

Isotopic Mapping of a Redox Boundary: Heterogeneities Across a Roll-front U Deposit

ANIRBAN BASU¹, SHAUN T BROWN¹, AND DONALD J. DEPAOLO¹

¹Center for Isotope Geochemistry, Lawrence Berkeley National Lab and UC Berkeley, Berkeley CA
anirbanbasu@berkeley.edu

Interaction between groundwater flow and abiotic and/or microbially induced redox regimes is important for metal transport in the environment. Understanding the relative contributions of groundwater hydrology and pore-scale chemical reactions is crucial for understanding formation mechanisms of redox-interface ore deposits as well as detecting natural reactions using redox-active isotope tracers. The redox-interface responsible for ore formation extends along the hydraulic gradient and gives rise to isotopic heterogeneity.

Here we report U isotopic characterization ($(^{234}\text{U}/^{238}\text{U})$ and $\delta^{238}\text{U}$) of a roll-front U deposit from Smith Ranch Highland, WY, USA, using sediments from 3 drill cores located along the hydraulic gradient. Our results show substantial variations in $\delta^{238}\text{U}$ (up to $\sim 2\text{‰}$) and $(^{234}\text{U}/^{238}\text{U})$ (ranging from 0.77 to 2.26) in U minerals with depth in each core and amongst the different cores. In each core, U concentration is correlated with $\delta^{238}\text{U}$; samples with highest U at the center of the mineralized zone exhibit high $\delta^{238}\text{U}$ ($> 0.0\text{‰}$) which decreases ($\delta^{238}\text{U} < 0.0\text{‰}$) both upward and downward. The $(^{234}\text{U}/^{238}\text{U})$ in each core is correlated with $\delta^{238}\text{U}$, with the lowest $(^{234}\text{U}/^{238}\text{U})$ ($\ll 1.0$) at the center of the mineralized zone.

Decreasing $\delta^{238}\text{U}$ along the hydraulic gradient at the center of the mineralized zone suggests a significant hydrological influence on U isotopic distribution. During ore formation reduction of dissolved U(VI) leads to the formation of U minerals enriched in ^{238}U . The remaining aqueous U(VI) is progressively enriched in ^{235}U as it flows downgradient. The resulting U minerals also become ^{235}U enriched relative to those forming upgradient. Dissolution of these ^{235}U enriched U minerals would produce isotopically lighter U(VI) in groundwater. To use $\delta^{238}\text{U}$ of groundwater for detection of U(VI) reduction, the abovementioned dissolution effects must be disentangled from the isotopic fractionation in the same direction generated by reduction. Future work will determine $\delta^{238}\text{U}$ and $(^{234}\text{U}/^{238}\text{U})$ in the porewater and adsorbed U(VI) for each sample.