate minerals contribute the bulk of the NP in these samples (Figure 4-3). All samples had lower siderite-corrected NP than carbonate NP, suggestive of the presence of carbonate minerals that do not contribute to NP (e.g. ferrous iron-bearing phases such as siderite and ankerite) and supports the identification of siderite and ankerite minerals in the samples analyzed by XRD.

No relationship was observed between siderite-corrected NP and cover hole depth (Figure 4-4).

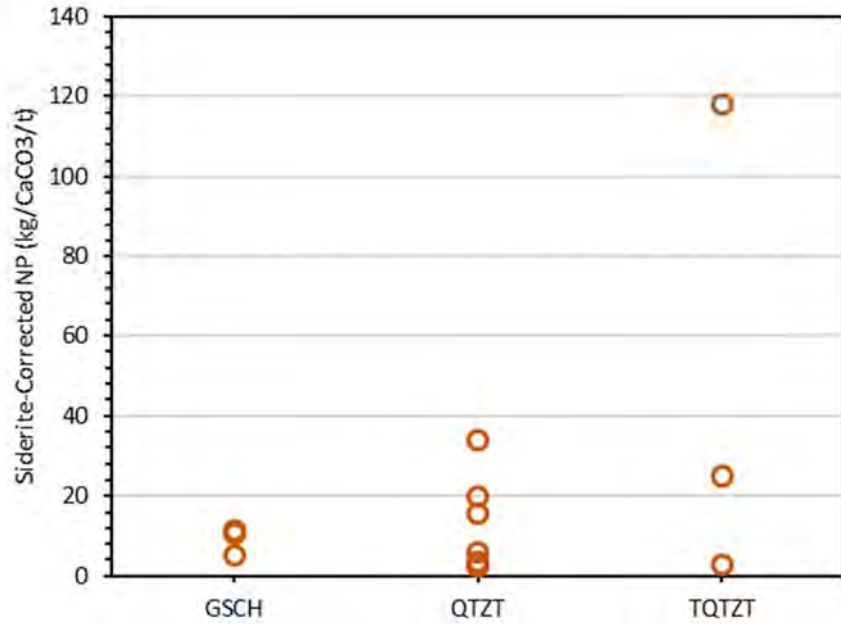
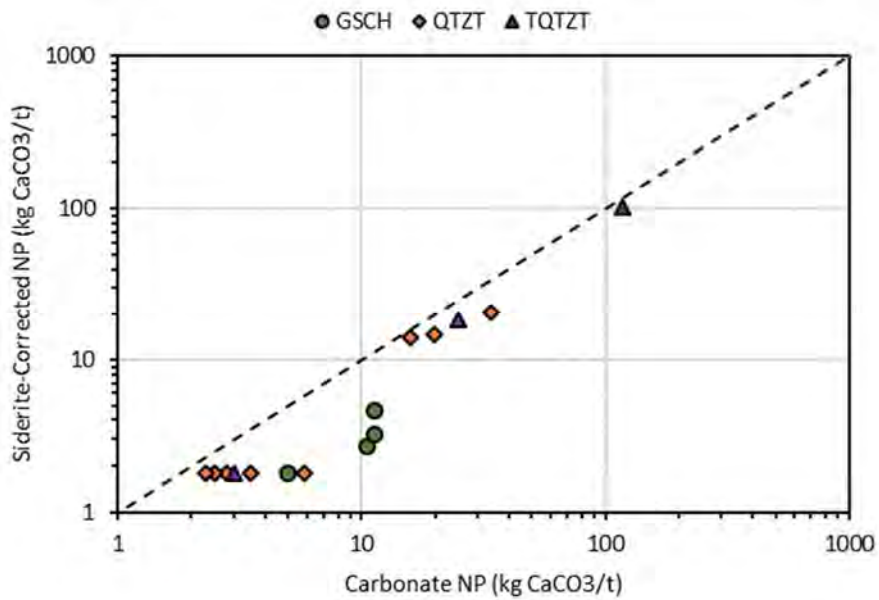


Figure 4-2: Distribution of NP by Lithology



Dashed Line Denotes Unity

Figure 4-3: Comparison of Siderite-Corrected NP with Carbonate NP

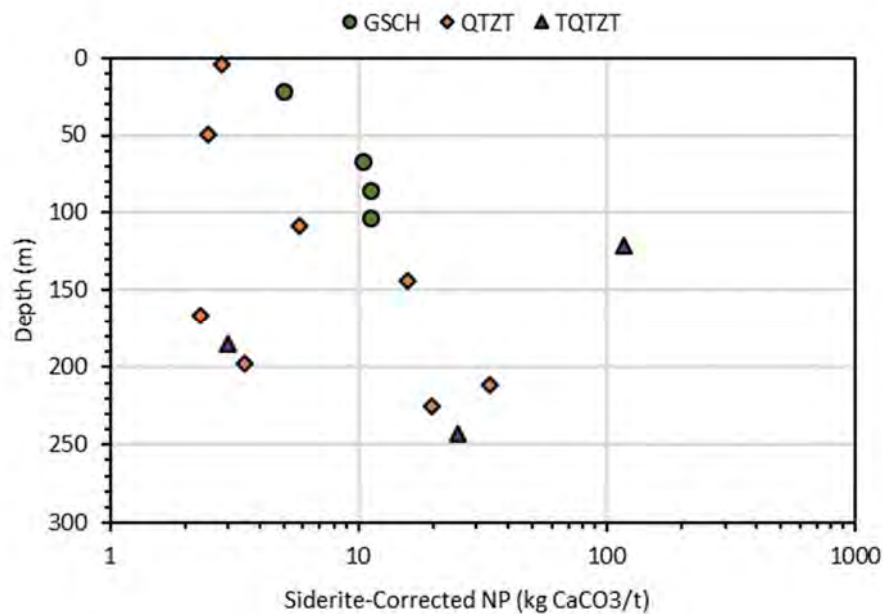


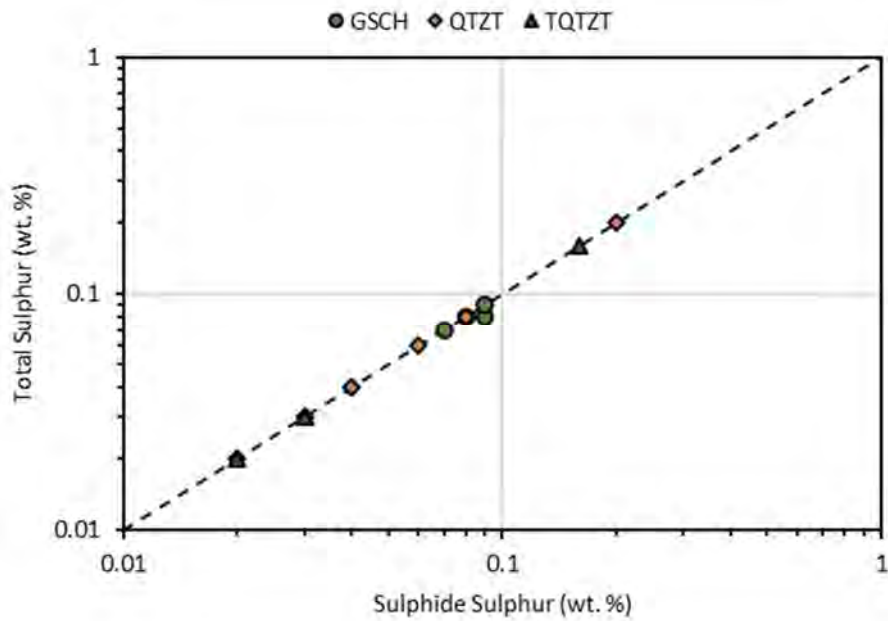
Figure 4-4: Siderite-corrected NP by Cover Hole Depth

4.2.3 Acid Potential and Sulphur Species

Knowledge of the chemical form, or speciation, of sulphur in a sample is key to predicting the acid generation potential (AP) and may also provide some insights regarding the capacity for short-term metal leaching. For example, sulphide is commonly encountered in the form of iron sulphide minerals such as pyrite (FeS₂), which has been identified by XRD analysis at trace levels in the Birmingham cover hole samples (Table 4-1). The oxidation of pyrite is an acid-producing reaction. As such, the measurement of the sulphide-sulphur content of a sample is important in order to calculate its AP. Sulphide-sulphur has been calculated here as the difference between the total sulphur concentration and the sulphate-sulphur concentration. Measurement of the sulphate-sulphur also has implications for metals that are readily soluble from waste rock since many metal sulphate minerals that accumulate during the oxidation of metal sulphides are highly soluble and are therefore susceptible to mobilization during flushing events.

Total sulphur in the analyzed samples ranged from below detection level (<0.02 wt.%) to 0.2 wt.% with a median concentration of 0.06 wt.%. The maximum sulphate-sulphur content in any of the samples was 0.01 wt.% and 14 of 15 sulphate analyses were below detection level (<0.01 wt.%). A comparison of the total sulphur and sulphide-sulphur concentrations (Figure 4-5 **Error! Reference source not found.**) indicates that almost all the sulphur content in the samples was present as sulphide. The low total sulphur content determined through ABA analysis agreed with XRD quantitative mineralogy analysis that identified sulphur mineral content (pyrite) in only two of four samples and at trace levels (0.1 and 0.2 wt.% pyrite).

No relationship was observed between sulphide sulphur content and cover hole depth (Figure 4-6).



Dashed Line Denotes Unity

Figure 4-5: Comparison of Total Sulphur Concentration with Sulphide-Sulphur Content

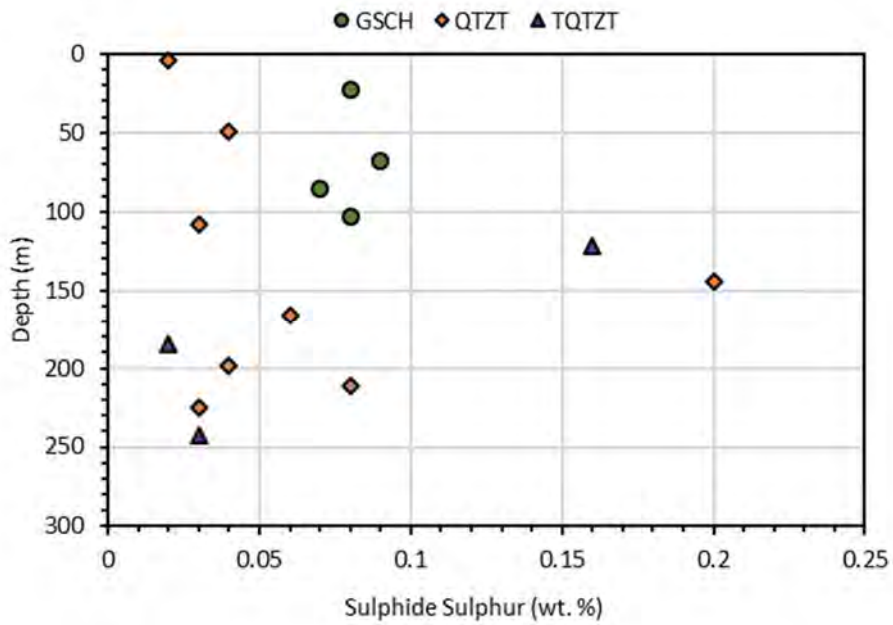


Figure 4-6: Sulphide Sulphur Content (wt. %) by Cover Hole Depth

4.2.4 Capacity for Acid Generation

The neutralization potential ratio (NPR) is defined as the ratio between the neutralization potential (NP) and acid potential (AP) and is calculated as NPR (i.e., $NPR = NP/AP$). Price (2009) states that the NPR can be used as an initial filter to predict the potential for exposed geological material to generate acidity such that:

- NPR<1 samples are potentially acid generating (PAG);
- $1 < NPR < 2$ samples are capable of acid generation but with some uncertainty; and,
- NPR>2 samples are not potentially acid generating (non-PAG).

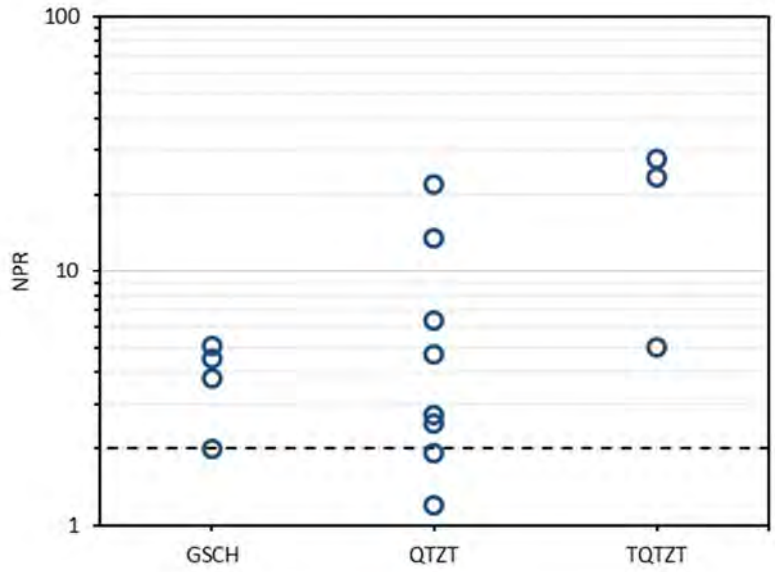
The distributions of NPR by lithology are shown in Figure 4-7. The distribution of samples in terms of the three NPR ranges indicated above are displayed in **Error! Reference source not found.** No samples returned an NPR<1. Three of 15 samples analyzed had $1 < NPR < 2$ (one each from the GSCH lithology and two from QTZT lithology) indicating uncertain acid generation potential. The remaining GSCH and QTZT and all of the TQTZT samples (87% of ABA analyzed samples) had NPR>2, suggesting material that is not expected to generate net acid.

A plot of NP versus AP is presented in Figure 4-8. Above an NP of 5 kg CaCO₃/t, all samples were classified as non-PAG while three of the five samples with NP≤5 kg CaCO₃/t were classified as having uncertain potential for acid generation. It should be noted that the three samples that have an NPR ≤2 all contain relatively low sulphide-sulphur content (0.04, 0.06, and 0.08 wt.%), suggesting that any acid generation that such samples may produce would be of limited extent.

As was the case for NP and AP separately, no trends were observed between NPR and cover hole depth, as shown in Figure 4-9.

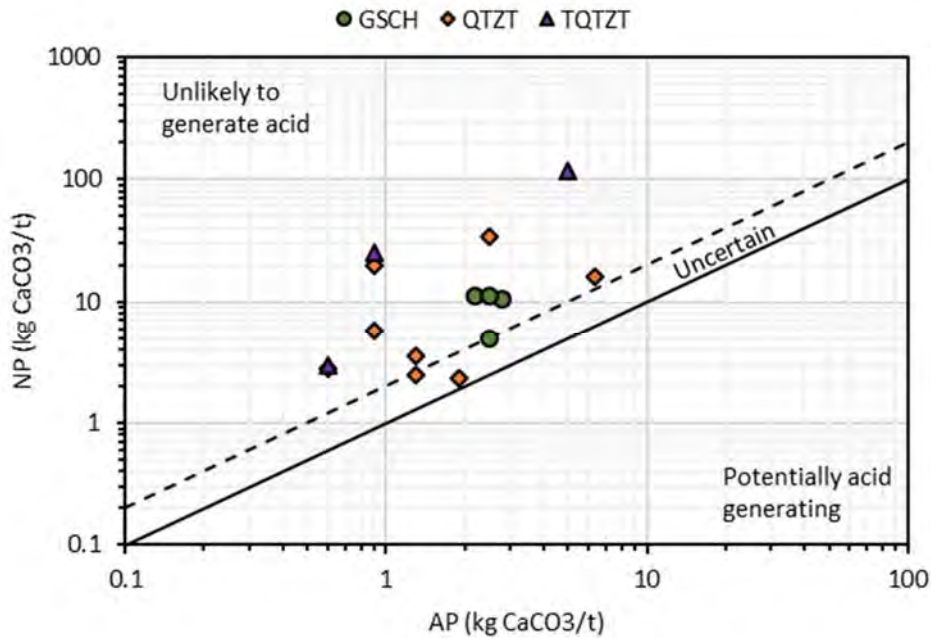
Table 4-3: Distribution of NPR Values by Lithology

Lithology	NPR<1	1<NPR<2	NPR>2	Count
	PAG	Uncertain	Non-PAG	
GSCH	0	1	3	4
QTZT	0	2	6	8
TQTZT	0	0	3	3
Total Samples	0	3	12	15



Dashed line indicates NPR = 2, above which acid generation is not likely.

