Extraction of ARD/ML Information from a Brownfield Site for Development of an ARD/ML Plan at the Detour Gold Mine, Ontario, Canada

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Abstract
The Detour Gold Mine is being re-developed from the original underground and open pit mine operated by Placer Dome from 1983 to 1999. A resource of 11.4 million ounces of gold has been defined in Archean-age mafic volcanic rocks containing low levels of pyrite, pyrrhotite and chalcopyrite mineralization associated with calcite. A new open pit and mill have been designed with production anticipated in early 2013. The provincial and federal EA processes required a comprehensive assessment of the acid rock drainage and metal leaching (ARD/ML) potential for all aspects of the project including new and old waste rock piles, tailings materials and pit walls. Sulphur concentrations in the rock were found to be typically upwards of 0.5%, and ARD potential was variable including materials characterized as both potentially ARD generating (PAG) and non-PAG, with approximately 17% of waste rock with NP/AP < 1.5.

The original mine had four small waste rock piles that are now up to 27 years old. ARD has not developed for any piles to date and seepage metal concentrations are relatively low. These stockpiles are the subject of an ongoing research program to investigate scaling effects between laboratory tests and full scale field facilities. This paper presents an overview of the characterization program to date for both historical and future waste rock. A preliminary assessment of a site specific scaling factor is also presented.

Key Words: source term predictions, empirical scaling methods, greenstone deposit

Background
Introduction
Detour Gold Corporation (DGC) has received operating permits to re-open the Detour Lake mine (DLM), located 180 km northeast of Cochrane, Ontario. The mine is being re-developed from the original underground and open pit mine operated by Placer Dome from 1983 to 1999. The original mine had four small waste rock piles that are now up to 27 years old. Acid rock drainage (ARD) has not developed for any piles to date and seepage rates and metal concentrations are relatively low.

An assessment of acid rock drainage and metal leaching (ARD/ML) for both the historic and proposed waste rock piles was included in the provincial and federal environmental assessment (EA). Looking forward, these stockpiles present an opportunity to compare the performance of existing waste ahead of new mine development. This paper provides a progress report on the geochemical assessment program for the DLM operation. The emphasis of the discussion is on waste rock as the new tailings have a low ARD potential.

Geological setting
The Detour Lake deposit is a quartz-carbonate vein hosted gold deposit located in the northwestern area of the Abitibi Greenstone belt. The gold is located within several shear zones in massive and pillowed basaltic rocks. Mineralization was accompanied by pervasive potassic hydrothermal alteration. The dominant sulphide mineral is pyrrhotite with lesser chalcopyrite and pyrite, and much less pentlandite and arsenopyrite. Sulphide mineralization is not associated with ore. Calcite is the dominant carbonate mineral with lesser dolomite.

The hanging wall is within overturned isoclinals folds that are part of the Upper Detour Lake Formation. The footwall is part of the Lower Detour Lake Formation that is within an anticline truncated by the later Sunday Lake Deformation Zone. The bulk of the gold mineralization is associated with the major east-west trending Sunday Lake Deformation Zone and is modelled to be within eight domains situated within the hanging wall.

The geology of the pit has been divided into five main groups and associated rock types:

1. Hanging wall: pillow flow (PF), weakly potassically altered pillow flow (WKPF), potassically altered pillow flow (KPF), carbonatized brecciated pillow flow (CBPF), massive flow (MF), weakly potassically altered massive flow (WKMF) and potassically altered massive flow (KMF).
2. Footwall: talc chlorite (TC), volcaniclastic (VC), footwall mafic volcanic (FMV), feldspar porphyritic volcanic (FPV) and chloritic greenstone (CG).
3. Chert marker horizon: chert (CH)
4. Relatively minor, late stage intrusive rocks: mafic intrusive (MI), ultramafic intrusive (UI), komatiitic basalt (KB), gabbro (GB) and felsic intrusive (FI).
5. Overburden.

The contact between footwall and hanging wall is structurally defined as the Sunday Lake Deformation Zone and lithologically by the chert horizon marker. The bulk of the waste rock is from the hanging wall (55%) and footwall (44%), with the chert marker horizon and intrusive lithologies comprising the remaining 1%. Overburden tonnages were calculated separately from waste rock.

Environmental setting
The DLM is located in the Boreal Forest Region between the Kapuskasing and Mattagami meteorological stations and is on approximately the same latitude as these stations. Mean annual precipitation and temperature values for DLM were developed by taking the average of the historical measurements from the two stations. The mean annual precipitation is estimated at 851 mm. Using Environment Canada data compiled from 1963 through 2007 (AMEC 2009), the mean annual temperature at the Detour site is 0.3˚C. The mean summer high temperature is 16.6˚C in July, while the mean winter low is -18.8˚C in January.

Mine plan
The DLM has a resource of 11.4 million ounces of gold and an estimated mine life of 16 years (BBA 2010). An open pit will be developed using a conventional truck and shovel operation at a 0.50 g/t gold cut-off. Mining will produce an estimated 1.1 billion tonnes of waste rock that will be managed by segregation according to potentially ARD generating (PAG) and non-PAG classifications. Two stockpiles areas will accommodate waste rock with PAG material stored separately from non-PAG material.

The mill currently under construction will have a capacity of 55,000 tpd. After an initial grinding and gravitational separation, the ore will be leached with cyanide and carbon-in-pulp (CIP) circuit. The tailings from the CIP circuit will be sent to a tailings thickener to recover cyanide and to produce 64% solids under flow. The slurry will then be re-diluted to 55% solid prior to treatment in a SO_2/Air cyanide destruction circuit. Final tails from cyanide destruction will be pumped at 55% solids in two parallel lines to the tailings pond. Tailings will be disposed by a perimeter spiggoting system in a tailings management area (TMA) comprised of three cells that will be sequentially developed over the mine life. This system has been designed to seasonally discharge only treated mine water to maintain the water balance. There will be no discharge of tailings water as all of this water will be consumed by a high percentage of recycle to service the mill.

