Application of an Advanced Mineralogical Technique: Sulphide Mineral Availability and Humidity Cell Interpretations based on MLA Analysis

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Abstract
Hope Bay Mining Ltd., a subsidiary of Newmont, is undertaking a comprehensive geochemical characterization program of mine wastes associated with gold deposits in the Hope Bay Greenstone Belt, Nunavut, Canada. Mineralogical characterization by X-ray diffraction (XRD) and a high throughput automated mineral liberation analyzer (MLA) was conducted for 43 humidity cell samples of waste rock and tailings. The MLA uses a scanning electron microscope (SEM) with energy dispersive X-ray spectrometers (EDS) and automated mineralogy software capable of quantitatively identifying thousands of mineral grains at submicron and trace levels, including less common sulphide minerals that are the sources of metal leaching from mine wastes. The extended back-scattered electron mode of the MLA system was used to determine the length of the free sulphide surface available for chemical reaction. This technique has not been widely applied in the assessment of metal leaching/acid rock drainage from mine sites.

Carbonate mineralogy in samples from this site was characterized by ferroan dolomite with lesser calcite, siderite and rare magnesite. Sulphide mineralogy was dominated by pyrite, and trace amounts of chalcopyrite, gersdorffite, pyrrhotite, arsenopyrite, galena, cobaltite, millerite, sphalerite, tetradymite and/or tetrahedrite. Humidity cell interpretations, specifically sulphide oxidation and metal release rates were coupled with the MLA data to explore relationships with sulphide mineralogy and chemical availability.

Key Words: humidity cell tests, mineral liberation analyzer (MLA), mineralogy, greenstone belt, gold deposit

Introduction

The Hope Bay Greenstone Belt is located within the Kitikmeot Region of Nunavut Territory, Canada, approximately 685 km northwest of Yellowknife and 125 km southwest of Cambridge Bay. The Belt extends over 80 km in length and is up to 20 km wide. The Doris and Boston deposits are in the north and south, respectively and the Madrid deposit is located 6 km south of Doris (Figure 1). All three deposits are Archean greenstone belt gold deposits but have distinctive geological controls on gold and other mineralization. Waste rock from Doris, Madrid and Boston is typically characterized by low sulphide content and high levels of carbonate minerals (Table 1). Higher sulphide levels are typically associated with zones of alteration proximal to the ore deposit.

A total of 39 mine rock (both waste and ore) and four metallurgical tailings samples from the three deposits were subjected to humidity cell testing and also analyzed for trace level mineralogy using a mineral liberation analyzer (MLA). MLA mineralogical data complement bulk chemical assays and are used to guide decisions in exploration, mining, mineral processing and metal refining. MLA analyses were applied to humidity cell samples to characterize and quantify major and trace mineral content. MLA data included trace mineralogy using a scanning electron microscope (SEM) with energy dispersive X-ray spectrometers (EDS) and automated quantitative mineralogy software. Also, using the Extended Back-Scattered Electron (XBSE) measurement with the MLA, mineral associations with sulphides and for pyrite, grain size and crystal morphology were also determined. This paper explores the relationships

between MLA data and contaminant release rates from humidity cell tests, with a focus on sulphate and arsenic leaching.