Figure 4-7: Distribution of NPR by Lithology



Solid and dashed lines indicate NPR = 1 and NPR = 2, respectively.

Figure 4-8: Variability in NP and AP of Birmingham Cover Hole Samples by Lithology

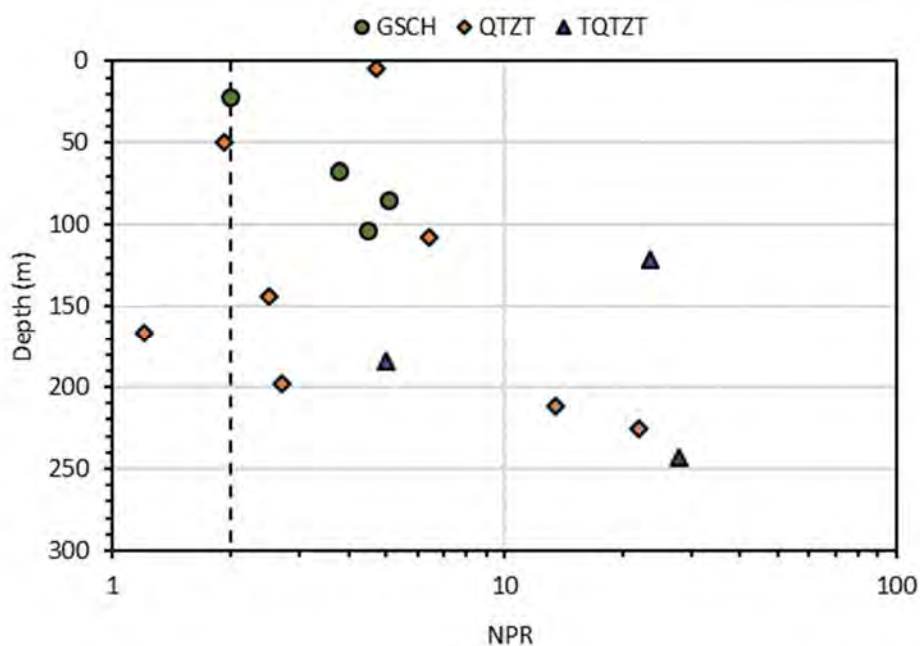


Figure 4-9: NPR by Cover Hole Depth

4.3 ELEMENTAL ANALYSIS

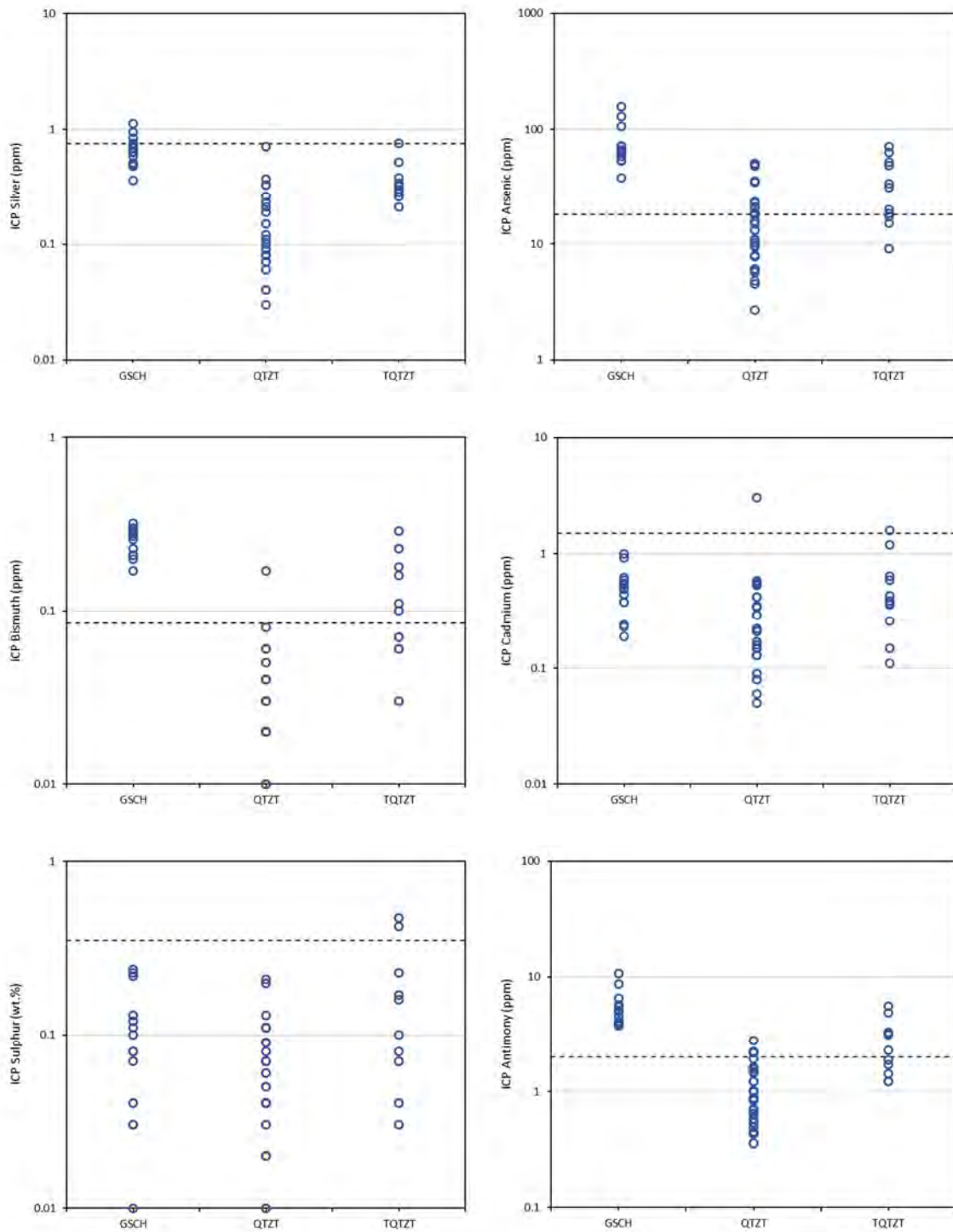
The tendency for an element to leach from its host rock is dependent on several factors including its mineral host, oxidation state and presence of complexing ligands. Although the bulk concentration of an element does not offer a direct measure of how mobile an element may be during weathering, it can provide a preliminary indication of constituents that should be monitored in subsequent leach and/or kinetic tests. Indeed, if correlations can be established between the leachable metal(loid) concentrations observed in static and/or kinetic testing and the bulk concentration, the bulk metal(loid) concentration may be used as a criterion in the waste rock management plan.

Bulk element concentrations were determined in all 55 cover hole core samples using aqua regia digestion and subsequent ICP-MS analysis of the digestate. The full element dataset is presented in Appendix A. Ten times the average elemental continental crustal abundance (CRC, 2005) was used as a qualitative threshold to identify elements that were present at elevated concentrations in these samples (Price, 2009). A statistical summary of elements that exhibited concentrations greater than their 10x crustal abundance threshold is provided in Table 4-4. Selenium (62% of samples), arsenic (60%), antimony (44%) and bismuth (40%) showed the greatest number of elevated concentrations with respect to average crustal abundance across the sample dataset. Tellurium also exhibited multiple exceedances of 10x crustal abundance (45%); however, this is largely because the aqua regia ICP-MS detection limit for tellurium was equivalent to its 10x crustal abundance (0.01 ppm).

Table 4-4: Summary Statistics for Selected Bulk Element Abundance in Dataset

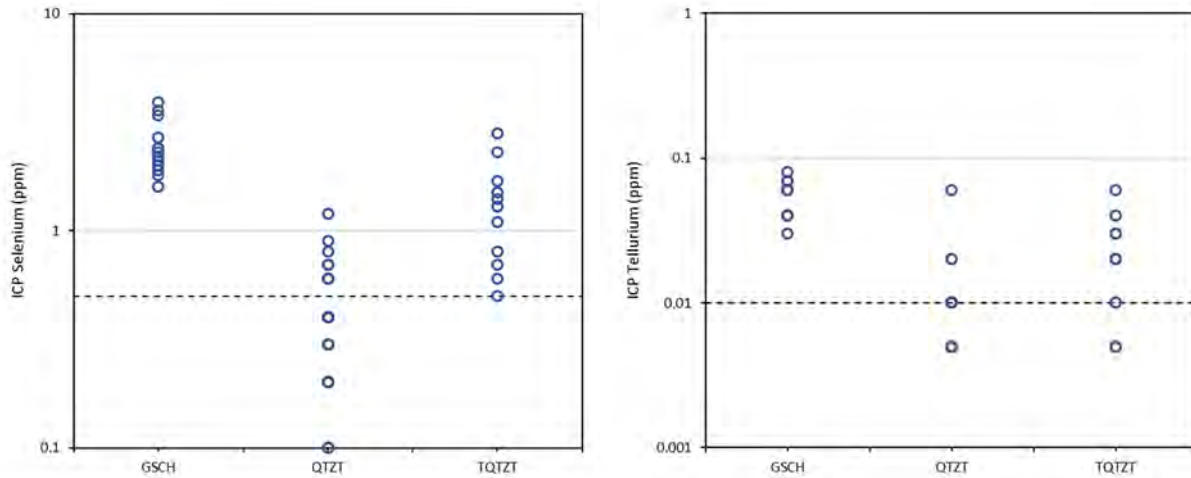
n = 55	Silver (ppm)	Arsenic (ppm)	Bismuth (ppm)	Cadmium (ppm)	Sulphur (wt.%)	Antimony (ppm)	Selenium (ppm)	Tellurium (ppm)
10x Crustal Abundance	0.75	18	0.085	1.5	0.35	2	0.5	0.01
Method Detection Limit	0.01	0.1	0.01	0.01	0.01	0.05	0.2	0.01
Maximum	1.12	157	0.32	3.01	0.47	10.7	3.9	0.08
3rd Quartile	0.505	53.45	0.205	0.535	0.11	3.93	1.85	0.04
Median	0.26	22.8	0.06	0.34	0.07	1.63	0.7	0.01
1st Quartile	0.1	11	0.02	0.165	0.04	0.88	0.35	0.005
Minimum	0.03	2.7	0.01	0.05	0.01	0.36	0.1	0.005
Samples >10x Crustal Abundance	9%	60%	40%	4%	4%	44%	62%	45%
Highlighted Results Exceed Crustal Value								

The distribution of the selected elements as a function of lithology is presented in Figure 4-10 and Figure 4-11. The highest bulk concentrations of several elements – silver, arsenic, bismuth, antimony, selenium and tellurium - were found in samples from the GSCH lithology. Of the 14 GSCH samples, all had arsenic, bismuth, antimony, selenium and tellurium content greater than 10x crustal abundance. The remainder of samples that had bulk concentrations in excess of 10x crustal abundance were from the TQTZT lithology (n=11); 91% had greater than 10x crustal selenium, 73% of TQTZT samples had arsenic content greater than 10x crustal abundance, 64% greater than 10x crustal tellurium, and 55% greater than 10x crustal abundance of bismuth and antimony. Additionally, the two samples with bulk sulphur content greater than 10x crustal abundance were from the TQTZT lithology. Bulk elemental concentrations were generally lower in the QTZT samples relative to GSCH and TQTZT lithologies.



Dashed line represents 10x crustal abundance

Figure 4-10: Distributions of Bulk Concentrations of Silver, Arsenic, Bismuth, Cadmium, Sulphur and Antimony by Lithology



Dashed line represents 10x crustal abundance

Figure 4-11: Distributions of Bulk Concentrations of Selenium and Tellurium by Lithology

4.4 SFE

The purpose of shake flask extraction (SFE) is to quantify the soluble constituents within geologic materials at a high water to solids ratio (3:1) (Price, 2009). SFE test results provide an indication of the soluble metal load that may be released in the short term from the interaction between excavated material and water. The complete set of 15 SFE results are presented in Appendix A.

The discussion of the results is focussed on constituents that were found to be elevated relative to crustal abundance from bulk elemental analysis and/or had SFE test data that were elevated relative to Canadian Council of Ministers of the Environment (CCME, 2017) or British Columbia Ministry of the Environment (BCMoE, 2016) long-term water quality guidelines for freshwater aquatic life. Where both CCME and BCMoE guidelines were available for a constituent, the most recently updated guideline was used since this captures the most recent science. Although such short-term leach extractions are not strictly comparable to water quality guidelines, such comparison aids the identification of elevated soluble constituent concentrations and the potential for trace element leaching. This comparison is strictly for reference purposes and does not indicate compliance or otherwise with CCME, BCMoE or other water quality guidelines. The minimum hardness observed in the nearest receiving waterbody, No Cash Creek (134 mg/L as CaCO₃ in 2016), was used to calculate guidelines for elements with hardness-dependent impacts: cadmium, copper, lead and nickel. Using the minimum hardness calculates a conservative guideline for comparison.

Based on the SFE data, concentrations of the following elements were found to exceed CCME or BCMoE water guideline in one or more samples:

- Fluoride;
- Aluminum;
- Arsenic; and
- Selenium.

The SFE leachate concentrations for these elements are summarized in Table 4-5. The SFE leachates were circumneutral to alkaline (pH 7.1 to 9.3), with three samples returning an SFE pH that exceeded the upper CCME pH threshold (pH 9), likely due to buffering by fine-grained silicates generated during the crushing of the drill core sample to <6.3 mm prior to SFE leaching.

Of those elements that had bulk concentrations greater than 10x crustal abundance, only arsenic (4 of 15 samples) and selenium (11 samples) also displayed elevated SFE-soluble constituent concentrations that exceeded their respective water quality guideline. Antimony, bismuth, silver and tellurium were not found in elevated concentrations in the SFE leachate despite elevated bulk concentrations relative to crustal abundance; indeed, SFE leachable tellurium and bismuth were both below method detection levels.

Table 4-5: Comparison of SFE Concentrations of all Samples with Aquatic Life Water Quality Guidelines

n = 15	pH	Fluoride	Aluminum	Arsenic	Selenium
		mg/L	mg/L	mg/L	mg/L
Guideline for Comparison	CCME	CCME	CCME	CCME	BCMoE
Guideline Value	6.5 - 9.0	0.12	0.1 ^a	0.005	0.002
Method Detection Limit	-	0.01	0.0005	0.00002	0.00004
Maximum	9.34	0.8	0.45	0.022	0.011
3rd Quartile	8.83	0.29	0.14	0.0064	0.0051
Median	8.53	0.13	0.065	0.0029	0.0031
1st Quartile	7.81	0.1	0.025	0.0019	0.0021
Minimum	7.09	0.04	0.0080	0.00074	0.00050
Samples >CCME/BCMoE	20%	53%	33%	27%	73%
Highlighted Results Exceed CCME/BCMoE					

^a Guideline based on receiving waters with pH>6.5

^b Guideline based on minimum hardness observed in No Cash Creek in 2016 (134 mg/L CaCO₃)

Although not present at elevated bulk concentrations, dissolved aluminum concentrations that exceeded the CCME guideline (0.1 mg/L at pH>6.5) were observed in 5 samples. These elevated concentrations are likely a result of the crushing process associated with the SFE analysis, which may have generated colloidal aluminosilicate material that passed through the 0.45 µm membrane used to filter the leachate prior to analysis.

