EXECUTIVE SUMMARY

Results from this study benefit the state of Minnesota in two fundamental ways. First, this experiment provides a large data set that can be used to validate experimental data collected by mining companies and their consultants as required by Minnesota Rule 6132.100. Second, this experiment design afforded development of a mathematical model that can predict (with some limitations) the composition of water draining from existing and future Duluth Complex waste rock stored on the Earth's surface. This model is a powerful tool that can be used to inform the state of Minnesota's environmental review and mine permitting processes for future mining projects. Furthermore, the potential for particle size experiments to aid environmental impact predictions and guide waste rock handling during mining operations and reclamation demonstrate the importance for this type of study to be included in waste rock characterization studies required for issuance of mine permits.

In this study three different rock types were characterized and different particle size samples of each rock type were subjected to laboratory dissolution tests for as long as 18 years to evaluate rock reactivity as a function of particle size. The rock types examined were norite (from the Duluth Complex, Mesaba prospect), diatreme, and mudstone. Each rock type was crushed and separated into a series of different particle size fractions ranging in size from <0.053 to 19 mm. Each size category from each rock type was analyzed for solid phase composition and subjected to humidity cell testing.

The particle size experiment provided insight into four key concepts that should be evaluated to assess the potential for proposed mining operations to impact the environment. These key concepts are 1) sulfide enrichment in fines, 2) leachate pH and sulfate release rate dependence on particle size, 3) sulfide mineral grain size distribution, and 4) long term leachate composition.

First crushing of rock can lead to enrichment of sulfide minerals in some particle size fractions. For norite, in which dominant sulfide mineral is softer than the host rock silicate minerals, the sulfur content of the smallest particle size sample was about twice that of the bulk sample. Thus, rates of sulfide mineral oxidation and the consequent acid production are enhanced not only by increased sulfide mineral specific surface area (area per unit mass) but also by increased sulfide mineral content of this fraction.

Second, the norite samples showed a systematic variation between both leachate pH and sulfate release rate and particle size. This relationship can be quantified and used to predict release rates for field scale waste rock piles. In addition, it indicates that the fine particles are dominant contributors to reactions in field scale rock piles.

Third, the substantial shift in pH and sulfate release rates observed between the 0.149-0.5 and 0.5-2.0 norite samples indicates that reducing norite rock particle size to less than 0.5 mm leads to near complete exposure of the majority of the sulfide mineral surfaces. Knowing this critical particle size in conjunction with a waste rock piles overall particle size distribution provides a gauge for the amount of highly reactive rock.

Fourth, the particle size experiment showed that essentially all the sulfide was reacted in particles finer than 0.5 mm, but for increasingly larger particles only a fraction of the sulfide was reacted over the reported experiment timespan. This demonstrates that not all sulfide minerals in a waste rock pile are readily available for reaction. Reaction of a considerable amount of these minerals will be controlled by the weathering and subsequent break down of the silicate mineral assemblage in which the sulfide minerals occur. The time required to dissolve silicates is orders of magnitude greater (thousands to tens of thousands of years for millimeters of weathering rind development (Colman and Pierce, 1981) than that for carbonates or sulfides.