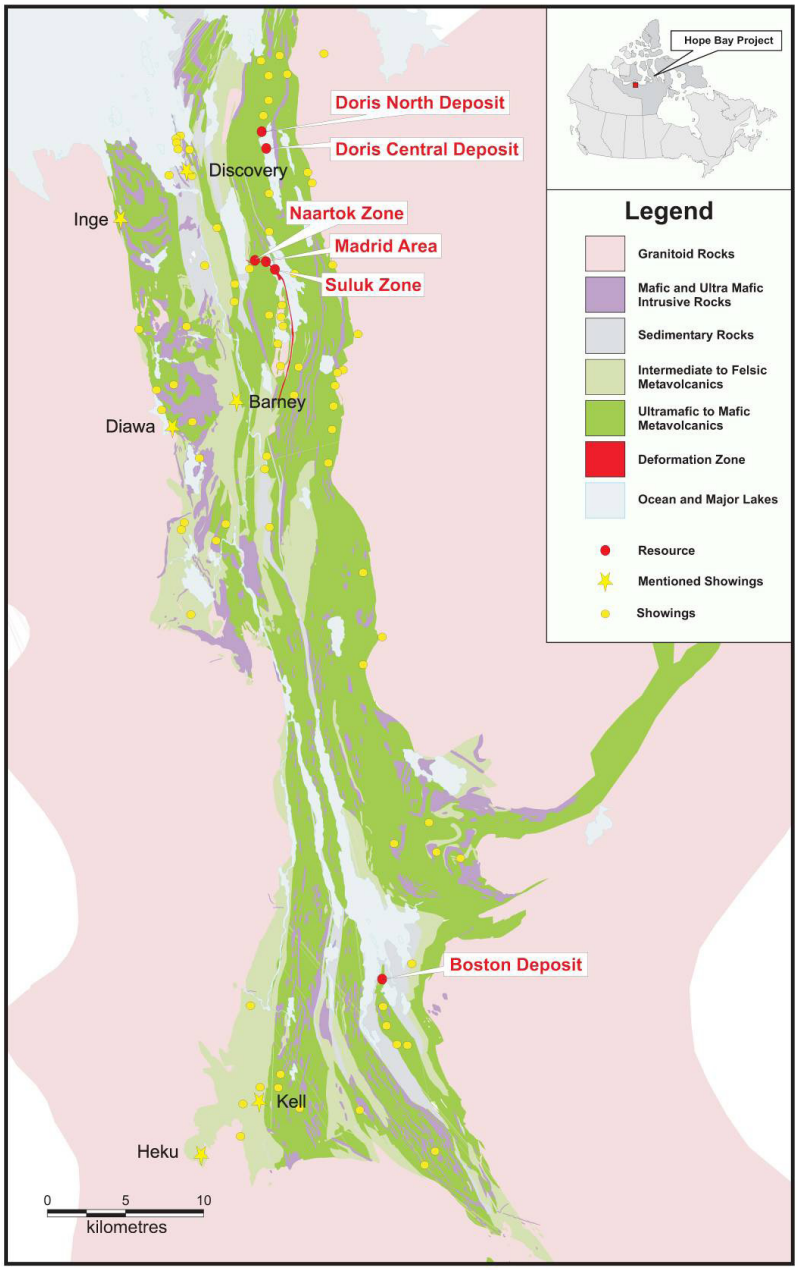

Figure 1: Geology of Hope Bay belt and Location of the Doris, Madrid and Boston deposits

Table 1: Median Levels of Selected ABA and Mineralogy Data

Deposit	Total S		NP		TIC		Ferroan Dolomite		Calcite	
	%S	n	$kgCaCO_3/t$	n	$kgCaCO_3/t$	n	wt. %	n	wt. %	n
Doris	0.15	675	145	675	216	602	22	244	0	244
Madrid	0.20	419	228	419	280	419	26	399	1	399
Boston	0.26	583	286	583	344	300	31	254	0	254

Methods

A total of thirty-eight mine rock (both waste and ore) samples from the Doris, Madrid and Boston deposits, and four samples of various metallurgical tailings products were submitted for humidity cell tests using the ASTM method (ASTM 2001). The humidity cell test charges were analyzed for modified acid-base accounting (ABA, MEND 1991), total inorganic carbon (TIC) and trace elemental content by aqua regia digestion with ICP finish. TIC was determined by using a Leco furnace to directly measure CO2 gas evolved from HCl treatment of the sample. At the time of data analysis for this paper, the test duration varied from 56 to 91 weeks and 16 of the tests were still operating on the basis of changing trends for sulphate and metal release rates. The samples were selected to represent both typical and "high sulphur" waste rock from each of the deposits, and typically contained low sulphides, and were classified as not-potentially acid generating. Humidity cell leachates were non-acidic in all of the tests.

Mineralogy for the HCT head samples was determined by Newmont Metallurgical Services (NMS) in Englewood, Colorado. Mineralogical methods included XRD and MLA. Mineral quantities from XRD analysis were determined by Rietveld refinement, using whole pattern fitting and based on chemical analyses. Limits of detection by XRD are 0.1% by weight depending on the crystallinity and matrices effects of the certain phases present. Due to a drop in confidence for phases with less than 1% weight NMS has reported such phases as trace (tr) or <1%. For XRD, there are no internal standards are available, consequently only crystalline phases are detected.

For MLA analysis, five grams from each sample were mounted and slurried in epoxy, polished, and carbon-coated for MLA analysis. Thirty-eight samples, including one tailings sample, were -¼" mesh size (the humidity cell size fraction) while four samples, including one waste rock sample, were analytic pulps (nominal 500 mesh). The samples were analyzed by MLA to detect trace minerals with a focus on characterizing sulphides using a scanning electron microscope (SEM) with energy dispersive X-ray spectrometers (EDS) and automated quantitative mineralogy software. All samples were analyzed using the Extended Back-Scattered Electron (XBSE) measurement. MLA/XBSE is an extended liberation analysis where back-scattered electron (BSE) images are collected and segmented based on gray levels. An EDS spectrum is then collected for each segmented gray level image or "phase" and matched to a standards (mineral) list by pattern fitting. Gold is commonly used as a standard to establish a gray level scale because of its brightness. Due to the similar gray levels of the complex mixed gangue found in the samples, copper was used to establish the gray scale. This elevated the contrast between gray levels which optimized the segmentation of gangue. The detection limit for these samples was 0.01%. The imagery is conducted in two dimensions.

The MLA report included data for the following:

- Trace mineralogy;
- For each sulphide mineral group: quantitative mineral associations (including liberated surfaces), proportion of liberated grains;
- For pyrite only: 50^{th} percentile (P50) and 80^{th} percentile(P80) values for grain size,
- Qualitative descriptions of crystal morphology and grain size at the mineral scale.