SFE leachable fluoride concentrations also exceeded the CCME guideline (0.12 mg/L) in 8 samples. It is interesting to note that the elevated fluoride concentrations were noted in all four GSCH samples (0.13 to 0.31 mg/L fluoride), with the highest fluoride concentrations observed in two of the three QTZT samples (0.44 and 0.88 mg/L). That these two lithologies comprised the majority of elevated SFE fluoride concentrations is likely related to the presence of fluoride-bearing aluminosilicates in such lithologies. XRD analysis of GSCH and QTZT samples identified illite-muscovite at 30.4 wt.% and 27.4 wt.%, respectively, compared to 0.9 to 1.2 wt.% found in the QTZT lithology samples (Table 4-1). Fluoride is a common substituent in muscovite, suggesting its partial dissolution, enhanced by the fine particle size generated from grinding the drill core to the <6.3 mm size fraction used for SFE, is likely responsible for the elevated SFE leachate fluoride concentrations.

Bulk trace element concentrations determined by aqua regia digestion were compared to SFE leachate concentrations to evaluate any relationships. Broadly positive correlations were found between the bulk trace element content and SFE concentrations for aluminum, arsenic and selenium (Figure 4-12), suggesting that the solid phase concentration exerts a control on aqueous mobility.

SFE leachate concentrations were also examined as a function of the sample cover hole depth. Only SFE leachable arsenic in QTZT samples exhibited a trend in which they broadly increased with depth such that the highest recorded SFE leachable arsenic concentrations were from samples collected at >200 m depth (Figure 4-13).

Overall, it is important to note that the elevated SFE leachate constituent concentrations were all within an order of magnitude of their respective water quality guideline. Given the small grain size employed in the SFE testing (<6.3 mm) relative to the waste rock produced in the field and the associated higher surface area and exposure of fresh surfaces during shake flask extraction, elevated soluble constituent concentrations are not anticipated from the Birmingham cover hole waste rock.

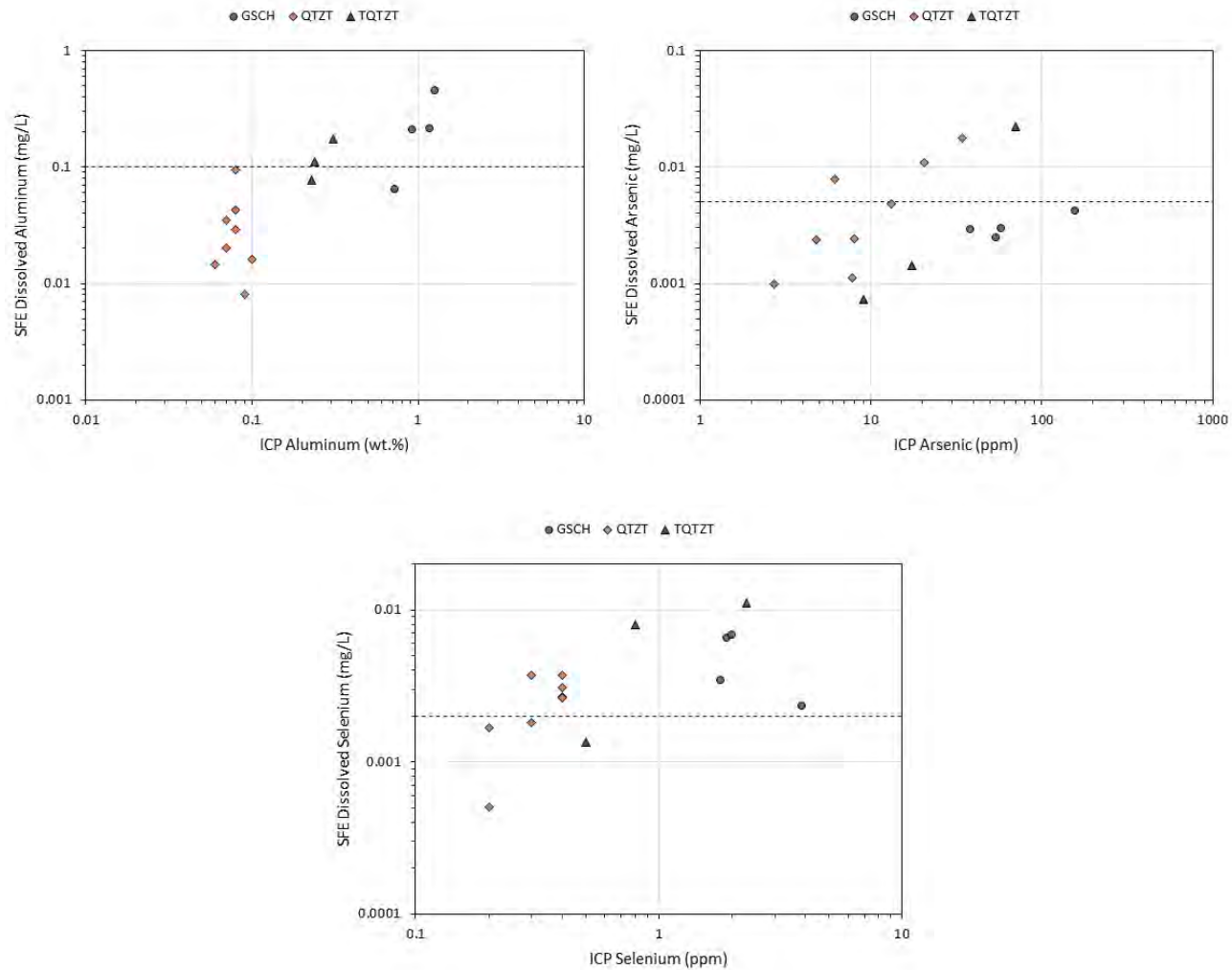


Figure 4-12: Comparison of SFE Leachable and Aqua Regia Bulk Concentrations of Aluminum, Arsenic, and Selenium

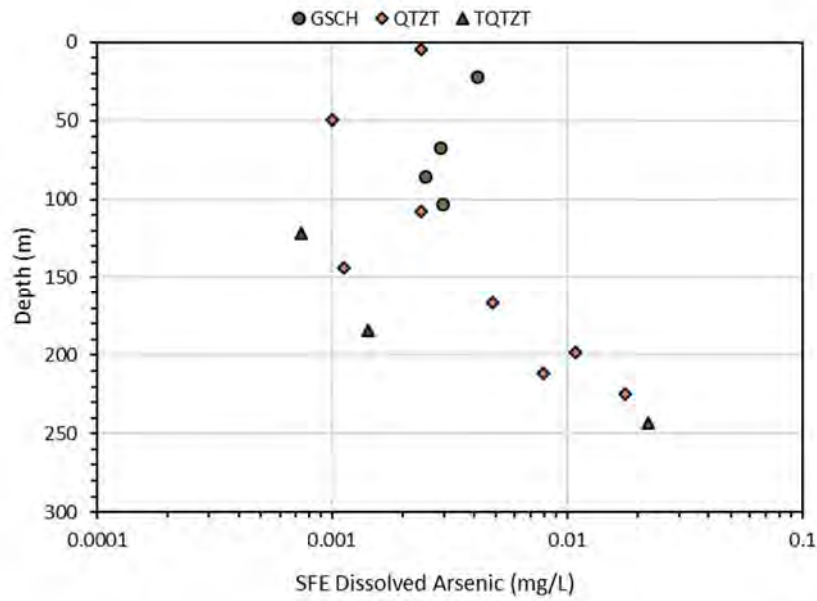


Figure 4-13: Comparison of SFE Leachable Arsenic to Cover Hole Depth

5 HISTORIC DATA AND REGIONAL CONTEXT

5.1 HISTORIC BIRMINGHAM SAMPLES

The 2017 Birmingham cover hole samples were compared to historic Birmingham Mine pit wall and waste rock dump samples collected and analyzed as part of the 1996 Site Characterization Report (AMC, 1996). Six samples were collected from the Birmingham pit wall and six samples were collected from the Birmingham waste rock dump (AMC, 1996). The samples were classified by lithology. These samples were re-analyzed SRK Consulting as part of the 2007/08 Geochemical Studies, Keno Hill Silver District, YT (SRK, 2009).

The historic Birmingham samples and their corresponding lithology are presented in Table 5-1. Note that four of the six waste dump samples are classified as “vein”. While vein does not technically define a lithological unit, mineralization occurs in irregular shoots within vein systems along vein faults particularly in quartzite units that are more brittle (Altura 2008a). The vein samples in the historic Birmingham waste rock dump would typically be dolomite, ankerite and siderite, quartz and calcite gangue with sulphide minerals including sphalerite, galena and arsenopyrite (Roscoe Postle and Associates Inc., 2017). Thus, vein samples would be expected to have relatively higher concentrations of metals and sulphur content. As such, it is unlikely that this sample would be classified as waste rock and thus the ICP and SFE results from this sample are not included in the comparison with 2017 Birmingham cover hole samples.

Table 5-1: Historic Birmingham Pit Wall and Waste Dump Sample Lithologies

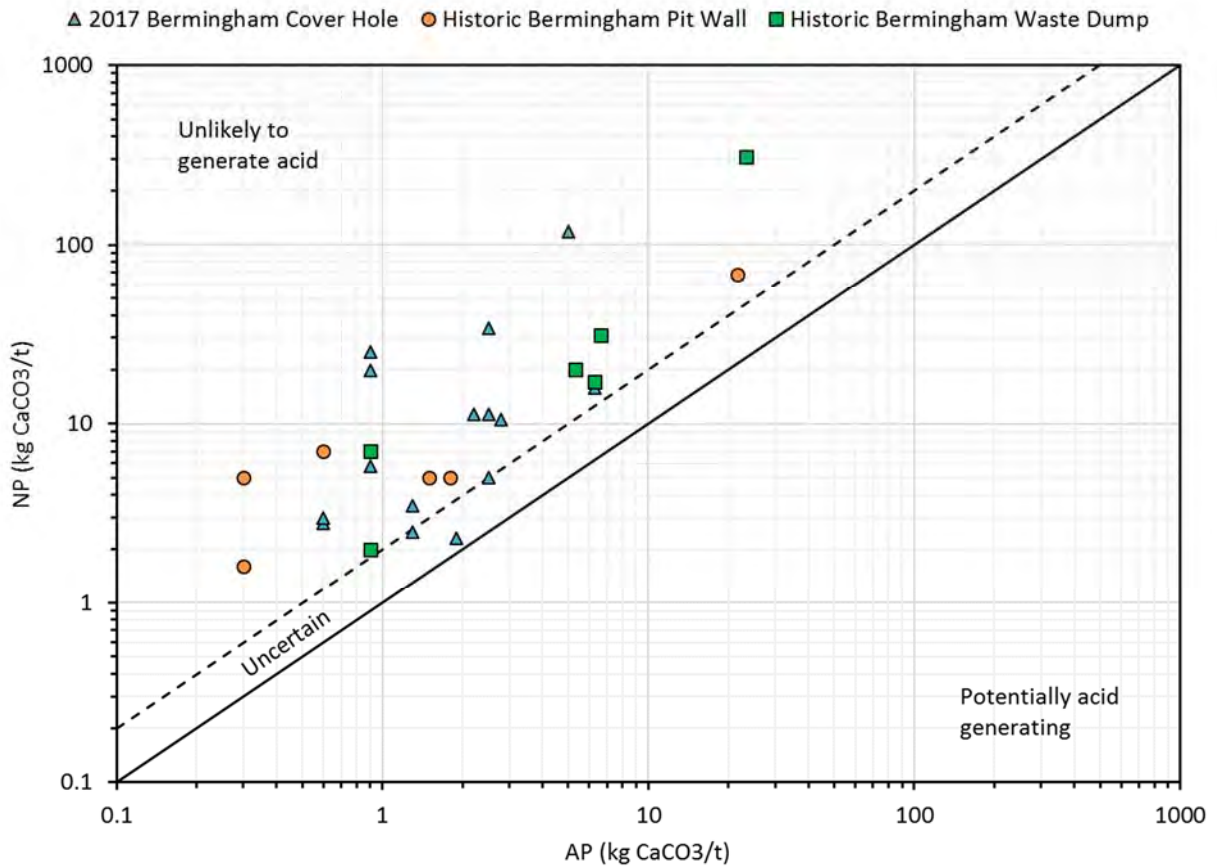
Sample Area	Sample ID	Lithology	Sample Area	Sample ID	Lithology
Historic Birmingham Pit Wall	95UKHBP01	QTZT	Historic Birmingham Waste Rock Dump	95UKHBD01*	Vein
	95UKHBP02	QTZT		95UKHBD02*	Vein
	95UKHBP03	QTZT		95UKHBD03*	Vein
	95UKHBP04	QTZT		95UKHBD04	SSCH
	95UKHBP05	QTZT		95UKHBD05*	Vein
	95UKHBP06	SSCH		95UKHBD06	QTZT
	95UKHBP07	SSCH		*Ore sample – ICP and SFE results not included in comparison with 2016 samples	

5.1.1 ABA

The ABA results from the historic 1995 Birmingham pit wall and waste dump samples (AMC, 1996) are presented in Table 5-2. A plot of NP versus AP for the 2017 Birmingham cover hole samples and the historic Birmingham Pit wall and waste dump samples is shown in Figure 5-1. In general, the historic Birmingham pit wall samples had relatively low NP and AP, whereas the historic waste dump samples were more variable. However, all thirteen of the historic samples from the pit wall and waste dump had NPR greater than 2 indicating a low potential for acid generation. Similarly, the majority (85%) of the 2017 Birmingham cover hole samples also had NPR>2.

Table 5-2: Acid Base Accounting Results for Historic Birmingham Pit Wall and Waste Dump Samples (AMC, 1996)

	Lithology	Paste pH	Total Sulphur	Sulphate Sulphur	Sulphide Sulphur	AP	Modified Sobek NP	Modified Sobek NPR
Units		pH Units	wt.%			kg CaCO ₃ /t		Ratio
95UKHBP01	QTZT	6.6	0.03	0.01	0.02	0.6	5	8
95UKHBP02	QTZT	7.0	0.02	0.01	0.01	0.3	5	16
95UKHBP03	QTZT	7.1	0.03	0.01	0.02	0.9	7	8
95UKHBP04	SSCH/QTZT	7.4	0.01	0.01	0.01	0.3	5	16
95UKHBP05	QTZT	6.9	0.07	0.06	0.01	0.3	1.6	5.0
95UKHBP06	SSCH	7.7	0.69	0.03	0.66	20	68	3.4
95UKHBP07	SSCH	8.2	0.02	0.01	0.01	0.3	7	22
95UKHBD01	Vein	7.4	0.17	0.16	0.01	4.4	20	5
95UKHBD02	Vein	7.4	0.2	0.17	0.03	4.7	17	4
95UKHBD03	Vein	7	0.75	0.21	0.54	17.8	308	17
95UKHBD04	SSCH	7.5	0.21	0.08	0.13	5.9	31	5.2
95UKHBD05	Vein	7.6	0.03	0.01	0.02	0.6	7	11
95UKHBD06	QTZT	7.6	0.03	0.01	0.02	0.3	2	6.4



Solid and dashed lines indicate NPR = 1 and NPR = 2, respectively.

