Chromium isotope effects induced by metamorphic, weathering, and hydrothermal alterations

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Chromium (Cr) isotopes, expressed as $\delta^{53}Cr=(^{53/52}Cr_{sample}/^{53/52}Cr_{SRM979} - 1)1000‰$, are an emerging redox proxy. However, many of the mechanisms responsible for Cr isotope fractionation are poorly understood. The purposes of this study are (1) to expand the current Cr isotope database pertaining to high-temperature rocks and (2) to investigate Cr isotope effects during high temperature metamorphism, black shale weathering and hydrothermal alteration.

Our $\delta^{53}Cr$ data from mafic-ultramafic and meta-mafic-ultramafic are within uncertainty the same as previously reported bulk silicate earth ranges (-0.12±0.10‰). Further, meta-carbonates that have experienced extensive high temperature fluid-rich alteration and element mobility yielded very limited Cr isotope variation. These results point to the unlikeliness of significant Cr isotopic variation under high temperature regimes and thus support the application of Cr isotopic composition as a tracer for low-temperature processes. However, hydrothermally altered mafic-ultramafic rocks (serpentinites) generated ~0.6‰ variation in $\delta^{53}Cr$. The heavy isotopic composition is likely related to incorporation of isotopically heavy seawater Cr that has gone through partial reduction during percolation through the oceanic crust.

Our data from a black shale weathering profile yielded ~0.5‰ variation in $\delta^{53}Cr$, with weathered black shale horizons being isotopically heavier than the relatively unweathered samples. Enrichment of heavy isotopes in the weathered section is accompanied by enrichment of Cr concentration. We propose that in the black shale weathering environment featuring acidic pH, the oxidized Cr(VI) is quickly re-sequestered by reduction. This indicates significant Cr redox cycling and Cr isotope fractionations at low pH in the presence of high environmental oxygen concentrations.