For the pulp samples, MLA analyses included trace mineralogy only.

Results

Mineralogy

The mineral liberation analyzer (MLA) method confirmed that ferroan dolomite ($Ca(Fe,Mg)(CO_3)_2$) was the dominant carbonate mineral, with lesser amounts of calcite ($CaCO_3$) and siderite ($FeCO_3$). All of the aforementioned carbonate minerals were detected by XRD, though siderite was previously identified by XRD as a solid-solution with magnesite ($MgCO_3$).

MLA results indicated that the dominant sulphide mineral was pyrite (FeS_2), and that trace amounts of chalcopyrite ($CuFeS_2$) and lesser gersdorffite ((Fe,Co,Ni)AsS), pyrrhotite ($Fe_{(1-x)}S$), arsenopyrite (FeAsS), galena (PbS), cobaltite (CoAsS), millerite (NiS), sphalerite (ZnS), tetradymite (Bi_2Te_2S) and/or tetrahedrite (Cu_3SbS) were present in the samples (Table 2). In contrast, pyrite was the only sulphide mineral detected by XRD, with a detection limit of 1%. Detection limits for the MLA were reported as <0.01%, indicating that a few particles of a mineral were present. Blanks reported in Table 2 indicate that no particles of that mineral were detected.

As presented in Table 2, gersdorffite was the primary arsenic sulphide mineral, though it was only present at trace levels (maximum 0.09% and 0.26% for waste rock and tailings samples, respectively). Cobaltite and arsenopyrite were also detected but at levels typically below detection. Arsenic levels were highest for samples from Madrid, with median levels of 91 ppm of arsenic equivalent as compared to 51 ppm of arsenic equivalent for Boston. For Doris samples, arsenic minerals were either below the level of detection or absent from the sample. Conventional mineralogical techniques used for these types of characterization programs are rarely able to identify, much less quantify minerals that are present at such trace levels.

The median grain size of pyrite was determined for each sample and ranged from 8.7 to 431 microns Table 2). Minerals associated with sulphides were also determined for each sample by MLA, including the length of the surfaces that were exposed, or not associated with another mineral phase. The measurements were reported as percent exposure. The free surface of suphides available for reaction ranged from 6 to 63%.

Humidity Cell Tests

The humidity cell tests had non-acidic leachates and were typically classified as non-potentially acid generating (non-PAG). Acid-base accounting (ABA) data have indicated that total sulphur levels for Doris, Madrid and Boston samples are representative of sulphide mineral content due to the absence fo sulphate minerals. Total sulphur levels determined by ABA ranged from 0.02 to 6% for the waste rock humidity cell samples and from 0.04 to 19% sulphur for the tailings samples (Table 2).

Stable release rates for all parameters were calculated based on uniform sulphate concentrations over a period of time. For tests where sulphate leaching trends had not yet stabilized, the stable rate was based on the last five cycles of data. Stable sulphate release rates range from less than 1 to 291 mg/kg/week, with the majority of samples (86%) having sulphate release rates of less than 10 mg/kg/week (Table 3). Stable arsenic release rates ranged from 0.0001 to 0.5 mg/kg/week, with the lowest rates for Doris samples and the highest for samples from Madrid and Boston (Table 3). It is noted that many of the samples had sulphate release rates that were at or close to detection limits.