Methods

Characterization of future (in situ) waste rock

A geochemical characterization program including acid-base accounting (ABA) and humidity cell tests was conducted in support of EA application for DLM (AMEC 2010a). A total of 980 samples of fresh waste rock were collected as drill core splits from the hanging wall and footwall (referred to subsequently as the "EA Dataset"). Selection was according to proposed tonnages of rock types to be mined, spatial distribution of the rock types in available drill core and variability in alteration and mineralization. Samples were distributed throughout the pit in isolated locations and were typically 1 m in length. These samples do not geostatistically or spatially represent the entire deposit due to the very large number of samples required. However they do provide an initial screening view of the ARD risks for the project. All samples were analyzed using the modified acid-base accounting method described by MEND (1991), sulphate sulphur by HCl digestion followed by colourimetric measurement, total inorganic carbon (TIC) by coulometry and a scan of 35 elements using ICP following aqua regia digestion under the supervision of SGS Canada Inc. in Burnaby, BC, Canada.

A subset of eighteen samples from the EA Dataset was selected for humidity cell tests (Table 1) and initiated by AMEC in 2008. Selection was intended to capture materials that encompassed both the spatial and expected geochemical variability (i.e. ARD generation potentials) of the major rock types from the proposed open pit. Samples were restricted to those with sulphide levels greater than 0.3% and NP/AP ratios of less than 3; however, emphasis was placed on samples with NP/AP ratios between 1 and 2. The samples are economically classified as waste and ore. Mineralogy was determined for each sample by XRD with Rietveld refinement at the University of British Columbia.

Table 1: Waste Rock Humidity Cell Tests

Geological Group	Rock Types[1]	HC ID	Paste pH	Total S	Sulphide	NP	TIC	NP/AP	TIC/AP	Calcite	Dolomite
				(%S)		(kg $CaCO_3$/t)				%mineral	
Hanging Wall	PF	HC-3	9.5	1.02	1.02	67	83	2.1	2.6	9	0
		HC-7	8.5	1.86	1.86	9	2	0.2	0.0	1	0
		HC-27	9.1	0.80	0.77	69	58	2.9	2.4	7	0
	KPF	HC-4	9.4	0.72	0.72	37	16	1.6	0.7	2	0
	MF	HC-1	8.7	0.36	0.36	22	11	1.9	1.0	1	0
		HC-5	9.3	0.77	0.77	30	26	1.2	1.1	2	0
		HC-6	9.1	0.71	0.71	10	1	0.5	0.0	0	0
		HC-15	9.3	0.58	0.58	26	14	1.4	0.8	1	0
		HC-23	9.4	0.34	0.32	27	14	2.7	1.4	2	0
	KMF	HC-2	9.5	0.60	0.60	23	13	1.2	0.7	2	0
Footwall	TC	HC-11	9.3	1.68	1.68	93	91	1.8	1.7	0	10
	VC	HC-24	8.5	2.21	2.19	18	12	0.3	0.2	1	0
		HC-25	9.1	0.43	0.43	20	18	1.5	1.3	1	0
	FMV	HC-18	9.1	0.94	0.94	21	13	0.7	0.5	2	0
		HC-22	8.6	0.79	0.79	47	42	1.9	1.7	4	0
	CG	HC-20	9.0	0.32	0.32	14	4	1.4	0.4	1	0
Intrusive	FI	HC-26	8.6	1.66	1.66	43	37	0.8	0.7	4	1
	MI	HC-19	8.9	0.35	0.35	19	7	1.7	0.6	0	0

[1] PF=pillow flow; KPF=potassically altered pillow flow; MF=massive flow; KMF=potassically altered massive flow; TC=talc chlorite; VC=volcaniclastic; FMV=footwall mafic flow; CG=chloritic greenstone; FI=felsic instrusive; MI=mafic intrusive

AP – Acid potential from sulphide sulphur

*Indicates currently operating as of December 21, 2011

Humidity cell tests were operated using the method described by MEND (1991) method at SGS Canada. Analytes include pH, EC, sulphate, acidity, alkalinity and a 35-parameter suite of trace elements by ICP-MS. Conductivity and pH were determined weekly. Weekly analysis of alkalinity, acidity, sulphate and a 35-parameter suite of trace elements by ICP-MS were determined until cycle 20, after which analysis decreased to every 5 cycles. These cells ran between 98 and 170 weeks, with six tests continuing to operate.

An additional ABA program was performed in 2011 ("2011 Dataset") to assess the distribution of PAG and non-PAG materials at the bench-scale and assess the viability of operationally segregating waste rock by ARD potential. Two drillholes each from the footwall and hanging wall were selected from within the proposed pit on the basis of sample accessibility and rock type. The four selected holes intersected the waste rock units expected to be excavated from the open pit. A total of 333 samples were selected. Each sample was a discrete rock type with a targeted length of three to four metres resulting in a continuous ABA record. Samples were analyzed at SGS Canada Inc in Don Mills, Ontario, Canada for total sulphur, total inorganic carbon (TIC) and elemental analysis by aqua regia digestion with ICP finish. Total sulphur and TIC were previously determined to be appropriate acid-base accounting (ABA) surrogates for AP and NP, respectively. A subset (10%) of samples was also analyzed for total carbon.

Characterization of historical waste rock

Characterization of the historical waste rock has included monitoring of seepage and a more recent characterization of the stockpile solids (AMEC 2010b).

In 2010, AMEC obtained samples of the waste rock material from the historic stockpiles using test pit and borehole methods (AMEC 2010b). Samples were sent to SGS Canada where they were analyzed for modified ABA (MEND 1991), total inorganic carbon (TIC) and trace metals (aqua regia digestion). In 2011, the fine fraction (<2mm) of the test pit samples was geochemically characterized using the same analytical package. Between analytical campaigns, samples were stored at room temperature.

