Constraining the sensitivity of oxidative weathering across the GOE using U isotope systematics

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The disappearance of detrital uraninite and pyrite, as well as mass independent sulfur isotope fractionation (MIF-S), across the Great Oxidation Event (GOE) at ~2.3 Ga, provides evidence for a rise in atmospheric O_2 from muted Archean levels. The exact nature and extent of this atmospheric O_2 rise and its impact on oxidative weathering, however, is debated. The redox-sensitive behaviour of uranium, and associated isotope fractionations, make this an important geochemical tool to study oxidative weathering processes.

Here we study Archean to Paleoproterozoic siliciclastic metasediments as representative of the upper continental crust, using U isotope systematics to quantify the impact of oxidative weathering processes. The samples include metasediments from Pilbara, Australia (~3.4Ga) and the Hurwitz Group and Huronian Supergroup, Canada (McKim, Pecors, Gowganda, Gordon Lake formations), spanning ~2.45-2.22Ga, across the timing of the MIF-S disappearence in this geological sequence. We use geochemical indicators for recent fluid-mobility and metamorphic overprinting (e.g. Pb and U-series systematics) to screen for disturbed samples, which significanty reduces the variability in the measured $^{238}U/^{235}U$ (from ~0.5 to 0.1 permil).

The screened data show, despite evidence of cation weathering loss, no evidence of U loss from oxidative weathering. The metasediments also have $^{238}U/^{235}U$ compositions typical for the continental crust. This includes the siliciclastic sediments from the upper Huronian sequence, that post-date the disappearence of detrital pyrite and uraninite and include occurences of redbeds and Mn sediment enrichments, all indicative of oxidative weathering processes. The lack of U mobility in these sediments suggest an increase in atmospheric O_2 that allowed for dissolution of detrital uranite and pyrite, but not at levels to oxygenate and mobilise U in other igneous U-carrying mineral phases within the timescales of sediment transport. Such observations, when combined with other biogeochemical evidence, may provide crititcal constraints on the exact levels of atmospheric O_2 across this key environmental transition in Earth's history.