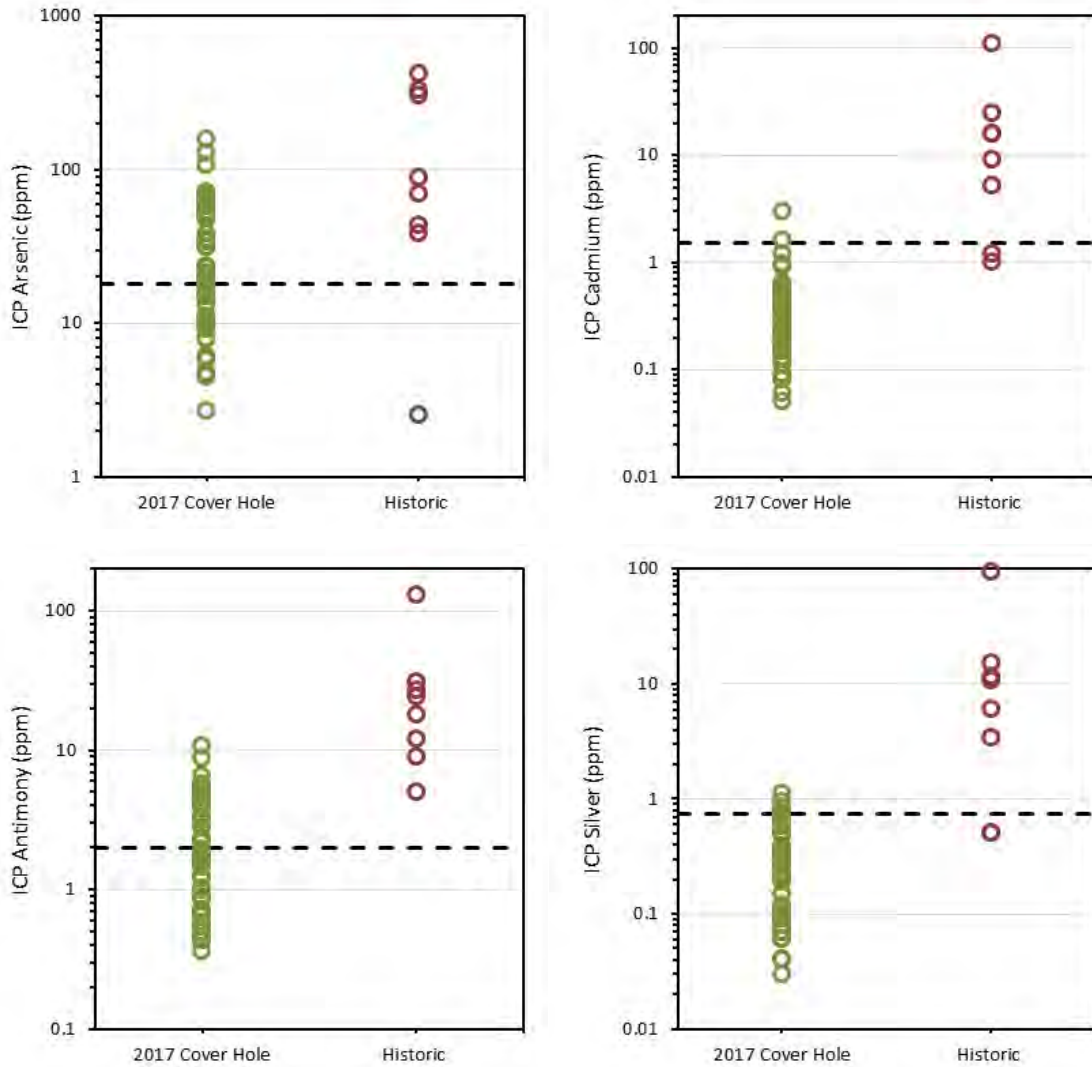
Figure 5-1: Variability in NP and AP of 2017 Birmingham Cover Hole and Historic Birmingham Pit Wall and Waste Rock Samples.

5.1.2 Elemental Analysis

A statistical summary of elements that exhibited concentrations greater than their 10x crustal abundance threshold in historic Birmingham pit wall and waste dump samples is presented in Table 5-3. In general, bulk element concentrations are greater in the historic Birmingham samples than in the 2017 Birmingham cover hole samples (Figure 5-2). Elevated concentrations of antimony, arsenic, cadmium, lead, silver, and zinc were noted in the historic Birmingham samples; however, these were typically biased high by the “vein” samples. Non-mineralized waste rock is unlikely to return such extremes with regard to elevated metal(loid) concentrations, as evidenced by the 2017 Birmingham cover hole bulk elemental analysis.

Table 5-3: Summary Statistics for Selected Bulk Element Abundance in Historic Birmingham Pit Wall (n = 6) and Waste Dump (n = 2) of QTZT (n = 4) and SSCH (n = 2) Samples Dataset

n = 8	Antimony (ppm)	Arsenic (ppm)	Bismuth (ppm)	Cadmium (ppm)	Lead (ppm)	Silver (ppm)	Sulphur (wt.%)	Zinc (ppm)
10x Crustal Abundance	2	18	0.085	1.5	140	0.75	0.35	700
Method Detection Limit	5	5	1	0.5		0.5	0.01	
Maximum	131	424	3	110	6010	95	0.71	3070
3rd Quartile	28	311	3	18	872	12	0.075	649
Median	21	79	2	12	339	8.4	0.025	451
1st Quartile	11.25	42	1	4.2	66	2.7	0.02	237
Minimum	5	2.5	1	1	18	0.5	0.01	112
Count Over 10x Crustal Abundance	8	7	8	6	4	6	1	1
Highlighted Results Exceed 10x Crustal Value								



Dashed line represents 10x crustal abundance

Figure 5-2: Distribution of Bulk Concentrations of Arsenic, Cadmium, Antimony and Silver by Lithology in 2017 Birmingham Cover Hole Samples and Historic Birmingham Pit and Waste Dump Samples

5.1.3 SFE

A summary of SFE leachate concentrations of historic Birmingham pit wall and waste dump samples (n=8; 4 QTZT and 4 SSCH samples) analyzed by SRK (2007) for select parameters is shown in Table 5-4. As discussed in Section 4.4, the SFE results were compared to the same long term freshwater aquatic life guidelines (CCME or BCMoE) as the 2017 Birmingham cover hole SFE results for comparison purposes only. Note that leachable fluoride was not analyzed by SRK in 2007. It should also be noted that the selenium method detection level used in the analysis was 0.001 mg/L, very close to the BCMoE aquatic life water quality guideline of 0.002 mg/L.

SFE leachable selenium, which exceeded aquatic guidelines in the greatest proportion of 2017 cover hole samples (73%), exceeded in only 25% of historic Birmingham pit wall and waste dump samples. Leachable aluminum and arsenic also exceeded aquatic life guidelines in a higher proportion of 2017 samples (33 and 20%, respectively), than in historic Birmingham samples (13%; 1 out of 8 samples). However, SFE leachable cadmium exceeded aquatic guidelines in 80% of historic Birmingham samples but in none of the 2017 cover hole samples. Additionally, SFE leachable lead, silver and zinc were in excess of their respective guidelines in at least one historic sample but did not exceed in any of the 2017 cover hole samples. These disparities are likely related to both the higher bulk concentrations of cadmium, lead, silver, and zinc in the historic Birmingham samples and the decades of weathering the historic Birmingham samples have experienced, which allows the formation of secondary minerals that are solubilized in the SFE testing.

Table 5-4: Comparison of SFE Concentrations of Historic Birmingham Pit Wall and Waste Dump Samples with Aquatic Life Guidelines

n = 8	pH	Aluminum	Arsenic	Cadmium	Lead	Silver	Selenium	Zinc
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Guideline for Comparison	CCME	CCME	CCME	CCME	BCMoE	CCME	BCMoE	BCMoE
Aquatic Life Guideline	6.5 - 9.0	0.1	0.005	0.0002	0.0079	0.00025	0.002	0.041
Maximum	7.6	0.84	0.0073	0.14	0.019	0.00038	0.0079	1.1
3rd Quartile	7.3	0.022	0.0012	0.016	0.0046	0.00016	0.0028	0.15
Median	6.9	0.020	0.00092	0.00091	0.0022	0.00008	<0.001	0.0094
1st Quartile	6.7	0.014	0.00074	0.00039	0.0015	0.000074	<0.001	0.0039
Minimum	6.2	0.0054	0.00023	0.000026	0.0007	0.000045	<0.001	0.003
Samples >CCME/BCMoE	13%	13%	13%	80%	25%	13%	25%	38%
Highlighted Results Exceed CCME/BCMoE								

^a Guideline based on receiving waters with pH>6.5

^b Guideline based on minimum hardness observed in No Cash in 2016 (134 mg/L CaCO₃)

5.2 REGIONAL CONTEXT

The 2017 Birmingham cover hole samples were also compared to waste rock data from other production zones from the KHSD including Bellekeno (Altura, 2008a), Onek (ACG, 2011a), Lucky Queen (ACG, 2011b), Silver King (ACG, 2011c), and Flame and Moth zones (ACG, 2015) (Figure 5-3). In addition to having representation from the GSCH, QTZT and TQTZT lithologies in the 55 Birmingham cover hole samples, samples of the greenstone (GNST) and sericitic schist (SSCH) lithologies are present in the waste rock sample dataset from the other KHSD production zones. The lithological distribution of samples in each production zone is presented in Table 5-5.

Table 5-5: Other KHSD Production Zones Sample Lithologies

Production Zone	Dominant Lithology (Number of Samples)					Total
	GNST	GSCH	QTZT	SSCH	TQTZT	
Bellekeno	12	13	12	11	0	48
Onek	4	14	17	8	0	43
Lucky Queen	0	2	13	0	9	24
Silver King	1	2	7	3	7	20
Flame and Moth	1	5	28	6	7	47
Total	18	36	77	28	23	182
Birmingham	0	14	29	0	11	55*

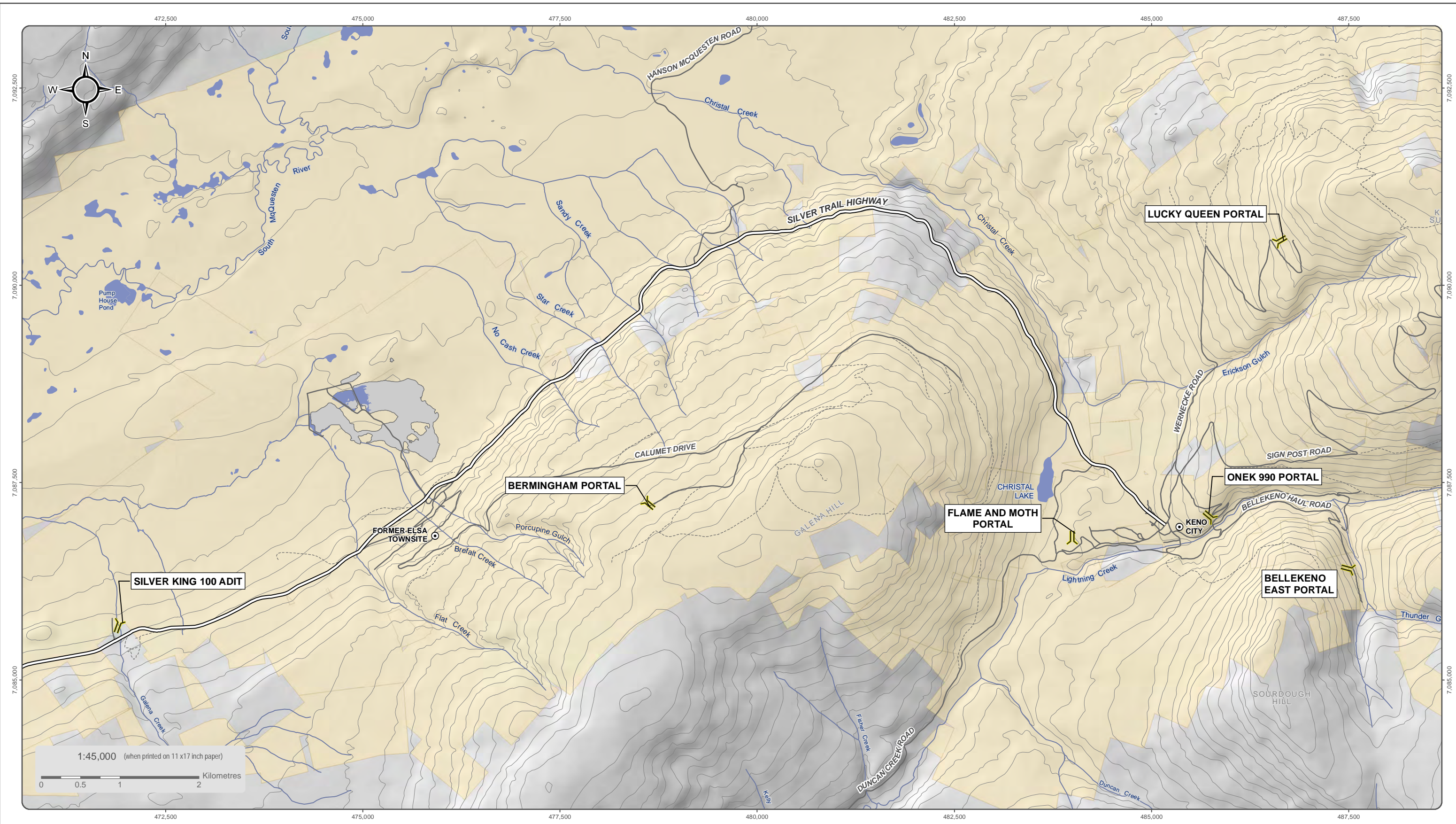
*An additional fault sample was analyzed.

5.2.1 ABA

The ABA testing results of the 2017 Birmingham cover hole samples were compared to the ABA test results of waste rock drill core collected at other deposits of Alexco exploration interest within the KHSD: Bellekeno, Onek, Lucky Queen, Silver King, and Flame and Moth (Figure 5-3). Plots of NP versus AP for the GSCH, QTZT and TQTZT lithologies are presented in Figure 5-4, Figure 5-5 and Figure 5-6, respectively.

The GSCH samples from the Birmingham cover hole (n=4) have low NP and AP relative to GSCH samples from other zones (Figure 5-4). The majority of GSCH samples in other zones have relatively higher NP and AP and return NPR values greater than two, indicating that acid generation is unlikely in those GSCH samples. Only the two Silver King GSCH samples had an NPR <1.

Like the GSCH lithology, the Birmingham cover hole QTZT samples (n=8) also had relatively lower NP and AP than QTZT samples from other zones (Figure 5-5). In most cases, the relatively higher AP in QTZT samples from other zones was offset by commensurately higher NP; however at least one QTZT sample from Onek, Lucky Queen, Silver King and Flame and Moth zones returned an NPR <1 indicating the potential for acid generation whereas all the Birmingham samples had NPR >1. Like the Silver King GSCH samples, the majority of QTZT Silver King samples had low NP but relatively high AP resulting in NPR <1.












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Satellite imagery obtained from Yukon Geomatics map service <http://mapservices.gov.yk.ca/ArcGIS/services> on September 2017

Datum: NAD 83; Map Projection: UTM Zone 8N

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-  Place of Interest
-  Adit
-  Valley Tailings
-  Alexco/ERDC Quartz Claims
-  Waterbody
-  Watercourse
-  Silver Trail Highway
-  Other Road
-  Limited-Use Road



ALEXCO KENO HILL MINING CORP.