Three seepage monitoring stations of the historic waste rock piles were established in 1993. Samples were collected from 1993 to 1997 in support of closure planning and later re-initiated in 2009. Each station has been sampled between four and eight times resulting in a total of 16 sample events. The database also includes a total of seven duplicate samples. The list of analytes is variable by station but overall includes pH, electrical conductivity (EC), sulphate, alkalinity and a 32-parameter suite of total or dissolved elements. Although no flow records were compiled, visual observations show very low flows and seasonal ephemeral drainages which dried up by mid-summer.

Results

In situ waste rock characteristics

ARD Potential

The sulphide mineralogy in the footwall and hanging wall rock includes pyrrhotite, pyrite and to a lesser degree chalcopyrite. Trace amounts of pentlandite and arsenopyrite have also been observed (Miller 2006). The intensity of sulphide mineralization has no particular correlation with ore grade, and as a result sulphide content can be elevated outside the ore domains. Carbonates are primarily calcite, as indicated by QXRD mineralogical methods (AMEC 2010a), but dolomite is also present, and is the dominant carbonate for the talc chlorite lithology sample (Table 1). Carbonate occurs at typical levels of 1 to 2% by weight but ranges up to 10%.

Sulphide content for the 980 waste rock samples in the EA Dataset was variable, ranging from 0.01 to 7.0% (median of 0.2%). Levels of NP and TIC ranged from 3 to 241 kg$CaCO_3$/t (median 27 kg$CaCO_3$/t) and 1 to 258 kg$CaCO_3$/t (median 20 kg$CaCO_3$/t), respectively. As reported in AMEC (2010), approximately 20% of waste rock is classified as PAG on the basis of NP/AP ratios of less than 2.

Table 2: Distribution of NP/AP

NP/AP	# of Samples	% Sample Set
<1	85	9
1 to 1.5	79	8
1.5 to 2	74	8
2 to 3	145	15
>3	597	61

For the purposes of waste rock management during operations, the ABA dataset was evaluated for the potential use of surrogates, defined as routinely measured parameters that can reliably replace specific ABA methods, to reduce the need for detailed analysis. For the EA Dataset, calculated sulphide (defined as the difference between total sulphur and sulphate) and total sulphur by Leco are correlated (Figure 1). This indicates that the analysis of total sulphur is an appropriate surrogate for sulphide and the calculation of the AP term for the purposes of operational segregation of waste rock. The resulting "site-specific" AP is referred to as AP*.

The acid neutralization potential (NP) of the waste rock is dominated by carbonate minerals, with measurements of total inorganic carbon (TIC, or carbonate) at near parity with NP determined by the MEND (1991) modified method (Figure 2). Departures at low NP's are due to the NP procedure digesting silicate at low carbonate contents. This initial assessment illustrates that TIC is an appropriate conservative surrogate for the determination of NP because carbonate occurs as calcite.

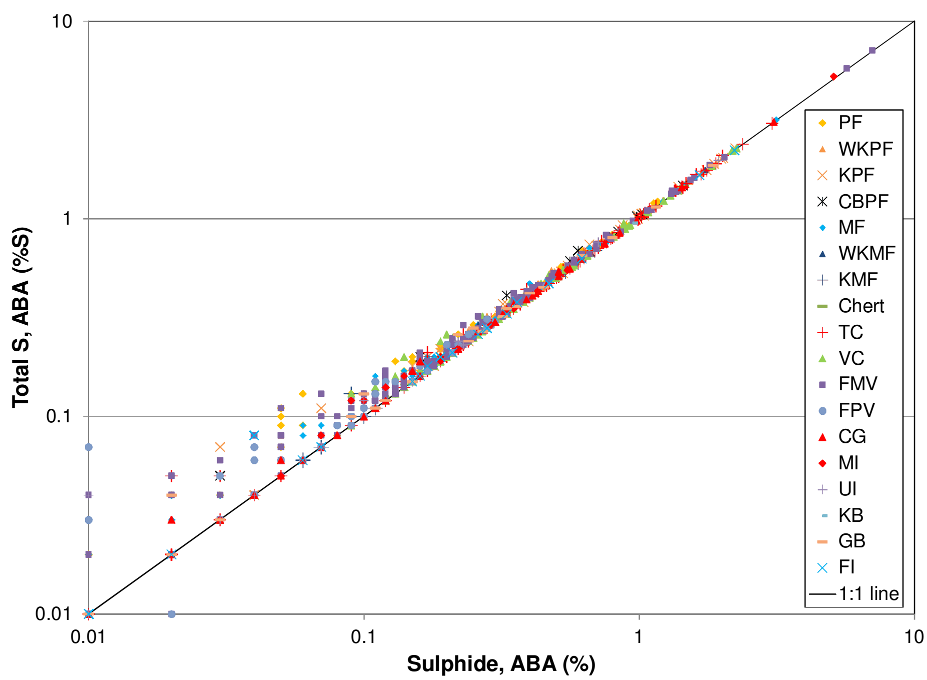

Figure 1: Relationship between Total Sulphur and Sulphide

To further explore potential surrogates, a subset (10%) of samples representing the rock types in the geological model was selected from the 2011 dataset for the analysis of total carbon. A comparison of the ABA data indicates that measurements of total carbon are equivalent to TIC (Figure 3). Accordingly, the data suggests total carbon is an appropriate surrogate for both TIC and modified NP, and is the proposed analytical surrogate for neutralization potential (denoted as NP*) for the purposes of operational segregation of waste rock.