Table 2: Sulphide Mineralogy as Indicated by ABA, XRD and MLA

Humidity Cell #	Deposit	Total Sulphur	Pyrite (FeS_2)	Pyrite (FeS_2)			Pyrrhotite ($Fe_{(1-x)}S$)	Chalcopyrite ($CuFeS_2$)	Arsenopyrite (FeAsS)	Cobaltite (CoAsS)	Gersdorffite ((Fe,Co,Ni)AsS))
		ABA	XRD	MLA							
		%S	wt. %	wt. %	Exposure %	P50 Grain size microns	wt. %	wt. %	wt. %	wt. %	wt. %
Waste Rock Samples											
HC-49	Doris	0.17		0.07	7	24	<0.01	<0.01		<0.01	
HC-42	Doris	0.1		0.24	12	110	<0.01	<0.01			
HC-43	Doris	0.52	<1	1.12	40	125	<0.01	<0.01			
HC-50	Doris	1.78	3	1.91	25	209	<0.01			<0.01	
HC-44	Doris	0.31		0.95	27	155	0.01	0.03		<0.01	<0.01
HC-45	Doris	2.37	2	4.66	50	215	0.02	0.01		<0.01	<0.01
HC-46	Doris	0.29		0.24	48	91	<0.01	<0.01			
HC-51	Doris	1.19	1	1.74	63	201	<0.01	0.03		<0.01	<0.01
HC-47	Doris	0.1	<1	0.03	40	33	<0.01	0.02			
HC-48	Doris	0.12	<1	0.08	39	56	<0.01	0.01			<0.01
HC-53	Doris	0.09		0.28	36	374	<0.01	<0.01			
HC-54	Doris	0.61	1	1.94	60	431	<0.01	<0.01			
HC-52	Doris	1.69	3	3.97	63	247	<0.01	<0.01		<0.01	
HC-36	Doris	6.03	2	6.17	27	266	<0.01	<0.01			
HC-27	Madrid	0.15	tr	0.14	36	82		0.03		<0.01	0.01
HC-25	Madrid	0.4		0.97	19	91	<0.01	0.03		0.01	0.01
HC-28	Madrid	1.31	3	3.63	26	98	<0.01	0.01		<0.01	0.02
HC-24	Madrid	2.17	3	3.69	28	125	<0.01	0.03		<0.01	0.03
HC-26	Madrid	3.93	7	6.61	20	102	<0.01	0.01			0.02
HC-21	Madrid	3.45	5	9.35	#N/A	#N/A	0.04	0.02		<0.01	
HC-23	Madrid	0.07		<0.01	9	9	<0.01	0.06			
HC-22	Madrid	0.02		0.02	16	10	0.03	0.06			
HC-29	Madrid	0.19		0.13	13	19		0.01		<0.01	0.01
HC-30	Madrid	0.55		0.72	31	182	<0.01	0.79			
HC-39	Madrid	0.54	0.8	1.09	17	72	<0.01	0.02			<0.01
HC-17	Madrid	0.37		2.13	13	342		0.03		<0.01	
HC-18	Madrid	0.12		0.13	26	106		0.05		<0.01	
HC-19	Madrid	0.24		0.58	24	170	0.18	0.04		<0.01	
HC-40	Madrid	0.11		0.26	9	40	<0.01	0.02		<0.01	
HC-41	Madrid	0.27		0.40	32	56		0.02		<0.01	0.03
HC-31	Boston	0.13		0.14	30	61		0.04		<0.01	<0.01
HC-55	Boston	0.29		0.75	33	223	<0.01	0.02		<0.01	0.01
HC-35	Boston	0.2		0.90	43	273	<0.01	<0.01		<0.01	<0.01
HC-34	Boston	0.81	2	1.93	6	29	0.15	0.03			<0.01
HC-37	Boston	1.48	2	2.14	26	302	<0.01	0.01	<0.01		0.07
HC-38	Boston	2.96	3	5.66	59	354	<0.01	0.06		<0.01	<0.01
HC-33	Boston	0.33	1	0.57	16	159	<0.01	0.02	0.02	<0.01	0.01
HC-32	Boston	0.86	1	0.96	36	288		0.01		<0.01	0.03
Tailings Samples											
HC-57	Doris	0.04		0.08	25	43	<0.01	<0.01	0.01		
HC-56	Madrid	0.08		0.35	#N/A	#N/A	<0.01			<0.01	0.01
HC-58	Madrid	18.75	30	41.93	#N/A	#N/A	0.08	0.27	<0.01	<0.01	0.26
HC-59	Madrid	0.98	1	1.93	#N/A	#N/A	0.02	0.02	<0.01	<0.01	0.02

Blank cell denote no mineral particles detected.

Trace amounts (less than detection) of tetrahedrite and spahlerite in many samples and of galena, millerite and tetrahydrite in a few samples.

Table 3: Selected Humidity Cell and Mineralogy Data

Humidity Cell #	Deposit	Arsenic		Sulphate
		Arsenic Assay (ICP-MS) ppm	HCT Release Rate mg/kg/week	HCT Release Rate mg/kg/week
Waste Rock Samples				
HC-49	Doris	2.2	0.0001	1
HC-42	Doris	1.7	0.0001	1
HC-43	Doris	21	0.0002	1
HC-50	Doris	63	0.0005	2
HC-44	Doris	12	0.0009	2
HC-45	Doris	51	0.0007	4
HC-46	Doris	7.6	0.0008	1
HC-51	Doris	48	0.003	2
HC-47	Doris	1.4	0.002	1
HC-48	Doris	3.4	0.0005	1
HC-53	Doris	2.6	0.0001	1
HC-54	Doris	7.7	0.0005	1
HC-52	Doris	42	0.0001	3
HC-36	Doris	90	0.0001	6
HC-27	Madrid	122	0.2	1
HC-25	Madrid	108	0.07	2
HC-28	Madrid	433	0.1	10
HC-24	Madrid	630	0.2	3
HC-26	Madrid	628	0.01	34
HC-21	Madrid	86	0.0003	43
HC-23	Madrid	27	0.001	2
HC-22	Madrid	3.1	0.0006	2
HC-29	Madrid	77	0.06	1
HC-30	Madrid	2	0.0002	4
HC-39	Madrid	64	0.006	2
HC-17	Madrid	11	0.0003	2
HC-18	Madrid	10	0.007	1
HC-19	Madrid	8.2	0.0004	7
HC-40	Madrid	7.1	0.002	1
HC-41	Madrid	273	0.3	2
HC-31	Boston	84	0.05	1
HC-55	Boston	138	0.03	1
HC-35	Boston	56	0.007	1
HC-34	Boston	74	0.0008	6
HC-37	Boston	549	0.1	5
HC-38	Boston	232	0.001	19
HC-33	Boston	372	0.2	2
HC-32	Boston	292	0.1	2
Tailings Samples				
HC-56	Madrid	338	0.06	3
HC-57	Doris	3.1	0.005	1
HC-58	Madrid	3665	0.0006	291
HC-59	Madrid	521	0.003	51

