Natural pyrite weathering rate in a small catchment compared with mined catchments and lab rates

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As part of the USGS background study of the Questa mine in northern New Mexico, a small catchment (Straight Creek) of about 2.67 km^2, was studied to determine the hydrogeochemical processes that naturally generate acidic, metal-rich surface waters and groundwaters. The predominant reaction is pyrite oxidation because there is excess pyrite (2-10 wt.%) in quartz-sericite alteration. A mass–balance calculation was performed reacting pure water to the median composition of 14 water analyses from 2000-2003 with median pH of 2.98 and median sulfate concentration of 2,030 mg/L. The most likely mass–balance model consistent with mineralogical analyses, assuming that rates are unaffected by solid/solution ratio or by evaporation, indicates oxidative dissolution of 8.66 mmol pyrite/kg$_{H_2O}$. When combined with a median discharge of 37.85 L/min measured simultaneously, the weathering rate was 5.46 mmol pyrite/h. This value is larger than batch abiotic laboratory rates, about 0.01 mmol/h for Fe(III) oxidation with pH close to 2, or microbial laboratory rates, about 0.22 mmol/h based on an interlab comparison. Evaporation effects or a “pooling effect” might be the main sources of discrepancy between apparent field rates based on mass balances and laboratory rates. Similar calculations for effluent water at the Leviathan Mine, CA (pH = 1.8) result in an apparent pyrite weathering rate of 40 mmol/h, 200 times higher than expected from laboratory rates; this result could be explained by the extremely fine-grained pyrite that occurs there as well as evaporation effects.

Calculations for Iron Mountain, CA a massive sulphide copper deposit that has been extensively mined and exposed to air and water, result in an apparent pyrite weathering rate of 17,100 mol/h, five orders of magnitude higher than laboratory rates. At Iron Mountain pyrite weathering has produced enormous amounts of efflorescent salts that periodically dissolve and reprecipitate in the underground workings. When the mass–balance is modified in terms of dissolving soluble salts, removal of some iron as goethite is required and the weathering rate becomes 24,800 moles soluble sulfates/h.

Regardless of how mass–balances are calculated, the field rate for pyrite oxidation is much faster than the laboratory rate suggesting that evaporation, pooling, or possibly surface areas, strongly influence these calculations for most mined sites. The pyrite weathering rate might be a guide to whether the mechanism is dominated by pyrite weathering or by precipitation/dissolution of soluble salts. Another conclusion dictated by the mass balance is that large amounts of iron and silica must precipitate. This conclusion is also supported by the saturation indices having reached saturation for silica in many of these waters.

Geochemical signatures of IOCG mineralization and alteration in till

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Introduction

As part of Canada’s Geomapping for Energy and Minerals (GEM) Program, an applied Quaternary research activity under the IOCG-Great Bear Project was undertaken in the Great Bear magmatic zone (Northwest Territories, Canada) to provide a practical guide for geochemical and indicator mineral exploration targeting iron oxide copper-gold (IOCG) and affiliated deposits in glaciated terrain. Detailed till sampling (n=111) was completed in the vicinity of the NICO Au- Co-Bi-Cu magnetite-group IOCG deposit as well as the Sue-Dianne Cu-Ag-Au magnetite- to hematite-group IOCG deposit, and near showings hosted within other IOCG-type alteration systems in the GBmz. Samples were collected up-ice, proximal to, and down-ice from mineralization, hydrothermally-altered host rocks and least-altered bedrock. Extensive lihogeochemical data set (n=1243) was available within the IOCG-Great Bear Project.

Results and conclusion

Lithogeochemical signatures of mineralization and/or alteration are reflected in the till matrix (K, Na, Ca, Mg, Ti, Cu, Ba, Cr, Co, Th, Bi, Mo, U, As) despite variable degrees of post-glacial weathering and textural differences. Possible IOCG deposit pathfinder elements in till (<2 and/or <63 µm fraction) include Cu, Mo, Bi and Co (enrichments), as well as Ti (depletion). However, given the high variability of IOCG and affiliated mineralization, a multivariate statistical approach was also applied to see if their associated, and more characteristic, alteration types left a clear signal. A principal component analysis (PCA) was performed on combined data sets of till geochemistry and lithogeochemistry. This innovative approach helps to isolate the role of hydrothermal processes from surface processes such as glacial communition and post glacial weathering in the internal variability of the till geochemistry. Results so far show: 1) grouping of till samples by the first 3 principal components, based on their related IOCG showings; 2) discrimination between anomalous till samples based on multi-enrichments of alteration related elements (K, Ca, Na), and 3) potential to identify the type of bedrock IOCG alteration in overlying till samples.