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Diavik Waste Rock Project: Characterization of Particle Size, Sulfur Content and Acid Generating Potential

Lianna J.D. Smith

University of Waterloo, Waterloo, Canada

Rio Tinto (Diavik Diamond Mines Inc.), Yellowknife, Canada

Richard T. Amos

University of Waterloo, Waterloo, Canada

Xiatong Chi

University of Waterloo, Waterloo, Canada

AMEC Earth and Environmental, Mississauga, Canada

David W. Blowes

University of Waterloo, Waterloo, Canada

Marek Stastna

University of Waterloo, Waterloo, Canada

Leslie Smith

University of British Columbia, Vancouver, Canada

David C. Sego

University of Alberta, Edmonton, Canada

Abstract

The heterogeneous distribution of physical and geochemical characteristics of waste rock has a major influence on the acid generating potential of the rock. This includes controlling the rate and extent of water, gas and thermal transport processes, which affect the rate of oxidation and leaching of oxidation products. Two experimental waste rock piles at the Diavik Diamond Mine have been characterized in terms of particle size ranging from boulders to fines, sulfur content of the bulk rock and individual size fractions of the rock, and the acid generating potential of the rock. The development of a digital image processing (DIP) technique provides a means of characterizing spatial distribution of the > 10 cm to boulder size fraction of waste rock. Combining the DIP techniques with traditional sieve analysis of the fine fraction provides a full-spectrum grain-size distribution of the waste rock. The average sulfur content of the two waste rock piles was determined to be 0.035 wt. % S (Type I pile) and 0.053 wt. % S (Type III pile), and both rock types are determined to be potentially acid generating using standard acid-base accounting methods. Detailed analysis of the fine fractions for both rock types suggests that the acid generating potential of the waste rock is not evenly distributed among particle sizes. Although both sulfur content and neutralization potential increase with decreasing particle size, overall acid generating potential also increases with decreasing particle size. This research provides a greater understanding of the spatial distribution of rock characteristics that control the generation of acidic leachate in waste rock piles.

Introduction

The heterogeneous distribution of physical and geochemical characteristics of waste rock, including particle size and sulfur content, has a major influence on the acid generating potential of the rock.

Particle size influences the rate and extent of water, gas and thermal transport processes, as well as the oxidation rate of sulfide minerals. The sulfide content of waste rock, and the distribution of the sulfide minerals among various particle sizes, will also influence the rate of oxidation and the potential for acid generation.

At the Diavik Diamond Mine, two uncovered experimental waste rock piles (test piles) have been characterized in terms of particles size ranging from boulders to fines, sulfur content of the bulk rock and individual size fractions of the rock, and the acid generating potential of the rock. The two test piles are referred to as Type I (low sulfide) and Type III (higher sulfide). The piles are 15 m high, with an upper surface area of 20 by 50 m, and side slopes at the angle of repose, approximately at 37.5° (Figure 1). The piles were constructed by end dumping in a single lift using standard mining equipment off a ramp constructed from low sulfide waste rock.

Figure 1. Type I (TI) and Type III (TIII) test piles with labeling of exposed faces used for DIP particle-size analysis.

Particle Size Characterization

During test pile construction, samples of the <50 mm fraction were taken to measure the particle size distribution and sulfide content of the matrix material. The particle size distributions of the Type I test pile and the Type III test pile were similar; however, the Type III test pile has a greater proportion of fine particles compared to Type I waste rock. The greater proportion of fines in the Type III waste rock is likely due to the higher proportion on biotite schist contained in Type III waste rock, which is more friable than the granite which makes up the bulk of the Type I and Type III waste rock (Smith, 2009).

A digital image processing (DIP) techniques was developed to characterize the spatial distribution of the waste rock size fraction greater than 10 cm to boulder size (Chi, 2011). The DIP technique was applied to photographs of the six exposed faces of the Type I and Type III test piles (Figure 1). Each image was divided into 18 sub-regions (Figure 2a) and a region-growing algorithm was applied to each sub-region to characterize the size of each individual particle greater than 10 cm. The image analysis results were combined with traditional sieve analysis to provide a full-spectrum particle size distribution for each sub-region (Figure 2b). Image analysis results show good reproducibility and compare well with large-scale particle size measurements obtained by physical sorting.

Particle size measurements for the six exposed faces of the Type I and Type III test piles show a range of particle sizes distribution, with the proportion of fines (diameter <10 cm) ranging from ~10% to over 40%. In general, the upper row of each face has significantly more fine particles than the lower two rows, and the lower two rows have more similar particle size distributions (Figure 2B). These results suggest that the upper portion of the pile could have a higher reactive surface area associated with the finer particle sizes; however, the finer particle size also reduce permeability, potentially reducing water and oxygen transport to the oxidation sites.

