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Microbial uranium reduction and uranium isotope fractionation in seawater: constraints of organic carbon availability on $\delta^{238}U$

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Environmental uranium (U) mobility is strongly tied to its redox chemistry. While highly soluble hexavalent U(VI) dominates under oxic conditions, its reduction to tetravalent U(IV) results in the precipitation of crystalline or amorphous U(IV) containing phases. U(VI) reduction can be mediated by dissimilatory metal- and sulfate-reducing bacteria, or abiotic reductants such as Fe(II)-bearing minerals or sulfide. Microbial reduction can shift U isotopic ratios ($\delta^{238}U$), leading to an enrichment of isotopically heavy ^{238}U in the U(IV) product due to the Nuclear Field Shift Effect. Sedimentary rocks, such as black shales, can record these heavy isotopic signatures, serving as a proxy for microbial U reduction and an indicator of an oxygen-depleted deposition environment.

Variations in $\delta^{238}U$ values of marine sediments are expected to reflect changes in the local deposition environment, such as differences in redox conditions or organic carbon input. Despite its potential impact, enzymatic U reduction in seawater and the associated isotope fractionation remain poorly constrained due to a limited number of experimental studies, thereby restricting the diagnostic reach of the U isotope system as paleoredox proxy.

Using the marine dissimilatory metal-reducing organism *Shewanella baltica* OS185, we conducted batch U reduction experiments in artificial seawater, monitoring U concentrations and isotopic signatures over time. To assess the impact of organic carbon availability on $\delta^{238}U$, we varied the electron donor concentration (0.05 vs. 20 mM lactate), which has been shown to impact the extent of U isotope fractionation and is expected to differ between local depositional environments. Uranium concentrations decreased over time, although quantitative reduction could not be achieved in the low lactate condition. With progressing reduction, the remaining aqueous U(VI) shifted to progressively lower isotopic values. Both incubation sets did not express the full intrinsic ε (~ 1.2 ‰) and the extent of U isotope fractionation was lactate dependent ($\varepsilon_{0.05\ mM\ lactate}$ = 0.81 ‰ vs. $\varepsilon_{20\ mM\ lactate}$ = 0.63 ‰).

We show the potential for enzymatic U reduction in seawater facilitated by a marine *Shewanella* strain. Furthermore, we observe a dependence of $\delta^{238}U$ on organic carbon availability, and overall smaller fractionation than the intrinsic ε commonly expected during microbial reduction.