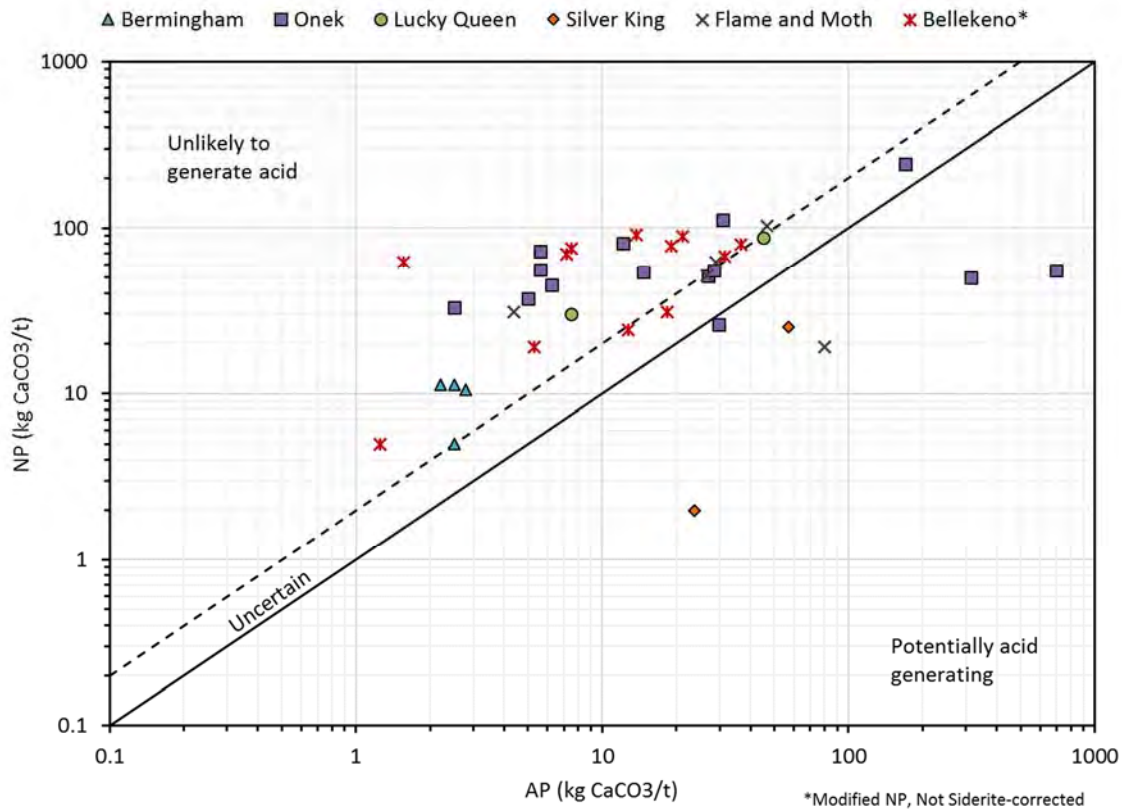
FIGURE 5-3
LOCATIONS OF WASTE ROCK ARD/ML STUDIES TO
SUPPORT ALEXCO KHSD DEVELOPMENT

SEPTEMBER 2017

D:\Project\AllProjects\ALEX-05-01\GIS\Map\Overview_Maps\Property_Overview\Alexco_Proposed_Deposit_Overview_20170914.mxd
(Last edited by: amastobetska, 15/09/2017 12:55 PM)

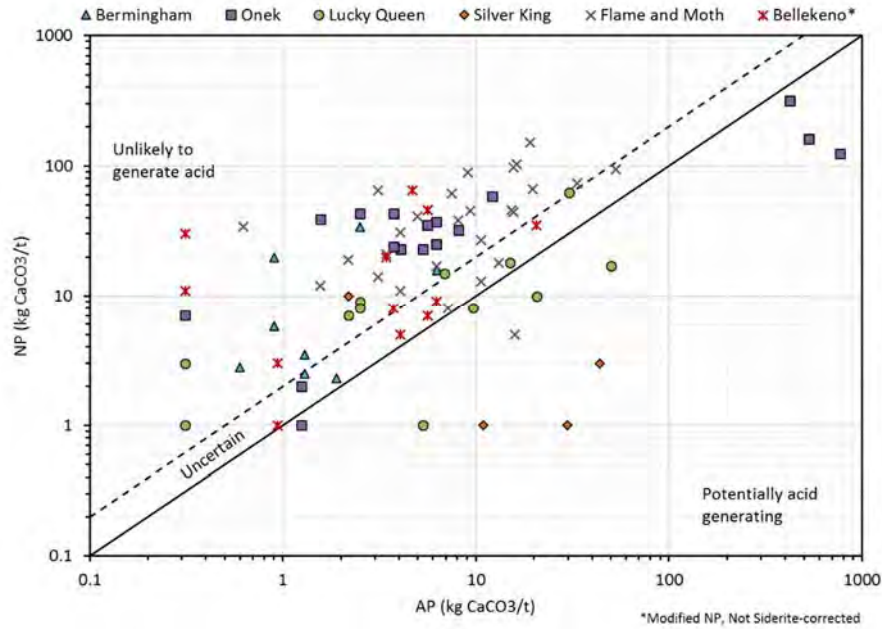
The TQTZT samples from the Birmingham cover hole (n=3) had comparable NP and typically lower AP than TQTZT samples from other zones (Figure 5-6). The relatively lower AP in the TQTZT Birmingham samples resulted in all samples having $NPR > 2$ whereas at least two TQTZT samples from each of Silver King and Flame and Moth had $NPR < 1$.

The GNST lithology was not intercepted by the Birmingham cover hole; however, it is anticipated that this lithology will comprise approximately 10% of the total Birmingham decline excavation (Table 2-1). The NPR of GNST samples from Onek, Silver King, Flame and Moth and Bellekeno zones are presented in Figure 5-7. The samples are generally characterized as having lower AP than samples from other lithologies such that 17 of 18 samples had an $NPR > 2$ indicating acid generation is unlikely from these materials. As such, GNST lithology samples from the Birmingham deposit are also expected to be predominantly non-acid generating.



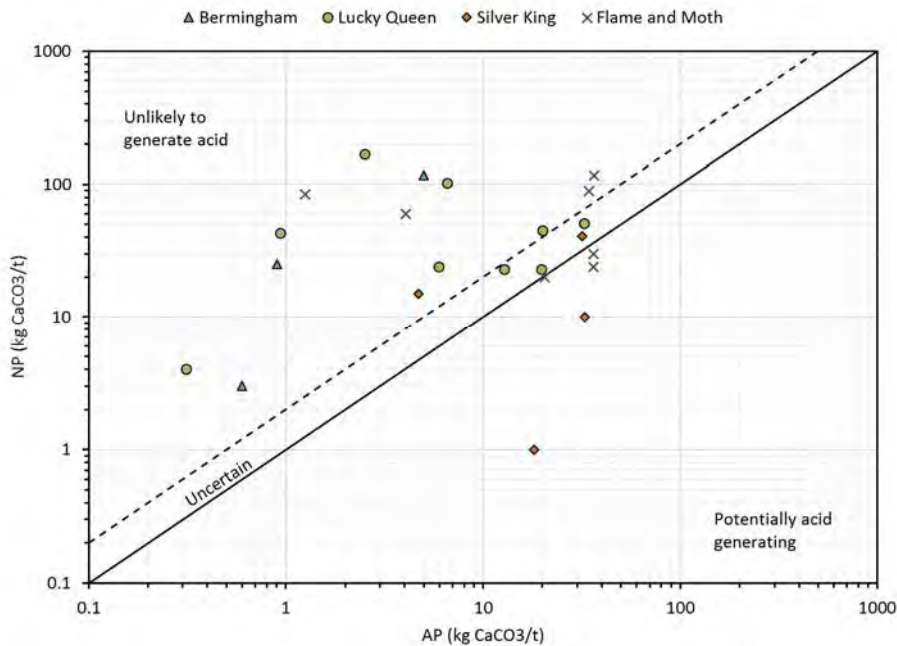
Solid and dashed lines indicate $NPR = 1$ and $NPR = 2$, respectively.

Figure 5-4: Variability in NP and AP of GSCH Waste Rock Samples from 2017 Birmingham Cover Hole and Other KHSZ Deposits



Solid and dashed lines indicate $NPR = 1$ and $NPR = 2$, respectively.

Figure 5-5: Variability in NP and AP of QTZT Waste Rock Samples from 2017 Bermingham Cover Hole and Other KHSD Deposits



Solid and dashed lines indicate $NPR = 1$ and $NPR = 2$, respectively.

Figure 5-6: Variability in NP and AP of TQTZT Waste Rock Samples from 2017 Bermingham Cover Hole and Other KHSD Deposits

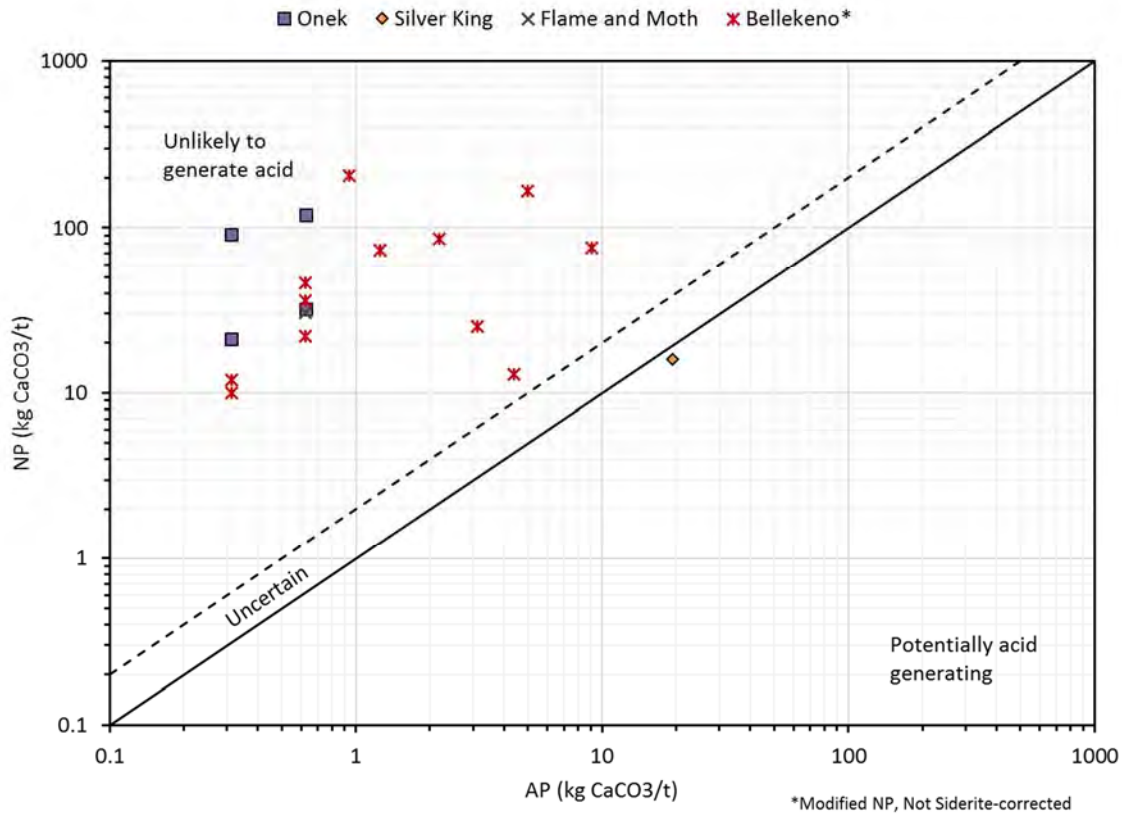
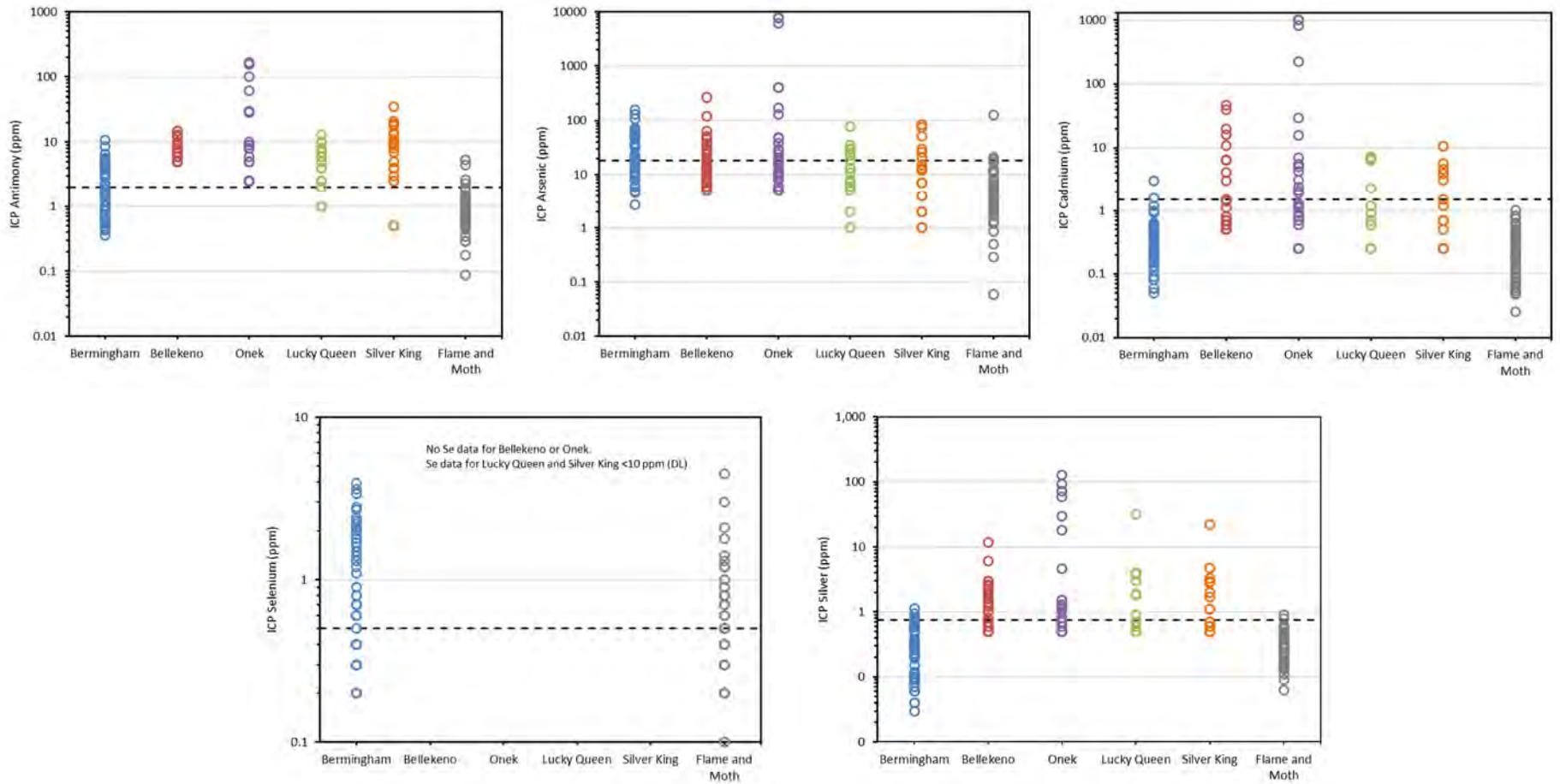


Figure 5-7: Variability in NP and AP of GNST Waste Rock Samples from Other KHSD Deposits

5.2.2 Elemental Analysis

Bulk element testing results of the 2017 Birmingham cover hole samples were compared with the bulk element concentrations of waste rock collected at other KHSD deposits: Bellekeno, Onek, Lucky Queen, Silver King, and Flame and Moth. The plots for concentrations of analytes that exceeded 10x crustal abundance in Birmingham samples - arsenic, cadmium, antimony, selenium and silver - are presented in Figure 5-8 (note: selenium data were unavailable or inappropriate for comparison due to high method detection levels used in the analysis of the Lucky Queen and Silver King samples). Bulk concentrations in Birmingham cover hole samples were within the range found in other KHSD deposits of interest, although bulk antimony, cadmium and silver concentrations in the Birmingham samples were broadly lower than those in waste rock analyzed from Bellekeno, Onek, Lucky Queen and Silver King zones (Figure 5-8).