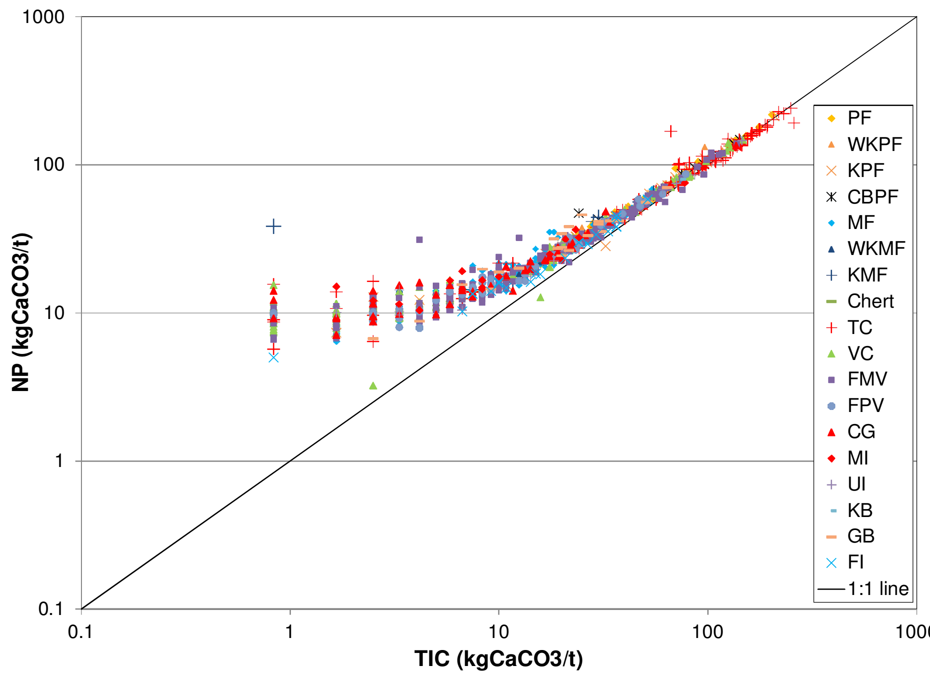

Figure 2: Relationship between Total Inorganic Carbon (TIC) and NP

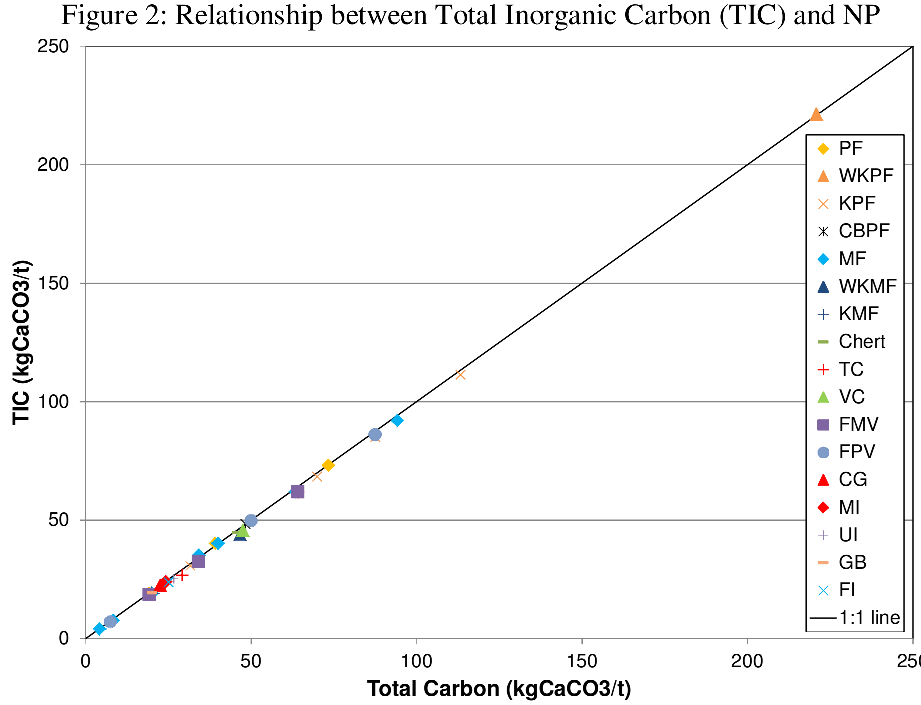

Figure 3: Relationship between Total Inorganic Carbon (TIC) and Total Carbon

Site Specific ARD Potential and Classification Criteria

For humidity cell testing, the relative rate of neutralization to acid generation (expressed as $(Ca+Mg)/SO_4$) is equivalent to the NP/AP ratio used in ABA. As shown in Figure 4, humidity cell testing on waste rock samples from Detour shows that values of $(Ca+Mg)/SO_4$ approaches 1. In these types of charts, the pattern shown is common (for example, Mattson 2005; SRK 2006). The apparent higher NP/AP at lower oxidation rates reflects preferential dissolution of carbonate minerals which is an artefact of the high water-to-rock ratio in the tests. At higher oxidation rates, the dissolution of carbonate minerals by acidity from sulphide oxidation allows the NP/AP ratio to stabilize between 1 and 2. The results show that a site specific NP/AP below 2 and nearer 1 is appropriate. For the purpose of waste classification at DGM, a criterion of NP*/AP*≤1.5 to define PAG waste rock has been selected using the following surrogate parameters to calculate NP*/AP*:

- NP* (kg $CaCO_3$/t) = $\frac{1000}{12} \times \text{Total Carbon } (\%, C)$
- AP* (kg $CaCO_3$/t) = 31.25 x Total Sulphur (%,S)

Using these parameters, Figure 5 illustrates the distribution of NP* and AP* for the EA Dataset, with classification of ARD potential using NP*/AP*≤1.5 to define PAG. PAG materials are located in both hanging wall and footwall lithologies. Figure 5 also illustrates that there were a higher proportion of higher sulphide levels in the old waste rock sample set (red squares) relative to the samples acquired to characterize the new waste materials.

