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Approaches to incorporating heterogeneity in characterization and reactive transport modelling of mine waste rock geochemistry

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Forecasting the geochemical evolution of mine-waste rock is of critical importance for waste management because of the potential negative impacts of these wastes on local environments. Reactive transport models offer a mechanistic approach to forecast evolving geochemical conditions in waste rock; however, numerical simulations are reliant on appropriate data, that may be difficult to obtain, to effectively represent the system. The geochemical evolution of a full scale waste-rock pile is challenging to forecast in part due to large size and geochemical and physical heterogeneity. A reactive transport model was developed for a large-scale test pile at the Diavik Diamond Mine (NT), to evaluate the influence of mineralogical and physical heterogeneity on effluent solute concentrations. A field component of the Diavik Waste Rock Project included collection of effluent from discrete collection lysimeters at the base of the test piles to quantify heterogeneity in solute concentrations and flow volumes. Additionally, the study included deconstruction of one test pile and collection and analysis of more than 500 spatially located samples for mineralogical, geochemical, and physical parameters to complement the effluent samples. Geostatistical analyses of the deconstruction data were used to describe the spatial distributions of geochemical (S, C) and physical (K_S) parameters within the pile. Model calculations included multi-year 2-D simulations using the reactive transport code MIN3P. Heterogeneity was incorporated into the model through spatially variable realizations of the primary geochemical and physical characteristics developed from the deconstruction program. This simulation approach was combined with varying control volume size to assess the influence of numerical parameterization (e.g., discretization) on effluent variability and to replicate the measured heterogeneity, providing a more robust representation of the geochemical conditions in the waste rock. Incorporating mineralogical and physical heterogeneity in reactive transport simulations produced variability that was representative of the measured effluent concentrations and mass loading for primary parameters indicating sulfide mineral oxidation, including pH, SO_4, and Ni, while overestimating variability in Fe. Quantification and consideration of this variation is necessary to assess the uncertainty associated with forecasts of future geochemical conditions associated with mine wastes.