Dashed line represents 10x crustal abundance

Figure 5-8: Distributions of Bulk Concentrations of Antimony, Arsenic, Cadmium and Selenium by Deposit

5.2.3 SFE

A summary of SFE leachate concentrations of Flame and Moth zone samples (n=50) analysed by ACG (2015) is shown in Table 5-6. As discussed in Section 4.4, the results were compared to the same aquatic life guidelines (CCME or BCMoE) as the 2017 Birmingham cover hole sample SFE results for reference purposes only. No SFE data are available for the other deposit areas that have appropriate trace element detection limits.

Table 5-6: Comparison of SFE Concentrations from Flame and Moth Zone Samples with Water Quality Guidelines

n = 50	pH	Fluoride	Aluminum	Antimony	Arsenic	Selenium
		mg/L	mg/L	mg/L	mg/L	mg/L
Guideline for Comparison	CCME	CCME	CCME	BCMoE	CCME	BCMoE
Aquatic Life Guideline	6.5 - 9.0	0.12	0.1	0.009	0.005	0.002
Maximum	9.2	4.49	6.2	0.13	0.012	0.030
3rd Quartile	8.7	0.94	0.63	0.027	0.0018	0.0036
Median	8.6	0.51	0.29	0.013	0.0012	0.0018
1st Quartile	8.4	0.28	0.10	0.0094	<0.0005	0.00085
Minimum	7.9	0.068	0.017	0.00099	<0.0005	0.00025
Samples >CCME/BCMoE	4%	92%	76%	78%	6%	46%
Highlighted Results Exceed CCME/BCMoE						

^a Guideline based on receiving waters with pH>6.5

^b Guideline based on minimum hardness observed in No Cash Creek in 2016 (134 mg/L CaCO₃)

The pH of both sets of SFE sample datasets was circumneutral to alkaline, with a few samples (three Birmingham and two Flame and Moth) in exceedance of the upper CCME pH guideline (pH 9.0). Elevated concentrations of SFE leachable fluoride (92% of samples exceeded 0.12 mg/L CCME guideline) and aluminum (76% of samples exceeded 0.1 mg/L CCME guideline) were observed in the Flame and Moth samples, whereas a lower proportion of exceedances (and lower concentrations) were obtained for the Birmingham cover hole samples (53% and 33% of samples exceeded guidelines for fluoride and aluminum, respectively).

A high proportion of SFE leachable antimony concentrations exceeded the BCMoE interim guideline (0.009 mg/L; 78% of samples) in the Flame and Moth dataset, whereas no exceedances were observed for the Birmingham samples despite higher bulk antimony concentrations in the Birmingham waste rock samples (Figure 5-8 and Figure 5-9). Conversely, a higher proportion of Birmingham cover hole samples had SFE leachable arsenic concentrations that exceeded the CCME water quality guideline (0.005 mg/L; 27% of samples) compared with the Flame and Moth SFE results (6% of samples), although both sets of data spanned a similar concentration range (Figure 5-9). Similarly, a lower proportion of Flame and Moth SFE leachable selenium concentrations exceeded the BCMoE guideline for selenium (0.002 mg/L; 46% of samples) compared

with the Birmingham dataset (73% of samples), although both sample datasets spanned a similar concentration range (Figure 5-9).

Broadly positive correlations were observed between SFE leachable and aqua regia bulk concentrations of aluminum and selenium (Figure 5-9), although the selenium correlation appears stronger within each deposit area's lithology rather than for the entire dataset.

Overall, the same constituents (fluoride, aluminum, and selenium) were observed at elevated levels in the SFE leachate from both the Birmingham and Flame and Moth samples. The only notable differences were the elevated arsenic concentrations observed in a quarter of the Birmingham samples, but only 6% of the Flame and Moth samples, and the elevated antimony concentrations which were recorded in the majority of Flame and Moth dataset, but which were below water quality guidelines in the Birmingham samples.

5.2.4 Summary

Overall, the ABA data for the Birmingham cover hole samples were consistent with that of other KHSD deposit areas in terms of a high proportion of non-acid generating samples (i.e., NPR >2), albeit with generally lower AP and NP content.

Bulk trace element concentrations in the Birmingham cover hole samples were within the range found in other KHSD deposits of interest, although the antimony, cadmium and silver contents of the Birmingham samples were broadly lower than those in waste rock analyzed from Bellekeno, Onek, Lucky Queen and Silver King zones, but comparable to the Flame and Moth waste rock dataset.

Finally, the Birmingham and Flame and Moth SFE data shared similar constituents present at elevated levels (fluoride, aluminium, selenium). Although fewer Flame and Moth SFE samples exceeded the CCME water quality guideline than Birmingham, both sets of data spanned a similar concentration range. Elevated SFE leachable antimony concentrations observed in the Flame and Moth SFE testwork were not present in the Birmingham SFE samples.

Given the similar ABA, bulk element content, and SFE characteristics of the Birmingham waste rock with those observed elsewhere in the district, including Flame and Moth, the interim use of Flame and Moth kinetic data (i.e., waste rock humidity cell and field barrel) and associated source terms appears appropriate.

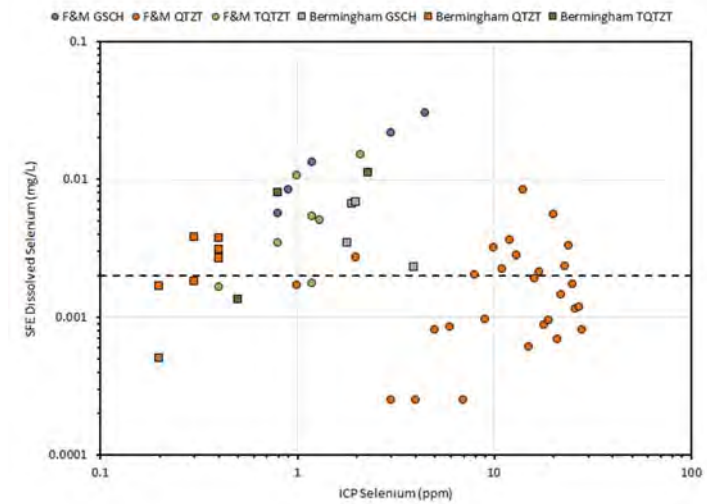
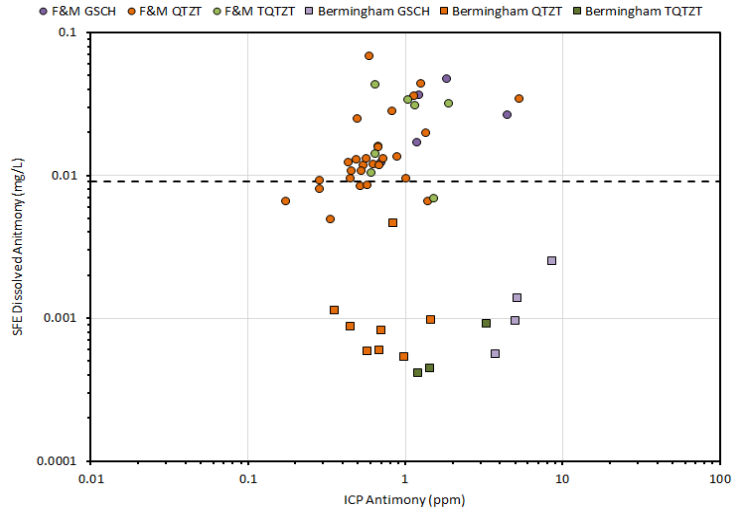
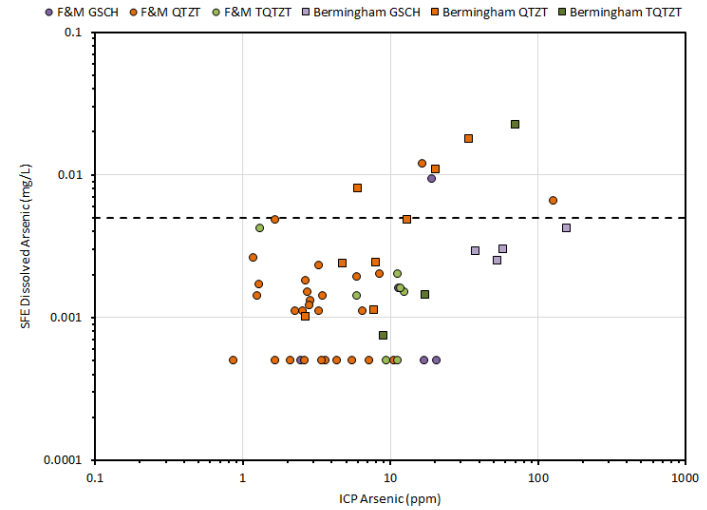
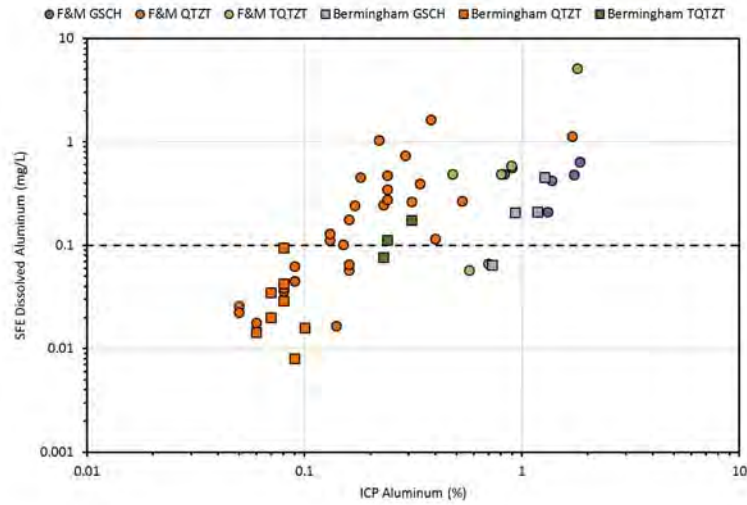
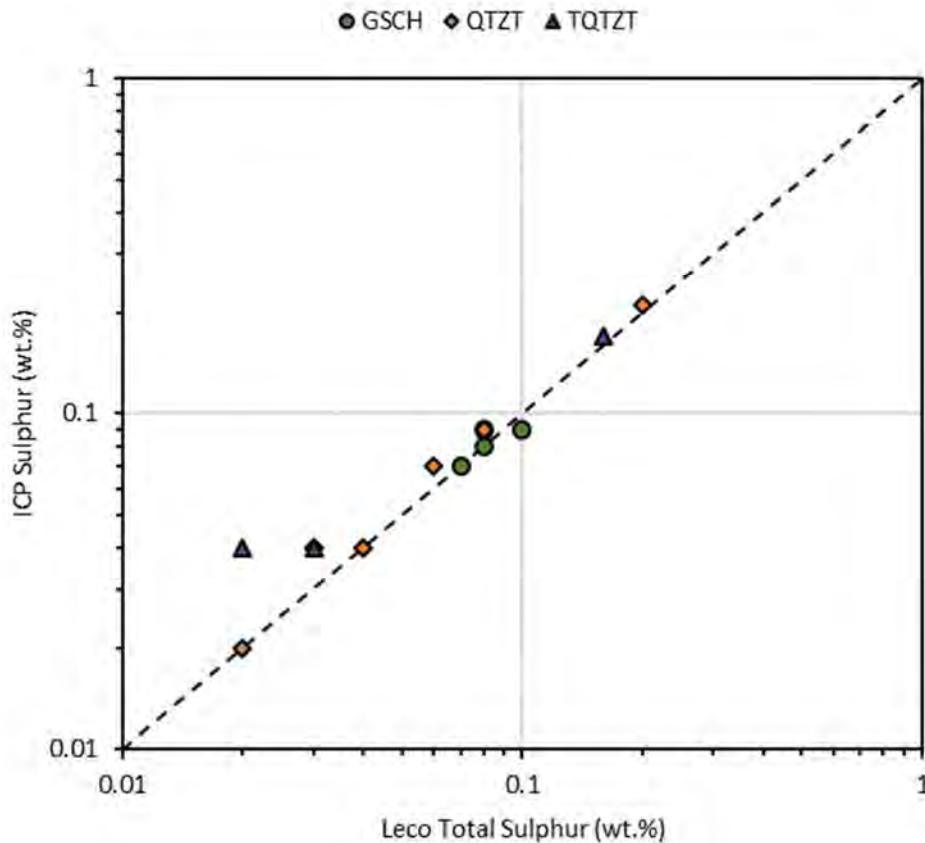


Figure 5-9: Comparison of SFE Leachable and Aqua Regia Bulk Concentrations of Aluminum, Antimony, Arsenic, and Selenium in Bermingham (squares) and Flame and Moth (circles)

5.3 IMPLICATIONS FOR WASTE ROCK MANAGEMENT

5.3.1 Surrogates for AP and NP Determination in Waste Rock Management

The total sulphur concentration determined by Leco and by ICP analysis following aqua regia digestion were in excellent agreement at a 1:1 ratio (**Error! Reference source not found.**), aside from some scatter close to the detection limit of both techniques. The close correlation indicates that ICP aqua regia sulphur concentrations could be used to calculate the surrogate AP of a sample. In ABA work, AP is calculated based on the sulphide sulphur concentration. The use of total sulphur concentrations rather than sulphide sulphur will lend some conservatism to the AP surrogate calculation, although ABA data indicate that sulphide sulphur comprises the vast majority of total sulphur in the Birmingham cover hole rock samples (Table 4-2).



Dashed line indicates unity.