Notes: blank cells denote mineral grains were not detected

Discussion

Relationship between Solids Assays and Mineralogy

Sulphide content by MLA was generally equivalent to total sulphur levels determined by Leco furnace (Figure 2) and XRD (Figure 3). There are fewer samples shown in Figure 3 because using XRD, less samples had detectable levels of sulphide (pyrite) due to higher detection limits (1%). These findings suggest that MLA provides a reasonably accurate measure of the sulphide content.

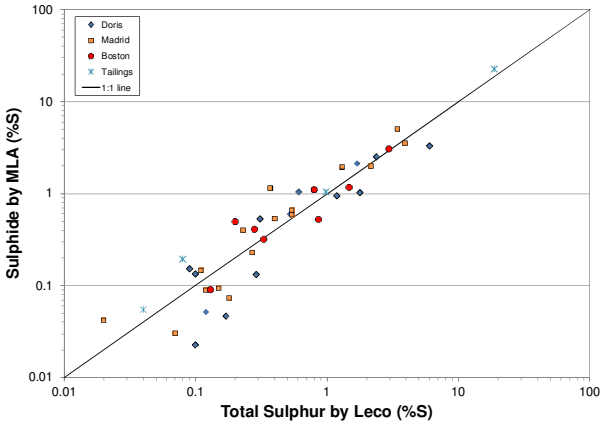

Figure 2: Comparison of Sulphide Content by MLA and Total Sulphur by Leco

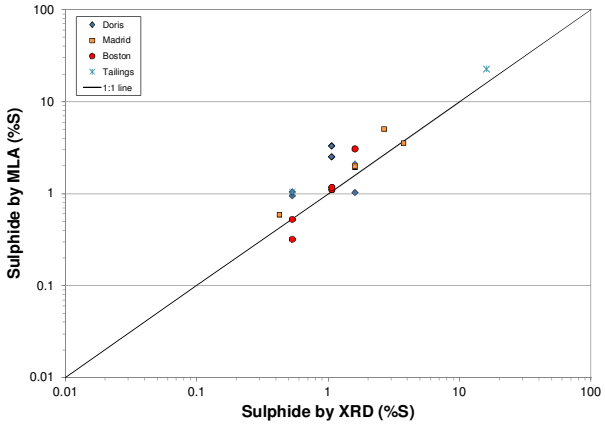

Figure 3: Comparison of Sulphide Content by MLA and Sulphide by XRD

Sulphate Release Rates

Sulphate release rates were correlated with total sulphur or sulphide content (Figure 4). The slope of the relationship varied by deposit, with Doris samples exhibiting lower sulphate release rates (or sulphide oxidation rates) than Madrid and Boston. Sulphate release rates were highest for the tailings samples. A number of samples had release rates around 1 mg/kg/week. Actual release rates for these samples may be lower as they represent the limit of detection for sulphate. To further investigate controls on sulphate release rates, samples containing low pyrite (less than 0.5%) and with rates near the limit of analytical detection for sulphate (less than 2 mg/kg/week) were removed from the data set.

As shown in Figure 5 and Table 4, the relationship between sulphate release rates and pyrite varied by deposit. The calculated regressions indicated that for Boston, there is a clear relationship between pyrite and sulphate release ($R^2 = 0.98$). For Doris ($R^2 = 0.86$) and Madrid ($R^2 = 0.85$) there is greater variance in the relationship, indicating that sulphate release rates are related to factors other than pyrite content. These other variables are represented by the residual sulphate release rate ($R(SO_4)_{res}$), which was calculated as follows:

$$R(SO_4)_{residual} = R(SO_4)_{HCT} - R(SO_4)_{calc'd} \qquad \text{(Equation 1)}$$

where $R(SO_4)_{HCT}$ is the stable sulphate release rate determined from the humidity cell test and $R(SO_4)_{calc'd}$ was the deposit specific sulphate release rate calculated from the pyrite content and the slope of the regression line. Relationships with the residual sulphate release rates with other variables were further explored to identify controls on sulphate release rates not explained by pyrite content. The results of these relationships are presented in Table 5.

For each sample, the MLA method determined the median grain size of pyrite. For Doris and Boston, there is a relationship ($R^2 = 0.30$) between the residual sulphate release and the median grain size of pyrite

(Figure 6), suggesting that grain size is an additional variable controlling sulphate release rate for these deposits. Overall, median grain size statistically accounts for 5% and 0.6% of the variability of sulphate release for Doris and Boston, respectively. There was no relationship observed for Madrid. For smaller grain sizes, there was more scatter in the data (i.e. higher residuals), with measured sulphate rate both higher and lower than calculated. This may be attributable to the higher propensity for smaller grains to be encapsulated by other mineral phases and the lower likelihood of their liberation during the sample preparation (crushing) process. This may lead to higher variability in mineral grain liberation, thus explaining the scatter in sulphate release at low exposure rates.