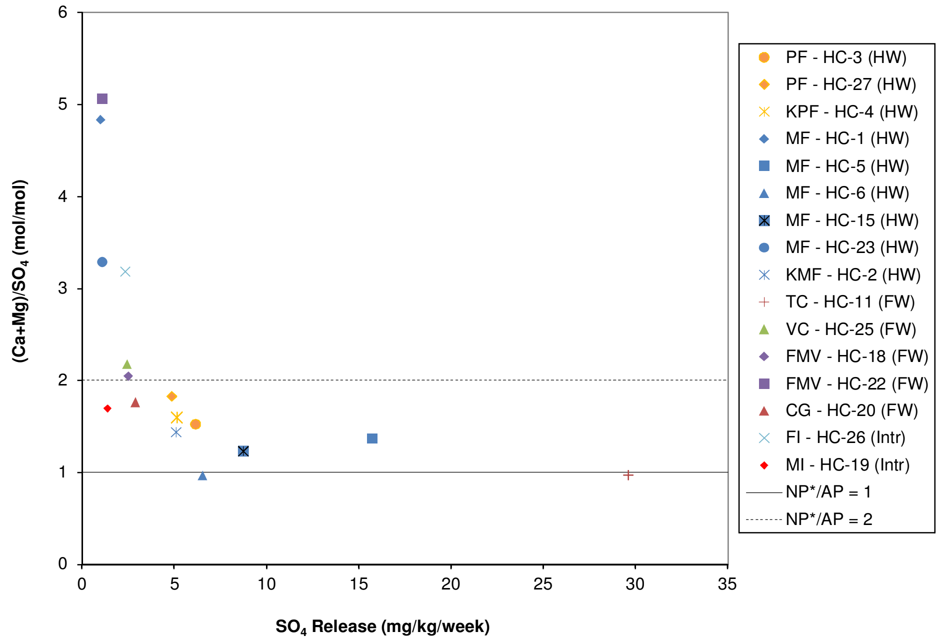

Figure 4. Relative Rate of Acid Generation Compared to Sulphide Oxidation Rate for Waste Rock Samples as indicated by humidity cells.

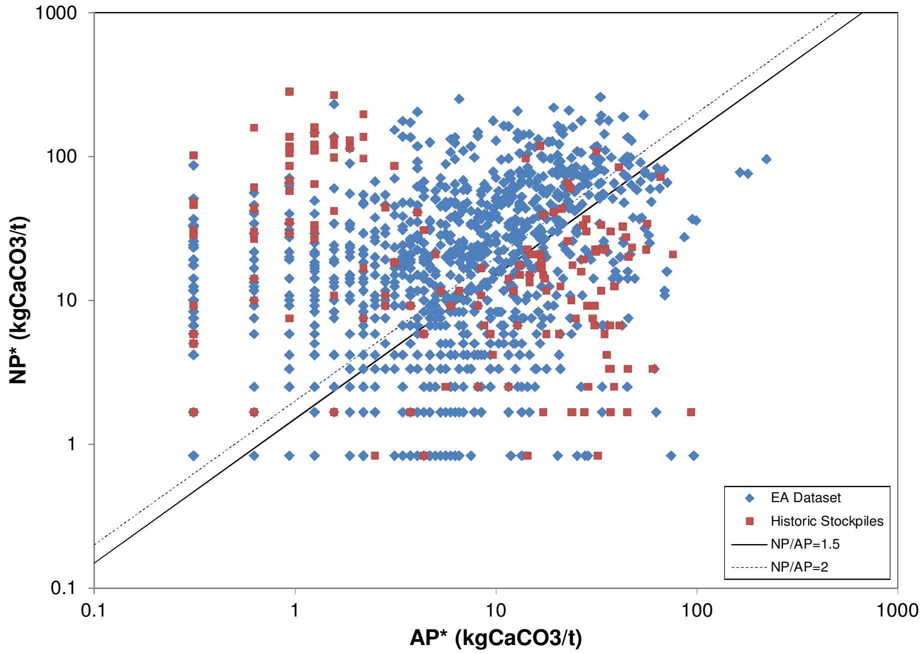

Figure 5. Classification of ARD Potential for the EA Dataset and Historical Stockpiles

Feasibility of Segregation

One particular concern that was defined when progressing from the theoretical commitment to separate rock based on NPR to an operational model was the feasibility of designing such a separation system. The concern was if contiguous units of ARD units were present and whether small amounts of PAG material occur within non-PAG materials and therefore could lead to non-PAG rock being "contaminated" with PAG rock. This latter scenario would result in higher volumes of PAG rock than has been used as a basis for waste management planning to date. The subsequent detailed 2011 study of the four drill holes illustrated that the continuity of PAG and non-PAG materials is sufficient for the operational segregation of waste rock. The following discussion illustrates the change from the initially adopted NPR cut-off criteria of 2 to the currently refined criteria of 1.5.

Table 3 summarizes ARD classifications of waste intervals only and also the number of intervals that would be classified as non-PAG for the purpose of waste management where PAG is defined as NP*/AP*≤ 2. These include non-PAG intervals extending over at least a bench height (i.e. roughly three samples) and single PAG intervals surrounded by non-PAG intervals. The total proportion of non-PAG intervals was 64% of which 58% is considered non-PAG for the purpose of segregation. By hole, this varies from a change of -24% to +24% as a fraction of intervals of non-PAG. The increase in non-PAG for DG-09-632 reflects the presence of PAG intervals that could become mixed with non-PAG as a result of mining. In general, non-PAG waste rock can be segregated but based on these data, 9% of all non-PAG intervals would be "diluted" by PAG rock and cannot be segregated.

Table 4 provides the same analysis but using a site specific criterion of NP*/AP* ≤ 1.5 to classified PAG rock. Due to the large number of samples classified as uncertain (1 ≤ NP*/AP* < 2), the overall proportion of non-PAG intervals increased from 64% to 83%. Non-PAG amenable to segregation was the same at 83% with no net loss of non-PAG rock.

This assessment illustrates that waste rock segregation using an NPR value of 1.5 can be used with confidence and that the potential quantity of non-PAG rock deposited in the PAG pile will be significantly reduced. This will ensure adequate capacity for the PAG stockpile as designed for the mine life.