Figure 5-10: Comparison of Sulphur Concentrations Determined by Leco and Aqua Regia ICP

A strong correlation was also observed between NP and aqua regia ICP calcium content (**Error! Reference source not found.**), since calcium-bearing carbonate minerals provide the majority of NP in these samples. Based on this correlation, the surrogate NP of a sample can be calculated from its aqua regia calcium concentration using the following equation:

$$\text{Surrogate NP} = 27.2 * (\text{wt.\%Ca}) + 2.74$$

$$R^2 = 0.9955$$

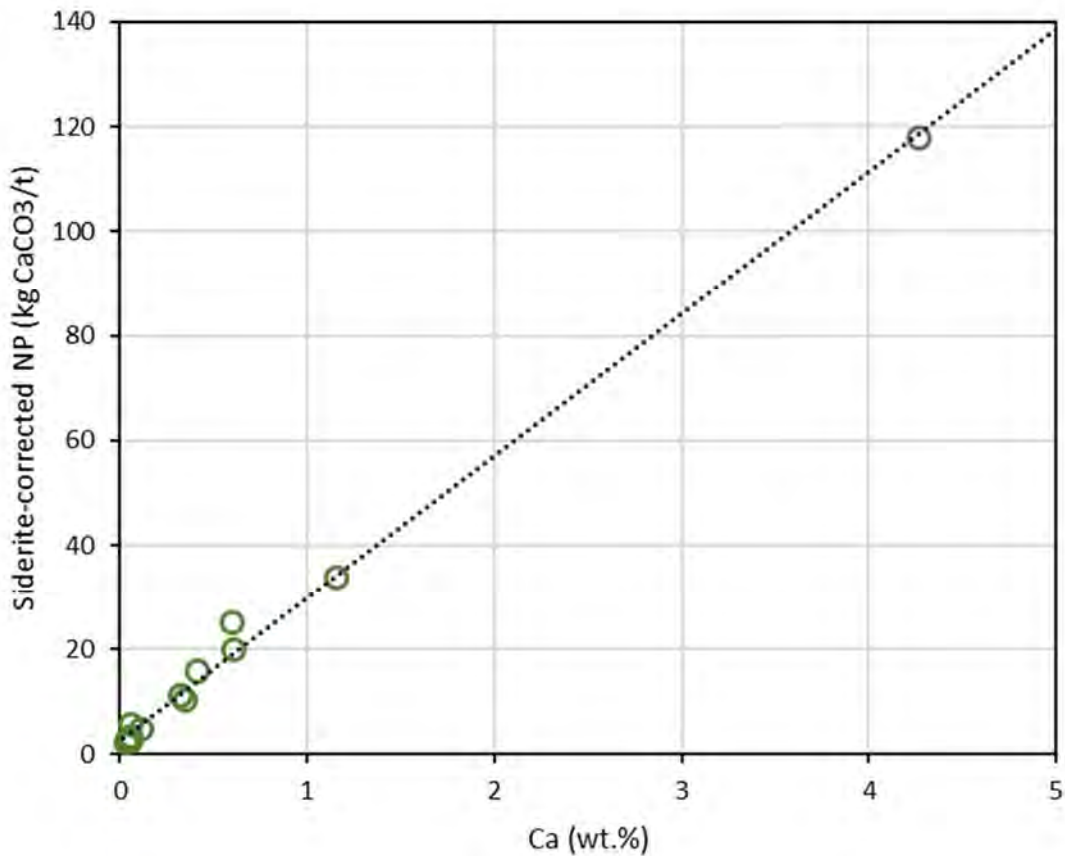


Figure 5-11: Relationship of Siderite-corrected NP with Aqua Regia ICP Calcium Content

As such, the aqua regia ICP results for the 55 Birmingham samples can be used to produce a larger surrogate ABA dataset (*cf.* the 15 sample ABA dataset) against which geochemical screening criteria can be evaluated. A comparison of the measured ABA and surrogate ABA data is presented in Table 5-7. Of the 15 samples, one sample was calculated by the surrogate data as non-PAG (i.e., NPR>2) but which the ABA data indicated was PAG (sample M369913). The surrogate data also calculated one other sample to be PAG which ABA data indicated was non-PAG (sample M369907). Such miscoding is due to the relatively low sulphur and calcium

concentrations, which give rise to relatively large analytical uncertainty; however, the low sulphur content in such samples suggests that any ARD arising from any miscoded PAG samples would be of limited extent. Overall, the PAG and non-PAG assignments based on the measured ABA and surrogate ABA were in good agreement.

Table 5-7: Comparison of Measured ABA and Surrogate-ABA Data

Sample	Lithology	ABA- AP	ABA-NP	ABA-NPR	ICP-Ca	ICP-S	Surrogate-AP	Surrogate-NP	Surrogate-NPR
Units		kg CaCO ₃ /t	kg CaCO ₃ /t		wt.%	wt.%	kg CaCO ₃ /t	kg CaCO ₃ /t	
M369943	QTZT	1.9	2.30	1.2	0.03	0.07	2.2	3.6	1.6
M369913	QTZT	1.3	2.5	1.9 ^a	0.06	0.04	1.3	4.4	3.5 ^a
M369907	GSCH	2.5	5.00	2.0 ^a	0.11	0.1	3.1	5.7	1.8 ^a
M369938	QTZT	6.3	15.8	2.5	0.41	0.21	6.6	13.9	2.1
M369952	QTZT	1.3	3.50	2.7	0.06	0.04	1.3	4.4	3.5
M369918	GSCH	2.8	10.5	3.8	0.35	0.08	2.5	12.3	4.9
M369927	GSCH	2.5	11.3	4.5	0.32	0.08	2.5	11.4	4.6
M369902	QTZT	0.6	2.80	4.7	0.04	0.02	0.6	3.8	6.1
M369948	TQTZT	0.6	3.00	5.0	0.04	0.04	1.3	3.8	3.1
M369922	GSCH	2.2	11.3	5.1	0.32	0.07	2.2	11.4	5.2
M369928	QTZT	0.9	5.80	6.4	0.06	0.04	1.3	4.4	3.5
M369955	QTZT	2.5	33.8	13.5	1.16	0.09	2.8	34.3	12.2
M369959	QTZT	0.9	19.8	22.0	0.61	0.04	1.3	19.3	15.5
M369932	TQTZT	5.0	118	23.5	4.27	0.17	5.3	118.9	22.4
M369963	TQTZT	0.9	25.0	27.8	0.6	0.04	1.3	19.1	15.2

^a Highlighted cells indicate mismatches regarding non-PAG (NPR>2) designation for measured ABA and surrogate ABA datasets

5.3.2 Geochemical Screening Criteria

Existing geochemical screening criteria based on ARD/ML analyses of waste rock from across the KHSD have been developed for waste rock sorting purposes. At present, two related sets of screening criteria have been developed for the Bellekeno and Flame and Moth deposits.

5.3.2.1 Bellekeno

Geochemical criteria were developed by Altura (2008b) to describe the ARD/ML controlling and correlating factors for the Bellekeno zone, based on a review of the Bellekeno geochemical dataset and a district-wide ARD/ML study (2008b). The work by Altura (2008b) was expanded upon by ACG (2012) by supplementing the study with additional static testing data, and additional fresh, unweather rock samples and weathered samples from across the KHSD. ACG (2012) determined that the criteria developed by Altura (2008b) were reasonable

and conservative, and proposed the following screening criteria for the identification of potentially acid generating or metal leaching (P-AML) rock:

- a) ICP contained $\text{Ca}\% \leq 0.75\%$ and S via ICP $\geq 0.25\%$;
- b) Or ICP contained $\text{S}\% \geq 1.5\%$;
- c) Or ICP contained $\text{Pb} \geq 5000$ ppm; or
- a) Or ICP contained $\text{Zn} \geq 5000$ ppm.

5.3.2.2 Flame and Moth

For the Flame & Moth project, Alexco proposed a simplified geochemical waste rock screening criteria by eliminating criterion a) (ICP contained $\text{Ca}\% \leq 0.75\%$ and S via ICP $\geq 0.25\%$) which would result in the co-disposal of intermediate sulphur P-AML material with low sulphur non-acid generating or metal leaching (N-AML) and intermediate sulphur, high NP N-AML material in surface waste rock dumps (AEG, 2016b). Along with experience and management-oriented rationale for removing this criterion, ABA data empirically indicated that samples screened as P-AML due to criterion a) would still result in excess bulk neutralizing potential and capacity when co-disposed with N-AML waste rock material. Even with the removal of criterion a), only 10% of the waste rock samples subjected to ABA testwork (n=50) were deemed potentially acid generating (i.e., $\text{NPR} < 2$) for the Flame and Moth study (AEG, 2016b).

5.3.2.3 Proposed Geochemical Screening Criteria for Birmingham

The Bellekeno and Flame and Moth screening criteria were applied to the 55 sample Birmingham dataset. Both the Bellekeno and Flame and Moth screening criteria classified all 55 samples as N-AML (Table 5-8); however, the surrogate ABA analysis returned five samples (9% of dataset) that had an NPR of between 1 and 2 (1.4 to 1.8). This is similar to the miscoding identified in the Flame and Moth work (AEG, 2016b). Although there is uncertainty with respect to acid generation for samples that have an NPR between 1 and 2, all of the five samples that had a surrogate NPR within this range and low sulphur content (0.06 to 0.11 wt.%), suggesting that any acid generation would be of limited extent and would likely be neutralized by non-PAG rock within the N-AML waste rock storage area.

Both the Bellekeno and Flame and Moth screening criteria are proposed for use for the Birmingham site. Although the Flame and Moth criteria may be used to segregate N-AML and P-AML rock into their respective waste rock storage areas, the more stringent Bellekeno criteria will be employed to screen rock for construction purposes outside of the Birmingham portal area. This provides additional conservatism to ensure that non-acid generating waste rock is diverted for construction.

Table 5-8: Comparison of Surrogate ABA Data with Bellekeno and Flame and Moth Geochemical Screening Criteria

Sample	Lithology	ICP-S	ICP-Ca	ICP-Pb	ICP-Zn	Surrogate-AP	Surrogate-NP	Surrogate-NPR	Bellekeno criteria	F&M criteria
Units		wt.%	wt.%	ppm	ppm	kg CaCO ₃ /t	kg CaCO ₃ /t			
M369943	QTZT	0.07	0.03	5.8	43	2.2	3.6	1.6 ^a	N-AML	N-AML
M369913	QTZT	0.04	0.06	1.5	14	1.3	4.4	3.5	N-AML	N-AML
M369907	GSCH	0.1	0.11	30.5	110	3.1	5.7	1.8 ^a	N-AML	N-AML
M369938	QTZT	0.21	0.41	4.7	27	6.6	13.9	2.1	N-AML	N-AML
M369952	QTZT	0.04	0.06	7.8	39	1.3	4.4	3.5	N-AML	N-AML
M369918	GSCH	0.08	0.35	13.5	79	2.5	12.3	4.9	N-AML	N-AML
M369927	GSCH	0.08	0.32	11.5	113	2.5	11.4	4.6	N-AML	N-AML
M369902	QTZT	0.02	0.04	3.3	25	0.6	3.8	6.1	N-AML	N-AML
M369948	TQTZT	0.04	0.04	13.9	51	1.3	3.8	3.1	N-AML	N-AML
M369922	GSCH	0.07	0.32	14.7	98	2.2	11.4	5.2	N-AML	N-AML
M369928	QTZT	0.04	0.06	1.8	18	1.3	4.4	3.5	N-AML	N-AML
M369955	QTZT	0.09	1.16	3.4	40	2.8	34.3	12.2	N-AML	N-AML
M369959	QTZT	0.04	0.61	2.9	75	1.3	19.3	15.5	N-AML	N-AML
M369932	TQTZT	0.17	4.27	6.1	32	5.3	118.9	22.4	N-AML	N-AML
M369963	TQTZT	0.04	0.6	4.1	169	1.3	19.1	15.2	N-AML	N-AML
M369901	QTZT	0.04	0.1	10.9	32	1.3	5.5	4.4	N-AML	N-AML
M369903	QTZT	0.01	0.03	1.9	10	0.3	3.6	11.4	N-AML	N-AML
M369904	QTZT	0.09	0.04	3.8	24	2.8	3.8	1.4 ^a	N-AML	N-AML
M369906	GSCH	0.01	0.18	16.9	60	0.3	7.6	24	N-AML	N-AML
M369908	GSCH	0.04	0.24	18.9	83	1.3	9.3	7.4	N-AML	N-AML
M369909	GSCH	0.12	0.23	20.3	87	3.8	9.0	2.4	N-AML	N-AML
M369911	GSCH	0.03	0.31	13.7	118	0.9	11.2	12	N-AML	N-AML
M369912	QTZT 75%/GSCH 25%	0.02	0.17	3.7	23	0.6	7.4	12	N-AML	N-AML
M369914	QTZT	0.11	0.1	4.6	60	3.4	5.5	1.6 ^a	N-AML	N-AML
M369916	TQTZT	0.07	0.34	6.5	88	2.2	12.0	5.5	N-AML	N-AML
M369917	FLT?	0.09	0.12	6.9	80	2.8	6.0	2.1	N-AML	N-AML
M369919	GSCH	0.22	0.5	27.4	126	6.9	16.3	2.4	N-AML	N-AML
M369920	GSCH	0.24	0.85	17.5	91	7.5	25.9	3.4	N-AML	N-AML
M369921	GSCH	0.23	0.72	19.6	113	7.2	22.3	3.1	N-AML	N-AML
M369924	GSCH	0.13	1.14	18.5	126	4.1	33.7	8.3	N-AML	N-AML
M369925	GSCH	0.11	0.27	18.1	211	3.4	10.1	2.9	N-AML	N-AML
M369926	GSCH	0.03	0.17	23.8	228	0.9	7.4	7.9	N-AML	N-AML
M369929	QTZT 70%/TQTZT 30%	0.2	5.5	10.5	98	6.3	152.3	24	N-AML	N-AML
M369931	TQTZT	0.42	13.2	17.9	51	13.1	361.8	28	N-AML	N-AML
M369933	TQTZT	0.16	0.62	6.8	61	5.0	19.6	3.9	N-AML	N-AML
M369934	TQTZT 75%/GSCH 25%	0.23	2.6	12.3	93	7.2	73.5	10	N-AML	N-AML
M369936	QTZT	0.08	0.39	10.6	63	2.5	13.3	5.3	N-AML	N-AML
M369937	QTZT 80%/ TQTZT 20%	0.11	0.21	6.4	31	3.4	8.5	2.5	N-AML	N-AML
M369939	QTZT	0.05	0.06	5.1	38	1.6	4.4	2.8	N-AML	N-AML
M369940	QTZT	0.06	0.02	3.3	40	1.9	3.3	1.8 ^a	N-AML	N-AML
M369941	QTZT	0.05	0.06	4.2	80	1.6	4.4	2.8	N-AML	N-AML
M369942	QTZT	0.02	0.05	3.8	61	0.6	4.1	6.6	N-AML	N-AML
M369944	QTZT	0.09	0.15	6.8	38	2.8	6.8	2.4	N-AML	N-AML
M369945	QTZT	0.13	3.68	6.6	37	4.1	102.8	25	N-AML	N-AML
M369947	TQTZT	0.47	0.96	12	164	14.7	28.9	2.0	N-AML	N-AML
M369949	TQTZT	0.1	1.16	17.4	148	3.1	34.3	11	N-AML	N-AML
M369951	QTZT	0.11	0.8	56.9	240	3.4	24.5	7.1	N-AML	N-AML
M369953	QTZT	0.03	0.07	8.8	45	0.9	4.6	5.0	N-AML	N-AML
M369954	QTZT	0.07	0.32	2.6	34	2.2	11.4	5.2	N-AML	N-AML
M369956	QTZT	0.07	0.14	2.5	21	2.2	6.5	3.0	N-AML	N-AML
M369958	QTZT	0.03	0.06	1.4	47	0.9	4.4	4.7	N-AML	N-AML
M369960	QTZT	0.04	0.06	3.3	59	1.3	4.4	3.5	N-AML	N-AML
M369961	QTZT 70%/TQTZT 30%	0.04	0.04	7.1	46	1.3	3.8	3.1	N-AML	N-AML
M369962	TQTZT	0.08	0.67	8.6	146	2.5	21.0	8.4	N-AML	N-AML
M369964	TQTZT	0.03	0.04	3.8	46	0.9	3.8	4.1	N-AML	N-AML

^a Highlighted cells indicate surrogate NPR<2 data, suggestive of uncertain potential with respect to acid generation.

5.3.2.4 *Birmingham Field Screening Criteria*

The field screening criteria proposed for use at Birmingham are the same as those for Flame and Moth. As such, any sample that meets one or more of the following conditions should be designated as P-AML:

- Visual estimated sphalerite >0.75%; or
- Visual estimated galena >0.5%; or
- Visual estimated pyrite >2%; or
- Paste pH \leq 6.0

In addition to satisfying the above criteria, any waste rock for construction outside of Birmingham portal area will be subjected to aqua regia digestion and ICP analysis to satisfy the Bellekeno screening criteria indicted in Section 5.3.2.1.