For Doris only, there was a relationship (R^2=0.38) with residual sulphate release rate and the proportion of exposed sulphide surfaces (Figure 7). For samples with a smaller proportion of sulphides exposed, there is more scatter in the data (i.e. higher residuals). This may be a methodological limitation related to the two-dimensional analysis of samples. With less exposure, there is a greater error in determining the amount of exposed surfaces when extrapolating the results to a three-dimensional model.

Some mineralogical relationships with residual sulphate release rates were also explored (Table 5). There was no relationship with non-pyritic sulphides and residual sulphide release rates, suggesting that the other sulphides present in the samples were not contributing appreciably to the sulphate release (i.e. pyrite was the dominant sulphide controlling this parameter). Other mineralogical controls on sulphate release, for example, the relationships between the residual sulphate release rates and dolomite and also residual release sulphate rates and quartz content at Doris and the relationship between residual sulphate release rates and albite at Madrid, may possibly be explained by different phase of alteration and mineralization, which could lead to differences in sulphide texture and availability.

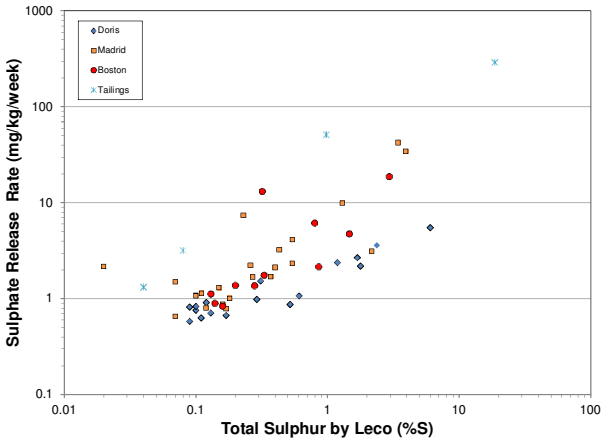

Figure 4: Relationship between Stable Sulphate Release Rate and Total Sulphur by Leco

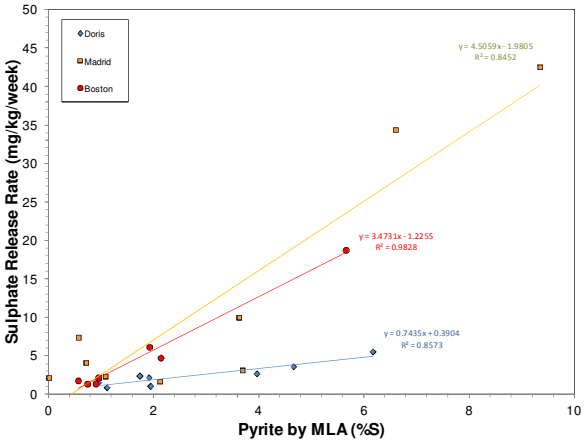

Figure 5: Relationship between Stable Sulphate Release Rate and Pyrite Content by MLA for Samples with Sulphate Release Rates above Detection

Table 4: Regression Values (R2) for Sulphate Release Rates and Pyrite Content

(Figure 5)**Variable**	**Doris**	**Madrid**	**Boston**
Pyrite	0.86	0.85	0.98

Table 5: Regression Values (R2) for Residual Sulphate Release Rates and Other Variables

Variable	**Doris**	**Madrid**	**Boston**	**Comment**
Grain size of pyrite	0.30	-	0.30	Actual sulphate release highest for small grain sizes
% Exposure of sulphide	0.38	-	-	Actual sulphate release highest for samples with the least exposure
Albite	0.23	0.30	-	Actual sulphate release highest where albite content was higher
Ferroan dolomite	0.45	0.15	-	Actual sulphate release highest where ferroan dolomite content was highest
Non-pyrite sulphide	0.07	0.09	0.09	Actual sulphate release rates highest for samples with additional sulphides (non pyritic forms) present
Quartz	0.41	-	-	Actual sulphate release rates lowest for samples with very high quartz content

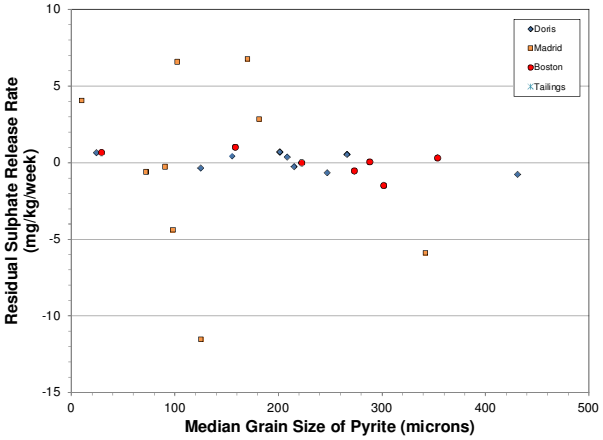

Figure 6: Relationship between Residual Stable Sulphate Release Rate and Median Grain Size for Pyrite