Table 3. Summary of Waste Rock Intervals Classification and non-PAG (NP*/AP*>2) Amenable to Segregation

Hole	PAG Intervals	non-PAG Intervals	Contiguous non-PAG Zones	
	By Length	By Length	By Length	Compared to Total
DG-08-610	39%	61%	50%	-18%
DG-09-632	33%	67%	83%	24%
DG-09-666	18%	82%	77%	-6%
DG-09-685	53%	47%	35%	-24%
Total	36%	64%	58%	-9%

Table 4. Summary of Waste Rock Intervals Classification and non-PAG (NP*/AP*>1.5) Amenable to Segregation

Hole	PAG Intervals	non-PAG Intervals	Contiguous non-PAG Zones	
	By Length	By Length	By Length	Compared to Total
DG-08-610	22%	78%	79%	0%
DG-09-632	16%	84%	87%	4%
DG-09-666	4%	96%	100%	4%
DG-09-685	28%	72%	66%	-9%
Total	17%	83%	83%	0%

Metal Leaching Potential

The trace elemental levels of the EA Dataset were screened by comparing values to ten times the average crustal abundance for basalt (Price 1997) as an indicator of enrichment. In general, the waste rock samples contained levels below this threshold with selected samples containing enriched levels of antimony, arsenic, cadmium, copper, lead, selenium, silver, sulphur and uranium (AMEC 2010). In addition to these elements samples of talc chlorite and volcaniclastics were elevated in chromium, nickel and zinc. Both the talc chlorite and volcaniclastic rock types are minor waste rock types for Detour, with each comprising less than 5% of the overall waste rock. This assessment shows that the majority of the waste rock has metal levels of less than ten times the crustal abundance, indicating no appreciable enrichment for these samples.

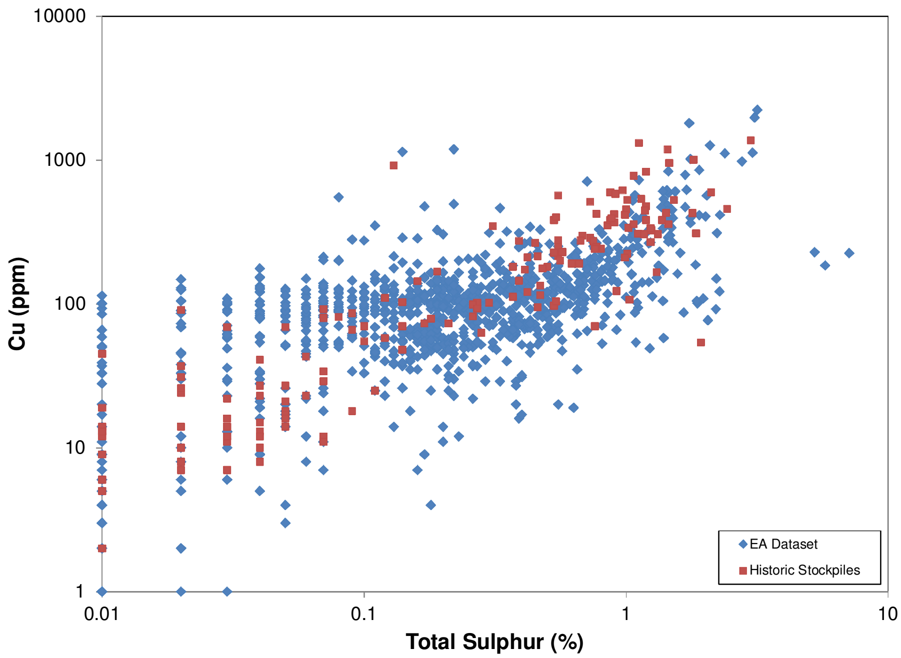

Figure 6. Relationship between Copper and Total Sulphur for the EA Dataset and Historical Stockpiles

There was a positive relationship between sulphide levels with cobalt, copper (Figure 6) and iron (AMEC 2010a), suggesting that these metals are associated with sulphide minerals. Nickel and lead levels are suggested to be related to sulphide content for samples of talc chlorite and volcaniclastics, respectively. As previously mentioned, these are minor waste rock types. In addition they will be encountered deeper in the pit and after the rock separation programs have been fully implemented and can be refined based on operating experience. A special program will be developed to ensure adequate isolation of these rock materials for the closure plan and post closure monitoring to minimize the risks from potentially reactive material and long term ARD/ML.

Kinetic Leaching Characteristics

The eighteen humidity cells contained sulphur in the range of 0.32 to 2.2% and were typically classified as PAG (AMEC 2010a) (NPR < 2). Though ore material will be handled separately from waste rock, geochemical data interpretations include the ore samples to explore the relationship between solid assays and leachate geochemistry of the sample set.

Initially, all samples had non-acidic pHs. Two of the humidity cell tests (HC-24 or volcaniclastic from the footwall and HC-7 or pillow flow from the hanging wall) have developed acidic leachates (pH < 5) while acidic conditions are currently developing for HC-6 (massive flow from the hanging wall). These aforementioned samples do not represent typical waste rock in that they were all classified as PAG and were characterized as having high sulphur levels and/or negligible levels of buffering (Table 1). Stable sulphate release rates for these acidic samples are relatively low, ranging between 7 and 37 mg/kg/week. The acidic humidity cell samples have elevated levels of arsenic, cadmium, cobalt, copper, iron, nickel, selenium and zinc relative to the tests yielding non-acidic leachates.

For the 15 cells non-acidic humidity cell samples, sulphate loading rates were below 9 mg/kg/week with the exception of HC-5 (mafic flow from the hanging wall) and HC-11 (talc chlorite from the footwall), which had rates of 16 mg/kg/week and 30 mg/kg/week, respectively. Leachate from HC-11 shows elevated non-acidic pH metal leaching of cobalt and nickel relative to other samples.

Existing waste rock
There are currently four rock piles (WRS #1 to WRS #4) originating from the historic open pit and underground mine that are now up to 27 years old and containing an estimated 7.6 million tonnes of waste rock (AMEC 2010c). Waste rock extracted during historical mining primarily originated from the hanging wall with lesser waste rock from the chert horizon, intrusive and selected footwall lithologies.

Seepage monitoring of the waste rock stockpiles was initiated in the 1990's and indicates that after 27 years of weathering, seepage from the stockpiles is non-acidic and metal levels are low (Table 5). Sulphate concentrations upwards of 660 mg/L indicate that sulphide oxidation is occurring within the stockpile. Seepage flow rates were not measured but were very low, seasonally ephemeral and dry by mid-summer. There was no evidence of impacts downstream of these seepages.

