Ni isotope signatures of Duluth Complex Cu-Ni-PGE mineralization

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The 1.1 Ga gabbroic Duluth Complex in Minnesota hosts numerous Cu-Ni-PGE deposits. Recent work has shown significant Ni isotopic variations of up to 1.1 ‰ in high-temperature magmatic rocks associated with sulfide mineralization [1,2]. Till, surface material, primary mineralization, and unmineralized rock were analyzed for whole-rock geochemistry and Ni isotopes. Results are evaluated for Ni isotopic fractionation between early cumulates, primary mineralization, and weathering products.

Samples were analyzed using the double-spiking method outlined in [1]. Ni isotope ratios are reported relative to the NIST SRM 968 standard with conventional delta notation and 2σ error of 0.06 ‰. Results show a spread of $\delta^{60/58}$Ni values from -0.97 ‰ to +0.21 ‰, comparable to Ni isotopic values reported previously [1,2]. Least fractionated values come from unmineralized mafic intrusives (-0.07 ‰), while olivine associated with sulfide mineralization exhibits values between 0.22 ‰ and -0.08 ‰. With increasing sulfide content, in-situ Ni isotopic ratios become progressively lighter, ranging from 0.15 ‰ to -0.97 ‰. Weathered outcrop material with variable amounts of sulfide and Fe-oxide shows values between -0.23 ‰ and -0.87 ‰. Till samples record intermediate values ranging from -0.02 ‰ to -0.77 ‰.

Results suggest isotopic fractionation from initial bulk silicate earth values close to zero for early phases to significantly fractionated Ni-bearing sulfide mineralization, accumulated at a later stage. This isotopic spread of up to 0.81 ‰ suggests that Ni was fractionated during sulfide formation by incorporating preferentially lighter Ni into the accumulating sulfide melt and resulting Ni sulfides. Surface samples also record lighter Ni isotope values with increasing degree of weathering, which is explained by the preferred adsorption of lighter Ni onto Fe-oxides as suggested by [3]. Ni isotopic values of surface samples, and their correlation with known mineralization, may be useful in distinguishing regions associated with Cu-Ni-PGE mineralization from barren areas.

[1] Gueguen *et al*. (2013) *Geost. and Geoana. Res.* **3**, 297-317. [2] Hiebert *et al*. (2014) *GSA Abst*. **46**, 467. [3] Wasylenski *et al*. (2015) *Chem. Geol.* **400**, 56-64