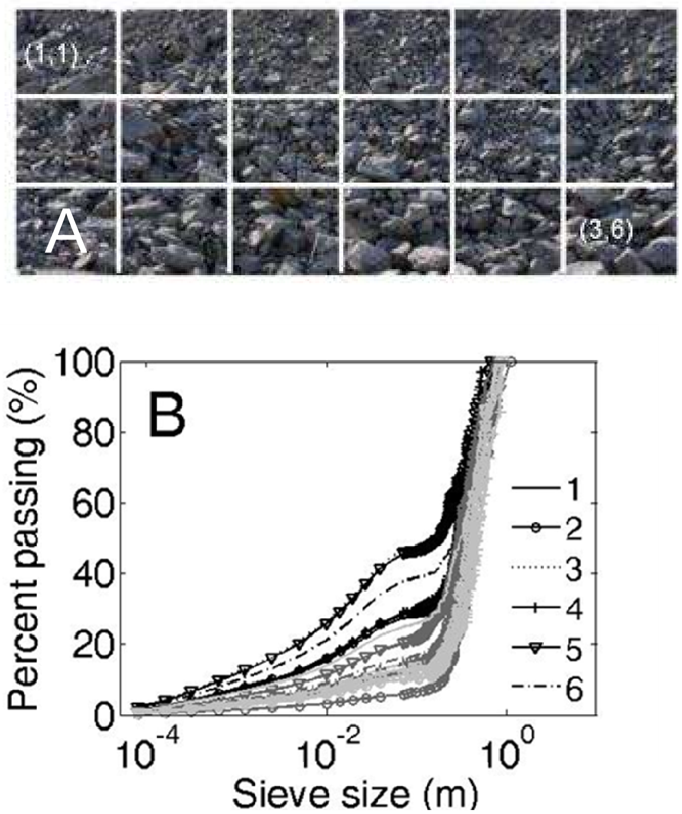

Figure 2. (A) Digital image of face TIN with grid showing 18 sub-regions analyzed with the DIP technique. (B) Particle size distribution curves for TIN obtained from image particle size analysis with sieve analysis results for particle sizes <0.1 m. The individual curves are shown in black: top row, dark grey: middle row, light grey: bottom row. Line styles and symbols representing the six columns, numbered from left to right, are shown in the legend.

Sulfur Content and Acid Generating Potential

The average sulfur concentration of the <50 mm fraction of the Type I test pile was 0.035 wt. % S (n= 242, σ=0.019), which is towards the upper end of the operational Type I waste-rock designation (< 0.04 wt. % S). Individual Type I test pile samples ranged from 0.0028 to 0.26 wt. % S. The average sulfur concentration of the <50 mm fraction of the Type III test pile was 0.053 wt. % S (n=270, σ=0.037), which is below the operation designation for Type III waste rock (> 0.08 wt. % S). Individual samples from the Type III test pile ranged from 0.0085 to 0.27 wt. % S (Smith 2009).

Discrete particle size fractions <50 mm showed increasing sulfur concentration for particle sizes ≤1.25 mm for waste rock from both Type I and Type III test piles (Figure 3). Sulfur concentrations are more variable for particles >1.25 mm have but lower than the finer fractions. Carbon content for the ≤1.25

mm size fractions also increased with decreasing particle size. The Type I and Type III waste rock had similar carbon concentrations (Smith 2009).

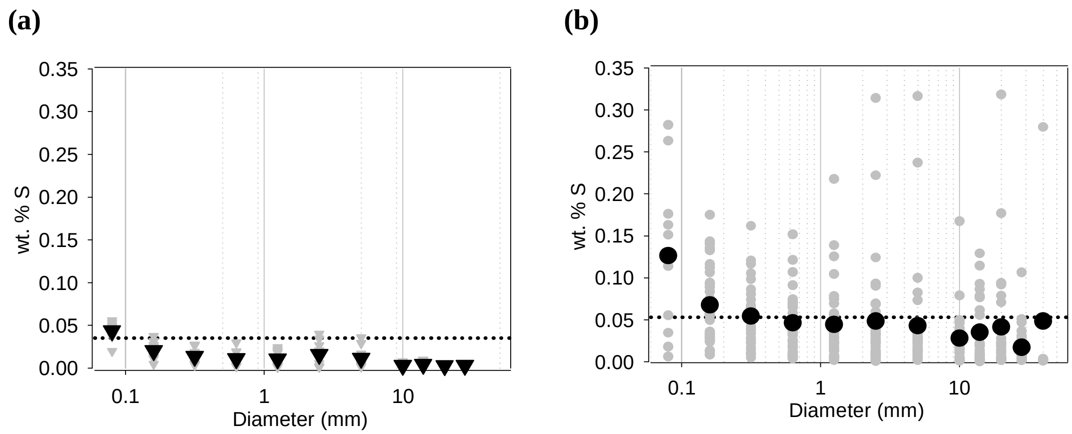

Figure 3. Sulfur distribution for discrete particle sizes for the (a) Type I test pile material and (b) Type III test pile material. Black symbols indicate average values and dotted line indicates test pile average.