6 SUMMARY

- Based on the ABA analyses of 15 samples, the material is largely non acid-generating as 80% of the samples had an NPR >2. Indeed, surrogate NPR calculations, based on the bulk sulphur and calcium concentrations, indicated 91% of the 55 sample dataset had a surrogate NPR>2.
- Those samples that had an NPR <2 had uncertain potential for acid generation (i.e., 1<NPR<2) and very low sulphur content (0.04 to 0.11 wt.% S), indicating that any acid generation would likely be of limited extent and neutralized by the bulk NP contained in the Birmingham waste rock;
- The NPR of the Birmingham cover hole samples plot broadly in the range of NPR of historic Birmingham waste rock and pit wall samples analyzed in 1996 (AMC, 1996) and 2007 (SRK, 2009);
- Birmingham samples generally had both lower NP and AP than waste rock analyzed from other KHSD production zones and did not have a higher proportion of samples that had NPR <2 than other zones;
- SFE testing of Birmingham cover hole rock returned elevated concentrations of fluoride, aluminum, arsenic, and selenium; however, the highest concentrations were within an order of magnitude of their relevant water quality guidelines. Given the small particle size of the material used in the SFE work relative to the field, significant metal leaching is not anticipated.
- Given the largely similar to benign ARD/ML properties of the Birmingham waste rock relative to other sites within the KHSD, the waste geochemical screening criteria previously developed at those sites are suitable for use at Birmingham.

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APPENDIX A

Static Data for Waste Rock Drill Core Samples from Bermingham Cover Hole

Appendix A: Aqua Regia ICP-MS Elements Data

AEG label	From	To	Lithology	% S	ppm Sb	ppm Sc	ppm Se	ppm Sn	ppm Sr	ppm Ta	ppm Te	ppm Th	% Ti	ppm Tl	ppm U	ppm V	ppm W	ppm Y	ppm Zn	ppm Zr
M369901	0.0	4.5	QTZT	0.04	2.17	0.9	0.3	<0.2	11.6	<0.01	0.06	3.7	<0.005	0.06	0.39	10	0.05	1.73	32	4.4
M369902	4.5	9.0	QTZT	0.02	0.99	0.2	<0.2	<0.2	2.6	<0.01	0.02	1.7	<0.005	0.02	0.13	1	0.05	0.78	25	0.8
M369903	9.0	13.5	QTZT	0.01	0.54	0.1	<0.2	<0.2	4.6	<0.01	0.01	1.3	<0.005	<0.02	0.09	1	<0.05	0.69	10	0.7
M369904	13.5	18.0	QTZT	0.09	0.87	0.4	0.4	<0.2	3.2	<0.01	0.01	1.4	<0.005	0.02	0.06	3	0.4	1.01	24	0.7
M369906	18.0	22.5	GSCH	0.01	4.15	2.1	1.6	0.3	11.6	<0.01	0.04	12.9	<0.005	0.06	0.42	14	0.34	6.38	60	5.5
M369907	22.5	27.0	GSCH	0.1	3.78	2	3.9	0.2	22	<0.01	0.08	10.6	<0.005	0.08	0.55	13	0.46	5.56	110	8.9
M369908	27.0	31.5	GSCH	0.04	3.94	1.9	2.4	0.2	11.9	<0.01	0.06	11.8	<0.005	0.06	0.49	15	0.28	5.65	83	8.3
M369909	31.5	36.0	GSCH	0.12	4.04	2	2.1	0.3	9.6	<0.01	0.04	12	<0.005	0.07	0.44	15	9.18	6.52	87	9
M369911	40.5	45.0	GSCH	0.03	5.6	2.2	2	0.2	13.2	<0.01	0.07	13.1	<0.005	0.06	0.4	15	0.24	6.36	118	7.7
M369912	45.0	49.5	QTZT 75%/GSCH 25%	0.02	1.5	0.8	0.6	<0.2	24.3	<0.01	0.02	3.8	<0.005	0.05	0.25	5	1.02	1.53	23	2.5
M369913	49.5	54.0	QTZT	0.04	0.36	0.2	0.2	<0.2	2.1	<0.01	<0.01	1.1	<0.005	<0.02	0.05	1	<0.05	0.65	14	0.8
M369914	54.0	58.5	QTZT	0.11	1.01	0.6	0.7	<0.2	2.3	<0.01	0.01	1.6	<0.005	<0.02	0.11	2	0.09	1.72	60	1.4
M369916	58.5	63.0	TQTZT	0.07	1.73	0.7	1.5	<0.2	11.3	<0.01	0.02	3.2	<0.005	0.05	0.24	5	1	3.77	88	3.7
M369917	63.0	67.5	FLT?	0.09	2.29	1.1	1.3	0.2	7	<0.01	0.03	6.7	<0.005	0.05	0.25	8	0.33	2.82	80	5
M369918	67.5	72.0	GSCH	0.08	5.17	2.5	1.9	0.3	15.5	<0.01	0.06	13.2	<0.005	0.07	0.43	21	0.1	5.14	79	5.5
M369919	72.0	76.5	GSCH	0.22	6.54	2.5	2.7	0.3	14.7	<0.01	0.06	12	<0.005	0.07	0.45	19	0.18	6.47	126	6.1
M369920	76.5	81.0	GSCH	0.24	5.48	2.1	2.3	0.2	15.8	<0.01	0.06	11.7	<0.005	0.06	0.39	12	0.15	6.07	91	7.3
M369921	81.0	85.5	GSCH	0.23	4.54	2.2	2.2	0.2	13.7	<0.01	0.07	11	<0.005	0.07	0.38	13	0.09	6.54	113	7.5
M369922	85.5	90.0	GSCH	0.07	5.02	2.1	2	0.2	13.3	<0.01	0.06	12.8	<0.005	0.07	0.41	14	0.09	5.99	98	6
M369924	90.0	94.5	GSCH	0.13	3.92	2.5	2.4	0.2	18.4	<0.01	0.04	10.3	<0.005	0.05	0.35	13	0.09	6.67	126	6.8
M369925	94.5	99.0	GSCH	0.11	5.72	2.3	3.6	0.3	10.2	<0.01	0.04	10.1	<0.005	0.07	0.48	14	0.09	5.65	211	6
M369926	99.0	103.5	GSCH	0.03	10.7	2.4	3.4	0.2	18.5	<0.01	0.07	10.2	<0.005	0.08	0.58	18	0.11	5.82	228	5.1
M369927	103.5	108.0	GSCH	0.08	8.7	2.5	1.8	0.2	11	<0.01	0.03	11.5	<0.005	0.06	0.38	20	0.07	5.39	113	5.9
M369928	108.0	112.5	QTZT	0.04	0.45	0.2	0.4	<0.2	1.5	<0.01	<0.01	1	<0.005	<0.02	0.05	1	0.2	0.61	18	0.8
M369929	112.5	117.0	QTZT 70%/TQTZT 30%	0.2	2.24	1.5	0.9	<0.2	140.5	<0.01	0.01	2.2	<0.005	0.04	0.36	6	0.65	5.75	98	4.7
M369931	117.0	121.5	TQTZT	0.42	2.31	3.1	1.7	<0.2	275	<0.01	0.03	3.4	<0.005	0.06	0.65	9	0.06	11.1	51	11.2
M369932	121.5	126.0	TQTZT	0.17	1.22	1.2	0.8	<0.2	83.2	<0.01	0.02	2.4	<0.005	0.03	0.18	5	0.9	3.6	32	4.4
M369933	126.0	130.5	TQTZT	0.16	1.88	1	0.6	<0.2	16.6	<0.01	0.01	2.6	<0.005	0.04	0.23	3	1.52	3.7	61	2.1
M369934	130.5	135.0	TQTZT 75%/GSCH 25%	0.23	3.28	2.2	1.3	0.2	44.4	<0.01	0.02	4.7	<0.005	0.05	0.37	10	0.19	5.14	93	6.5
M369936	135.0	139.5	QTZT	0.08	1.22	0.3	0.3	<0.2	10.3	<0.01	0.01	1.5	<0.005	0.02	0.09	2	0.06	1.22	63	1.1
M369937	139.5	144.0	QTZT 80%/ TQTZT 20%	0.11	1.63	0.4	0.6	<0.2	8.4	<0.01	0.01	1.9	<0.005	0.03	0.12	2	0.06	0.99	31	1.2
M369938	144.0	148.5	QTZT	0.21	1.46	0.3	0.4	<0.2	11.1	<0.01	0.01	0.8	<0.005	0.09	0.1	1	<0.05	0.86	27	0.7
M369939	148.5	153.0	QTZT	0.05	0.49	0.1	0.8	<0.2	2	<0.01	<0.01	1.3	<0.005	<0.02	0.07	1	0.05	0.7	38	1.2
M369940	153.0	157.5	QTZT	0.06	0.43	0.2	0.2	<0.2	1.9	<0.01	<0.01	1.2	<0.005	<0.02	0.1	1	1.3	0.68	40	1
M369941	157.5	162.0	QTZT	0.05	1.62	0.4	0.7	<0.2	7.8	<0.01	<0.01	1.4	<0.005	<0.02	0.47	2	0.22	1.94	80	2.4
M369942	162.0	166.5	QTZT	0.02	0.89	0.3	0.3	<0.2	7.5	<0.01	<0.01	1.6	<0.005	<0.02	0.31	1	0.5	1.61	61	1.9
M369943	166.5	171.0	QTZT	0.07	0.71	0.3	0.3	<0.2	4.4	<0.01	<0.01	2.3	<0.005	<0.02	0.2	1	0.11	1.27	43	1.7
M369944	171.0	175.5	QTZT	0.09	1.22	0.2	0.3	<0.2	7.6	<0.01	<0.01	1.5	<0.005	0.06	0.23	1	0.09	1.07	38	1.6
M369945	175.5	180.0	QTZT	0.13	1.94	0.9	1.2	<0.2	65.5	<0.01	0.01	3	<0.005	0.05	0.4	4	0.06	3.05	37	10.5
M369947	180.0	184.5	TQTZT	0.47	4.87	2.4	2.8	0.2	18.9	<0.01	0.04	6.7	<0.005	0.18	1.42	12	0.06	8.88	164	15.5
M369948	184.5	189.0	TQTZT	0.04	3.32	0.7	2.3	0.2	7.2	<0.01	0.06	3.8	<0.005	0.04	0.66	4	0.08	1.73	51	7.9
M369949	189.0	193.5	TQTZT	0.1	5.58	3.5	1.4	0.3	34.2	<0.01	0.03	8.6	0.022	0.08	0.58	23	0.15	7.75	148	10.1
M369951	193.5	198.0	QTZT	0.11	1.57	3.4	0.7	0.2	72.4	<0.01	<0.01	3.9	0.073	0.28	0.45	27	0.32	5.33	240	5.6
M369952	198.0	202.5	QTZT	0.04	0.58	0.3	0.4	<0.2	2.6	<0.01	<0.01	1.2	<0.005	<0.02	0.09	1	0.16	0.7	39	0.9
M369953	202.5	207.0	QTZT	0.03	0.43	0.2	0.2	<0.2	1.6	<0.01	<0.01	1	<0.005	<0.02	0.07	1	0.2	0.68	45	0.6
M369954	207.0	211.5	QTZT	0.07	0.7	0.3	0.2	<0.2	4.7	<0.01	<0.01	1.1	<0.005	<0.02	0.13	1	0.12	0.89	34	0.9
M369955	211.5	216.0	QTZT	0.09	0.84	0.4	0.4	<0.2	14.3	<0.01	<0.01	1.2	<0.005	<0.02	0.1	2	<0.05	1.03	40	0.9
M369956	216.0	220.5	QTZT	0.07	0.64	0.4	0.2	<0.2	3.1	<0.01	<0.01	1.7	<0.005	<0.02	0.13	2	<0.05	0.75	21	1
M369958	220.5	225.0	QTZT	0.03	0.65	0.3	0.2	<0.2	1.2	<0.01	<0.01	1	<0.005	<0.02	0.07	2	1.19	0.61	47	0.8
M369959	225.0	229.5	QTZT	0.04	0.69	0.4	0.3	<0.2	6.1	<0.01	<0.01	1.2	<0.005	<0.02	0.09	3	0.22	1.09	75	0.9
M369960	229.5	234.0	QTZT	0.04	1.02	0.3	0.4	<0.2	2.1	<0.01	<0.01	1	<0.005	<0.02	0.24	2	0.28	0.8	59	1.1
M369961	234.0	238.5	QTZT 70%/TQTZT 30%	0.04	2.81	0.4	0.6	<0.2	3.5	<0.01	<0.01	2	<0.005	0.03	0.19	3	0.32	0.99	46	2.3
M369962	238.5	243.0	TQTZT	0.08	3.13	1.3	1.1	<0.2	17.4	<0.01	<0.01	4.4	<0.005	0.04	1.09	9	0.23	4.01	146	5.3
M369963	243.0	247.5	TQTZT	0.04	1.44	0.6	0.5	<0.2	23.3	<0.01	<0.01	2.2	<0.005	<0.02	1.37	5	0.44	3.16	169	4
M369964	247.5	252.0	TQTZT	0.03	1.22	0.5	0.7	<0.2	8.7	<0.01	<0.01	2.6	<0.005	0.02	0.33	4	0.56	1.32	46	2

Appendix A: Acid-base Accounting Data

				pH Units	wt%	Kg CaCO3/t	wt%	wt%	wt%	Kg CaCO3/t	Kg CaCO3/t	N/A	Kg CaCO3/t	N/A
AEG label	From	To	Lithology	Paste pH	CO2	CaCO3 Equivalent	Total S	HCl Extractable Sulphur	Sulphide Sulphur (by diff.)	Acid Generation Potential	Siderite Corr. Neutralization Potential	Fizz Rating	Net Neutralization Potential	Neutralization Potential Ratio
M369902	4.5	9.0	QTZT	7.62	<0.08	<1.8	0.02	<0.01	0.02	0.6	2.80	NONE	2.20	4.7
M369907	22.5	27.0	GSCH	7.24	<0.08	<1.8	0.09	0.01	0.08	2.5	5.00	NONE	2.50	2.0
M369913	49.5	54.0	QTZT	8.12	0.08	1.8	0.04	<0.01	0.04	1.3	2.5	NONE	1.2	1.9
M369918	67.5	72.0	GSCH	8.35	0.12	2.7	0.09	<0.01	0.09	2.8	10.5	NONE	7.70	3.8
M369922	85.5	90.0	GSCH	8.32	0.20	4.6	0.07	<0.01	0.07	2.2	11.3	NONE	9.10	5.1
M369927	103.5	108.0	GSCH	8.29	0.14	3.2	0.08	<0.01	0.08	2.5	11.3	NONE	8.80	4.5
M369928	108.0	112.5	QTZT	8.08	<0.08	<1.8	0.03	<0.01	0.03	0.9	5.80	NONE	4.90	6.4
M369932	121.5	126.0	TQTZT	8.63	4.51	102.5	0.16	<0.01	0.16	5.0	118	STRONG	113	23.5
M369938	144.0	148.5	QTZT	8.09	0.61	13.9	0.20	<0.01	0.20	6.3	15.8	SLIGHT	9.50	2.5
M369943	166.5	171.0	QTZT	7.21	<0.08	<1.8	0.06	<0.01	0.06	1.9	2.30	NONE	0.400	1.2
M369948	184.5	189.0	TQTZT	8.02	<0.08	<1.8	0.02	<0.01	0.02	0.6	3.00	NONE	2.40	5.0
M369952	198.0	202.5	QTZT	8.32	<0.08	<1.8	0.04	<0.01	0.04	1.3	3.50	NONE	2.20	2.7
M369955	211.5	216.0	QTZT	8.65	0.91	20.7	0.08	<0.01	0.08	2.5	33.8	MODERATE	31.3	13.5
M369959	225.0	229.5	QTZT	8.59	0.65	14.8	0.03	<0.01	0.03	0.9	19.8	SLIGHT	18.9	22.0
M369963	243.0	247.5	TQTZT	8.36	0.80	18.2	0.03	<0.01	0.03	0.9	25.0	SLIGHT	24.1	27.8