The stockpiles were geochemically characterized for ARD potential as mixtures of PAG and non-PAG materials (AMEC 2010b), as shown in Figure 5 relative to the EA dataset. Sulphur levels ranged from 0.10 to 3.0% (median 0.5%). NP and TIC levels ranged from 4 to 279 $kgCaCO_3/t$ (median 25 $kgCaCO_3/t$) and 1 to 282 $kgCaCO_3/t$ (median 18 $kgCaCO_3/t$), respectively. Rinse tests on the fine fraction (<2 mm) of the AMEC (2010b) samples indicated that selected PAG samples are presently acidic. This suggests that discrete areas of selected stockpiles may be acidic, however, sample storage at room temperature for over one year likely accelerated sulphide oxidation and the generation of acidic conditions. Accordingly, these results are considered conservative and acidic pH's may not be currently present within the stockpiles. If acidic conditions do currently exist, the occurrence of non-acidic seepage (Table 5) indicates the presence of buffering minerals along the seepage flow path within the stockpile.

Table 5. Maximum Seepage Chemistry from Historical Stockpiles

Parameter*	**Unit**	**Seep 1**	**Seep 2**	**Seep 3**
Period of Record		1993-2010	1993-2010	1993-1997
Number of Samples**		1-9	1-7	2-8
pH		7.8	7.4	8.0
Alkalinity	mg/L	390	515	130
SO4	mg/L	661	--	71
Ca	mg/L	204	--	--
K	mg/L	10.6	--	--
Mg	mg/L	30.6	--	--
Na	mg/L	5.57	--	--
Co	mg/L	0.0006	--	0.006
Cu	mg/L	0.056	0.005	0.014
Pb	mg/L	0.008	0.007	0.002
Zn	mg/L	0.152	0.004	0.005

*Expressed as dissolved. pH values are minimum values.
**List of analytes varies between years.

Discussion - Comparison of historical and future waste

Composition of Historic Rock Piles

In terms of ARD potential, there is overlap in the geochemical characteristics of the historic stockpile and the EA Dataset (Figure 5). The historic stockpile samples geochemically represent samples of future waste characterized as i) PAG, ii) high sulphur (both PAG and non-PAG) and iii) non-PAG materials characterized by low sulphur and high NP. This suggests that the behaviour of PAG stockpile material in stockpiles 1 to 4 is an analog to future PAG waste rock. As discussed later, stockpiles 3 and 4 will be studied over the long term research program.

As with the EA Database samples, materials from the historic stockpiles exhibit a relationship between copper and sulphide mineral content (Figure 6), with overlap in the distribution in data for the upper levels of both copper and total sulphur. This suggests that the bulk geochemical properties, including sulphide and more specifically copper, are representative of those of future waste rock, and are site-specific analogs for sulphide weathering and leaching.

Scaling of Oxidation Rates

Data obtained from humidity cells and the stockpiles allowed a scoping level comparison of sulphide oxidation rates and calculation of laboratory to field scaling factors. Average oxidation rates in humidity cells expressed in mg/kg/week were obtained as the average stable rates following initial decrease of sulphate release observed early in the testwork program. Oxidation rates are approximately correlated with sulphur content (Figure 7). Based on the range of sulphur content of the stockpiles as indicated by 5th percentile (P5), median and P95, the range of oxidation rates under laboratory conditions would be 1 to 9 mg/kg/week (median 3 mg/kg/week,

Table 6).

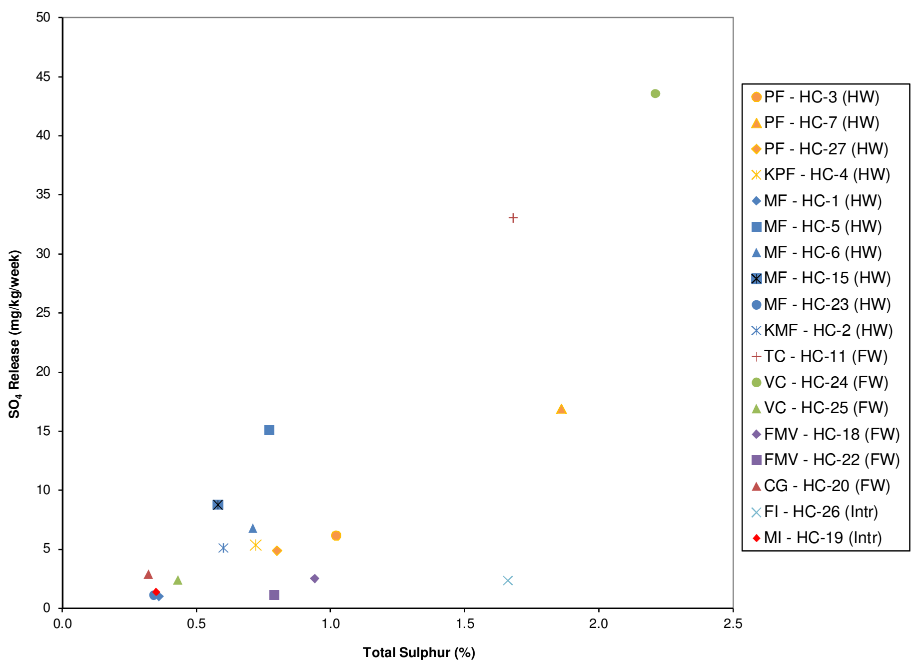

Figure 7. Correlation of Sulphate Release in Humidity Cells and Sulphur Content

Data available to calculate the equivalent sulphate release rate for the stockpiles were limited. The calculations were performed for Stockpiles 1 to 4 using the following assumptions: seepage volume was estimated using total annual precipitation for the site (851 mm/year), the estimated area and mass of the stockpile was 57 ha and 7.6 million tonnes, respectively, and about 50% of total precipitation will infiltrate was assumed. As indicated in Table 5, a range of seepage chemistry was observed but based on understanding of the sampling locations, the low sulphate concentrations likely reflect dilution at the sampling location. The higher end concentration was therefore selected as indicative of contact water chemistry.