The ratio of neutralization potential (NP) to acid-generating potential (AP) of the Type I and Type III waste rock was determined for each size fraction assuming that the analytically-determined sulfur concentration consisted entirely of pyrrhotite with the composition $Fe_{0.85}S$ [$Fe_{17}S_{20}$], and the analytically-determined carbon content consisted entirely of $CaCO_3$, which is consistent with mineralogical observations (Smith 2009).

The NP:AP ratios of the <50 mm Type I waste rock ranged from 0.14 to 6.91 and averaged 1.49 (n=90, σ=1.40 Figure 4). Smaller particle fractions generally had lower mean NP:AP ratios with fractions <0.315 mm fraction being potentially acid generating while the larger size fractions are of uncertain acid generating potential. For Type III waste rock NP:AP values for the <50 mm fractions ranged from 0.01 to 15.27 with a mean of 0.76 (n=355, σ=1.67), indicating that the rock is potentially acid generating. Type III had lower NP:AP ratios than the Type I waste rock but with a similar trend of progressively lower NP:AP values for fractions <10 mm (Smith 2009).

Geochemical analysis of effluent from the Type III show pH values regulalry below 4.5, SO_4 concentration above 1000 mg L^{-1}, elevated concentrations of metals, and depleted alkalinity, indicating that the rock is acid generating consistent with the prediction from acid-base accounting. For the Type I test pile, geochemical analysis Effluent form the Type I test pile has maintained a near-neutral pH (ranged from 5.8 to 8), low concentrations of SO_4 (< 500 mg L-1), Fe (< 1.4 mg L-1) and other metal, and contains measurable alkalinity, indicating that the rock is not acid generating in the initial stages of leaching (Smith et al., 2009; Bailey et al., 2009).

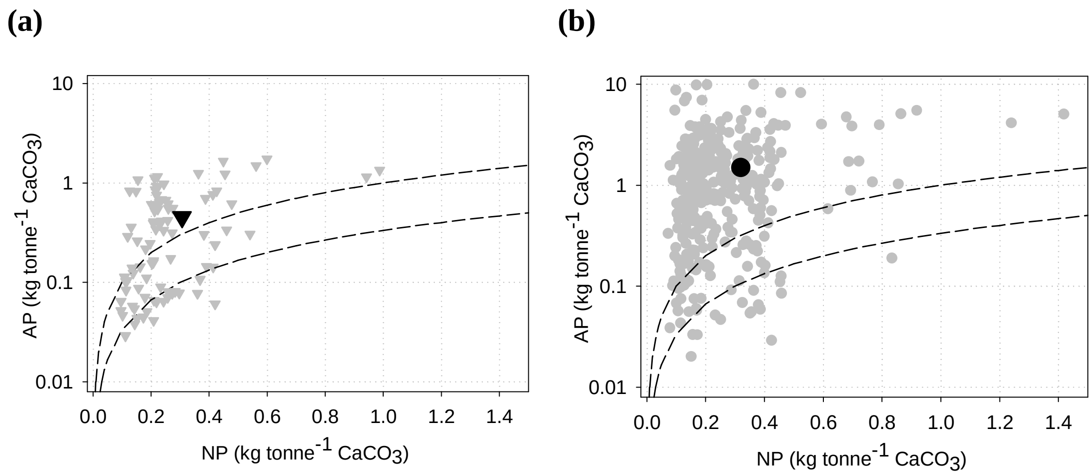

Figure 4. NP:AP ratios for all particle size fractions for (a) Type I test pile material and (b) Type III test pile material. The average values for NP:AP are illustrated by the larger symbols. NP:AP < 1 indicate potentially acid generating waste rock, 1 < NP:AP <3 indicate uncertain acid generating potential, and NP:AP > 3 indicate non-acid generating waste rock.

Conclusions

This research indicates that at the large and fine scale, the non-uniform distribution of various waste-rock characteristics will affect physical and geochemical processes controlling the rate and extent of sulfide mineral oxidation and leaching of acidic drainage from waste rock. At the large scale the finer particle size distribution toward the top of the pile can potentially influence the available sulfide surface area, and the rates of water and gas flow. At the fine scale, the distribution of particle size and sulfide content will control sulfide oxidation. Sulfide oxidation and the neutralization potential of the waste rock control the effluent quality from large-scale waste-rock piles.

This research provides a greater understanding of the spatial distribution of rock characteristics that control the generation of neutral and acidic mine drainage in waste rock piles, and highlights the need for thorough characterization of waste rock properties at multiple scales.

References

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