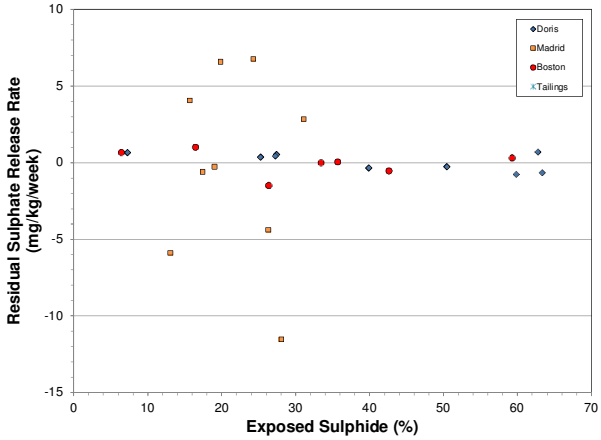

Figure 7: Relationship between Residual Stable Sulphate Release Rate and Proportion of Exposed Pyrite

Arsenic

For samples containing arsenic minerals, the arsenic equivalent was compared to levels determined by aqua regia digestion with ICP finish (Figure 8). In Figure 8, sample points denoted with a circle indicate that the calculation of arsenic content was based exclusively on mineral levels reported as below detection (i.e. <0.001%). These levels indicate the MLA detected arsenic mineral grains but at low quantities. For selected samples from Madrid and Boston, arsenic levels determined by aqua regia digestion with ICP finish were comparable to the arsenic mineral content, suggesting that for these samples the majority of the arsenic inventory could be accounted for by the arsenic minerals identified through MLA. Where arsenic levels by MLA were lower than those by ICP, this suggests arsenic is present as a trace element in other mineral phases.

The amount of arsenic present as a trace element in minerals (As_{trace}) was calculated using the following formula:

$$As_{trace} = As_{ICP} - As_{MLA} \quad \text{(Equation 2)}$$

where As_{ICP} is total arsenic and As_{MLA} is the amount of arsenic attributed to arsenic minerals identified through MLA. For the Doris samples only, there is a relationship between trace arsenic levels (As_{trace})and pyrite content, which may indicate that trace amounts of arsenic are present in the pyrite (Figure 9). Alternatively, this may simply be due to relationships between the amount of arsenic minerals and pyrite (Figure 10). Element mapping or other types of microprobe analyses would be needed to determine whether the "missing" arsenic occurs as pyrite.

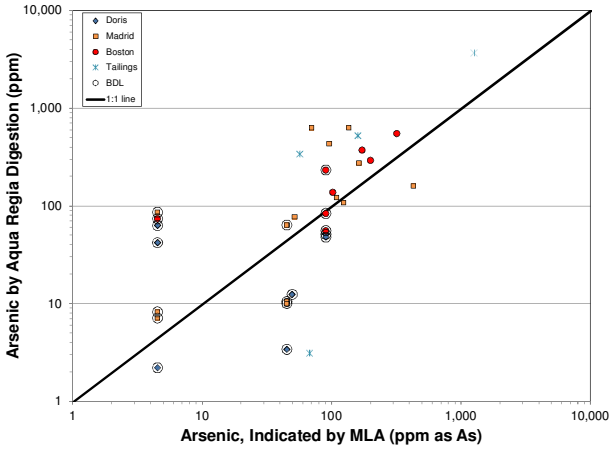

Figure 8: Relationship between Arsenic Content as Indicated by Aqua Regia Digestion and MLA

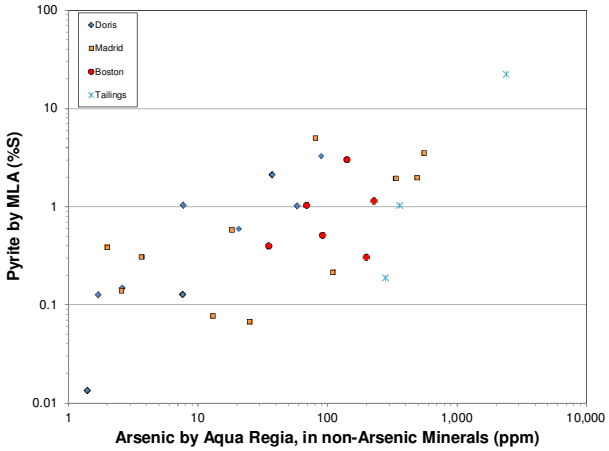

Figure 9: Relationship between Arsenic Content in non-Arsenic Minerals and Pyrite by MLA

