

Relation between redox processes in groundwater and an adjacent lake at an abandoned mine site

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Integrated Field Investigation

Sulfide-rich mine tailings, when exposed to the atmosphere, will oxidize and release acid and metals to tailings pore waters. Discharge of this metal-rich water can lead to severe degradation of water quality in lakes and streams. Prediction of the surface water composition in mine-impacted lakes requires incorporation of hydrological, geochemical and microbiological processes occurring in the mine waste piles, lake sediments and directly in the lakes. An integrated groundwater and surface water study to evaluate the geochemical evolution of a severely impacted mine lake in northern Manitoba, Canada, was conducted. Microbially-mediated sulfide oxidation reactions have led to the depletion of sulfides in the upper 50 cm of the tailings. Concentrations of sulfide oxidation products are very high in the tailings pore water (Fe > 129,000 mg/L, SO₄ > 280,000 mg/L, pH < 1, Al and Zn > 5000 mg/L, Cu > 1500 mg/L, As > 50 mg/L, Cd, Co and Pb > 5 mg/L), with highest concentrations of metals and lowest pH conditions present in the zone of active oxidation. Concentrations of metals are sufficiently elevated to result in the formation of a massive hardpan slightly below the zone of highest metal concentrations. This hardpan leads to the formation of a transient perched water table causing large variations in the chemical composition of groundwater discharging to an adjacent lake. Concentrations of metals and SO₄ in the lake are elevated, with maximum concentrations observed at deep sampling locations in isolated embayments (Fe > 8500 mg/L, SO₄ > 20,000 mg/L, Al > 100 mg/L, Zn > 30 mg/L). These elevated concentrations lead to large increases in density, limiting normal mixing processes. Mineralogical and chemical analysis of the tailings indicate large accumulations of soluble secondary solids, including the Fe(II) rich phase melanterite, which are available for continued release. Metal loadings to the lake are predicted using a fully coupled reactive solute transport model which incorporates kinetically controlled microbial oxidation reactions and mineral precipitation/dissolution reactions. This integrated approach provides a unique opportunity to evaluate redox processes along the entire flow path.

PGEs in Abitibi komatiites

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PGE abundances in the mantle are of great interest because of relevance to several fundamental planetary problems. Komatiites are excellent samples for probing mantle PGE abundances.

In this study, high-precision PGE data for 2.7 Ga Pyke Hill komatiites from Munro Township obtained by ID-ICP-MS are reported. Twenty whole-rock drill core samples and olivine, chromite and sulfide separates from two komatiite lava flows that exhibit classic differentiated profiles were analyzed. Electron probe mineral data and whole-rock major element systematics indicate that the erupted liquid was an Al-undepleted komatiite with ~28% MgO and was derived by ~50% partial melting of depleted mantle. Major element variations after eruption were controlled by 30% fractionation of olivine Fo₉₄.

The erupted komatiite liquid was characterized by (Pd/Os)_N = 2.9, (Os/Ir)_N = 1.3 and elevated abundances of Os and Ir (3.0 and 2.2 ppb). These parameters are similar to those we observed in the Alexo komatiites, but are different from those of the 2.8 Ga Kostomuksha komatiites, which have more fractionated PGE patterns, lower Os and Ir (~1.5 ppb) and a chondritic Os/Ir. This is attributed to the distinct melting conditions and specific melting histories of the respective mantle sources. Ru abundances in all three komatiites are similar, consistent with D(Ru) = 1 during mantle melting and provide evidence that all three suites were derived from mantle sources with similar PGE contents.

Variations in PGE abundances within individual flows show that Os and Ir were compatible (bulk Ds up to 7), that Ru was slightly compatible (D = 1.5) and that Pt and Pd were highly incompatible (Ds = 0.1) during lava differentiation. Os, Ir and Ru were moderately incompatible (D = 0.5-0.7) and Pt and Pd were highly incompatible in olivine. Although chromite has high Os, Ir and Ru abundances (D = 27-30) and can potentially control IPGE budget of the magma, there is no evidence for chromite fractionation based on Cr variations. The origin of fractionation trends in the lavas is not yet clear. Os-Ir fractionation is often attributable to the presence of alloys, but they should not be stable in komatiitic magma due to high solubility of OsIr metal. The mineral assemblage contains 0.01-0.02% pyrrhotite enriched in Os and Ir (D_{Os} = 10⁴, D_{Pd} = 10³), but it is unlikely that such a high-degree melt would be saturated in sulfide or that MSS would crystallize at such high T.