The resulting annualized sulphate release rate on a weekly basis is 0.4 mg/kg/week. Comparison of the laboratory and field release rates indicates a field to laboratory rate ratio ranging from 0.05 to 0.3 (

Table 6). This "scaling factor" incorporates a composite of potential scaling effects including temperature, particle size, flow contact and mineral solubility differences. At DLM, temperature is a significant factor due to the low average annual site temperature. Assuming internal waste rock temperature of 0.3°C and pyrrhotite as the main sulfide mineral, the ratio of field to laboratory rates would be 0.2. Typical particle size and contact factors are 0.2 and 0.5, respectively resulting in a composite scaling factor of 0.02 would be calculated. This compares favorably with the 95th percentile scaling factor of 0.05 calculated using site specific data. The scaling factor is higher for those humidity cell tests with P5 and median sulphur content.

There are a number of differences between the historic and future mining, including scale of development, mining method, rock types and waste rock management. Specifically, future mining will occur at a much larger scale than historic mining and will be exclusively by open pit. Waste rock will be represented by more rock types, all of which were characterized for the EA application. Current mine plans are to segregate PAG rock for separate disposal whereas the historic stockpiles represent passive blends of PAG and non-PAG materials.

Table 6: Comparison of Laboratory and Field Sulphate Release Rates (mg/kg/week)

Stockpile Sulphur Content		Sulphate Loading Rates (mg/kg/week)		Scaling Factor
		Humidity Cell Test	Historic Stockpile	
P5	0.01%	1	0.4	0.3
Median	0.37%	3		0.1
P95	1.46%	9		0.05

Application to development of waste rock management plan
Based on the information obtained by comparison of the characteristics of the historic stockpiles and the future waste rock, the performance of the historic stockpiles is considered a reasonable analog for the performance of future waste rock.

Despite the apparent low weathering rates for the old dumps after 27 years and in the majority of the kinetic cell samples of the new waster rock, a conservative approach has been adopted for the mine operations. The new waste rock management plan incorporates segregation of PAG and non-PAG waste rock using site specific AP and NP measures (AP* and NP*, respectively) with assumptions about mineralogy, and a humidity cell indicated NP*/AP* criterion of 1.5. Some uncertainty will always exist around waste rock segregation for ARD potential. However, the risk of non-PAG waste rock stockpiles generating significant ARD, or non-acidic drainage with metal leaching issues is considered low for this site due to the occurrence of PAG and non-PAG rock in zones which can be segregated using conventional mining technology developed for ore and waste management. The lab testing has indicated that some of the material classified as PAG may become acid generating over time. Other samples in this category have not shown reactivity after 170 weeks of kinetic testing. In order to address the scale up issues for the new waste piles additional work is needed on large samples/test piles. The historic stockpiles will be studied in a comprehensive research program to better understand the geochemical dynamics and delay to onset of ARD so that the new waste rock can be managed in the best way possible.   The waste rock management plan includes activities to monitor stockpile performance.

Research Plan
Greenfield mine sites usually rely on scale-up of laboratory tests and consideration of off-site analogs to calibrate water quality predictions. DGC, University of Alberta and University of Waterloo are using the opportunity at Detour Mine to investigate scaling directly because the existing decades-old stockpiles

contain similar rock to the future mine. The current research plan will involve sampling two piles as they are removed for new operations and the instrumentation of two other piles for long-term monitoring. The results of these studies will be presented in future conferences. However, this work is noted to emphasize the potential value that can be obtained from examining historic waste materials to assist in attempting to obtain better predictions of the future performance of new mine materials. Such information is invaluable in developing comprehensive waste control plans for the future mine.

Conclusions

The information available from the historic waste piles has been combined with a comprehensive predictive assessment of the new waste rock materials to yield several conclusions that have assisted the development of the operating plans for all waste material from the new mine. These are summarized as follows:

1. The analysis of total sulphur is an appropriate surrogate for sulphide and the calculation of the AP term for the purposes of operational segregation of waste rock.
2. The assessment of carbon speciation data suggests total carbon is an appropriate surrogate for both TIC and modified NP, and is the proposed analytical surrogate for neutralization potential (denoted as NP*) for the purposes of operational segregation of waste rock.
3. The assessment of the four focused drill holes illustrates that waste separation is feasible for PAG and non-PAG waste rock. Further assessment showed an NPR value of 1.5 can be used with confidence and that the potential quantity of non-PAG rock deposited in the PAG pile will be significantly reduced to ensure adequate capacity for the PAG rock as designed in the mine plan.
4. Despite the evidence of sulphide oxidation, the reactions within the old waste piles have not advanced to result in leachate problems during the 27 years of history.
5. The observed lab oxidation reaction rates as reflected by sulphate generation were higher than calculated rates for the historic 27 year old waste piles by a scaling factor of 0.05 to 0.3. This indicates that the majority of the waste rock should have a low reactivity over the long time period. However this initial indication needs to be verified by appropriate specific studies over the mine life to add to the past 27 years of records. Operational monitoring is also specified in a comprehensive program outlined in the provincial Environmental Compliance Assessment (ECA) and be the federal MMER monitoring program.

The limitation of lab testing for long-term prediction and the scale up challenges require extensive research work to better understand the long-term. DGC has already made a start on such work and has a general objective to obtain as good an understanding as possible of the local geochemistry in order to reduce the closure liability and associated financial assurance costs.

In summary a rigorous waste rock management program has been developed based on the use of old and new data from historic waste piles and predictive testing of samples from the new waste rock materials. The program for segregation of rock types is conservative and requires management of approximately 10 to 15 % of the waste materials in a PAG stockpile. To confirm and refine the predictions a comprehensive monitoring program has been defined or rock and water seepages throughout the entire site. In addition a research program has been implemented and is planned for ongoing development of the mine.

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