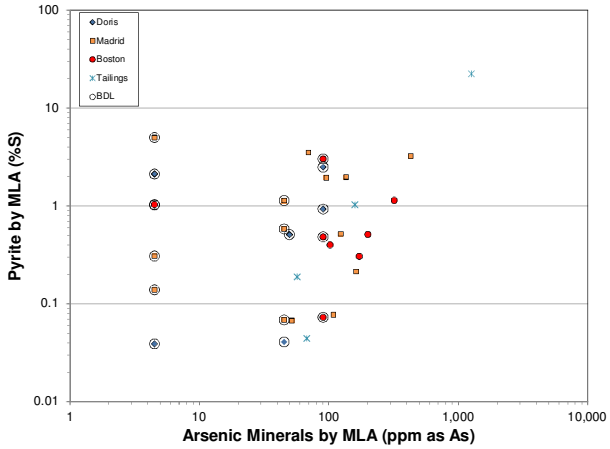

Figure 10: Relationship between Pyrite and Arsenic Mineral Content

For samples containing arsenic minerals above the level of detection, there was a relationship between arsenic mineral levels and arsenic release rates (Figure 11). This relationship was completely absent for the tailings samples and may be explained by sorption to iron (oxy)hydroxides, which would be more abundant in the samples with relatively high iron sulphide concentrations. This relationship is shown in Figure 12, where samples with the lowest arsenic release rates tended to have the highest sulphate release rates, and vice versa. Moreover, pyrite oxidation forms localized pH depression, an ideal condition for

arsenic adsorption. MLA has the capability of detecting iron hydroxides, however, if present, they were not detected separately because the mineral group classification list was not included for these samples. The inventory of possible amorphous iron hydroxides would be included in the inventory of the iron oxides, such as hematite and magnetite. In any case, the MLA analyses were completed on fresh samples, and would therefore not include any iron hydroxides that would have formed during humidity cell testing.

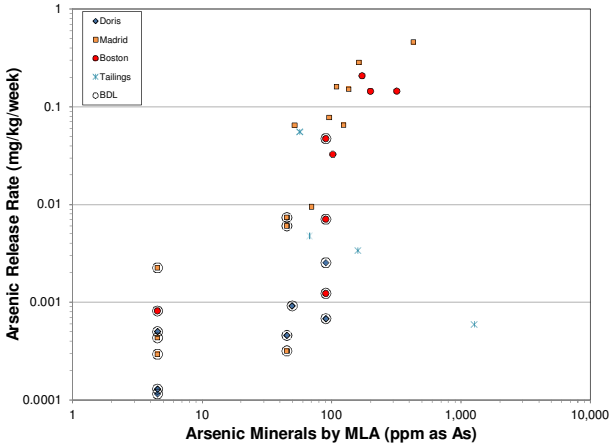

Figure 11: Relationship between Arsenic Release Rates and Arsenic Mineral Content

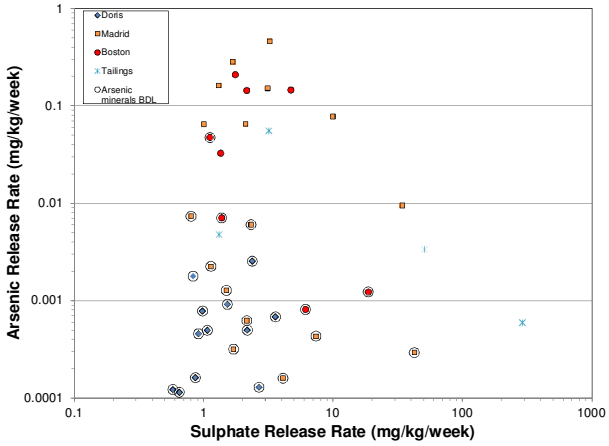

Figure 12: Relationship between Arsenic and Sulphate Release Rates

Conclusions

Quantitative mineralogy was determined for a total of fourty-two humidity cell tests from the Hope Bay Greenstone Belt using XRD and MLA methods. XRD identified pyrite as the dominant sulphide mineral, whereas MLA also quantified trace levels of chalcopyrite, gersdorffite, pyrrhotite, arsenopyrite, galena, cobaltite, millerite, sphalerite, tetradymite and/or tetrahedrite. The MLA is an accurate tool in quantifying trace amounts of sulphide minerals and provides much better detection limits than XRD.

The objective of the paper was to explore the application of MLA data to the assessment of metal leaching and acid rock drainage from a mine site. Overall, the greatest insight to the study was the trace mineralogy, particularly the identification and quantification of arsenic minerals. The results showed that not all of the arsenic could be accounted for by the specific arsenic minerals identified in this study, implying that some of the arsenic was present as a trace element in some other type of sulphide mineral, likely pyrite. Microprobe analysis or elemental mapping may provide further insights on the forms of arsenic that are present in these deposits. The relationships between sulphide oxidation and MLA data suggested secondary controls on sulphate release rates (pyrite grain size and the proportion of exposed sulphide mineral edges), however overall, the findings were limited. This is due in part to the data set itself, which was characterized by low sulphide content, low sulphate release rates and the predominance of pyrite.

The authors recommend MLA as a specialized mineralogical tool for sites that are known to have a broader suite of sulphides, such as polymetallic deposits, where there are multiple primary mineralogical controls on weathering and water quality.

References

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