Weathering evolution of nickel and sulfur in pyrrhotite within a low-sulfide, granitic, mine-waste rock in the Canadian Arctic

JEFF LANGMAN[1]*, STEVE HOLLAND[1], SEAN SINCLAIR[1], DAVID WILSON[1], LESLIE SMITH[2], DAVID SEGO[3] AND DAVID BLOWES[1]

[1]Department of Earth and Environmental Sciences, University of Waterloo, Waterloo, ON Canada
[2]Department of Earth, Atmospheric and Ocean Sciences, University of British Columbia, BC, Canada
[3]Department of Civil and Environmental Engineering, University of Alberta, Edmonton, AB, Canada
(*correspondence: jlangman@uwaterloo.ca)

The oxidation of sulfide minerals in waste rock can produce acid-rock drainage (ARD), which is characterized by low pH, elevated SO4 concentrations, and the increased mobilization of metals such as Co and Ni. A laboratory- and field-scale project was conducted to examine the generation of ARD in a low-sulfide, run-of-mine, waste rock in the Canadian Arctic. As part of this project, rock with different concentrations of sulfide minerals (primarily 4C-pyrrhotite [Fe7S8] containing trace quantities of Co and Ni) and calcite were weathered in the laboratory and in the field to examine mineral alteration and element release rates. Grains from different periods in the experiments were analyzed for element oxidation states and secondary mineral formation. These characteristics were evaluated with leachate geochemistry to compare weathered mineral conditions and corresonding ARD geochemistry. Application of x-ray spectroscopy techniques including SEM, μ-XRD, and synchrotron radiation were used to evaluate the transformation of pyrrhotite to a shrinking sulfide core with intermittent layers or areas of marcasite [FeS2], polysulfides, elemental sulfur, and Fe(II)- and Fe(III)-(oxyhydr)oxides. The relation of S and Ni is strongly monotonic in leachate from the field-scale experiment but not as strongly correlated in leachate from the laboratory experiment. As the pyrrhotite is transformed to various S and Fe minerals, retention or release of Co and Ni, which preferentially remain in the +2 oxidation state, is correlated with the oxidation state of S. This relation can be used to interpret the weathered state of pyrrhotite from the subsequent ratio of the elements in the leachate. Identifying the generation of oxidation products from the evolving transformation of pyrrhotite in this climate assists in understanding appropriate element-release rate factors for prediction of ARD.