Uranium Isotope Fractionation as a Signature for Biotic Reduction Processes

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Reductive immobilization of the radionuclide uranium in the environment is responsible for the formation of some U(IV) ore deposits [1-2] and is widely proposed as a remediation technique for the U-contaminated subsurface [3]. U is also proposed as a paleoredox proxy shedding light on the oxygenation of atmosphere and oceans [4]. However, the mechanism of the U reductive transformation in the environment –whether biotic or abiotic– remains elusive. We address this question by the investigation of the U isotopic signature of during biotic and abiotic reduction.

We found that enzymatic U reduction results in a clear isotopic signature of ^{238}U enrichment in the U(IV) products. In contrast, abiotic U reduction displays negligible U isotope fractionation. Based on these findings, we propose that $^{238}U/^{235}U$ ratios can be used as a reliable method capable of discriminating between biotic and abiotic U reduction pathways. The generally heavy $^{238}U/^{235}U$ isotope signatures observed in sequestered U(IV) in field bioremediation studies, as well as in low-temperature redox-sensitive U deposits and in organic-rich sediments of anoxic ocean basins (e.g. Black Sea) implies that microbially driven U reduction is widely responsible for U reduction in natural and engineered settings. Therefore, we propose $^{238}U/^{235}U$ ratios as a novel proxy for enzymatically-driven reduction in paleo environments that may be used complementary to traditional paleoredox tracers.

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