Origin of enriched mid-ocean ridge basalts: A perspective from uranium and molybdenum isotope ratios

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Contrasting origins of incompatible element rich portions of the upper mantle as represented by enriched-mid ocean ridge basalts (E-MORB) have been proposed. Many have argued for the involvement of recycled mafic oceanic crust [e.g., 1]. Others have invoked low degree partial melts of uppermost mantle, that metasomatize overlying oceanic mantle lithosphere and are subsequently recycled into the upper mantle [2, 3]. Both models have gained recent champions from the perspectives of novel geochemical techniques [4, 5].

To add to this debate, we present uranium (U) and molybdenum (Mo) isotope data on non-plume influenced E-MORB from the northern mid-Atlantic ridge. Samples show U and Mo isotope ratios indistinguishable from bulk silicate Earth but distinct from normal-(N)MORB and show no correlations with tracers of mantle enrichment in E-MORB. Elevated $^{98}\text{Mo}$ in E-MORB, as found in our samples, is compatible with small but not large degrees of melting, as previously discussed [5]. However, low degrees of melting even under reduced conditions are unlikely to fractionate U isotopes given their high incompatibility [6]. Thus, chondritic U isotopic compositions in E-MORB requires additional explanation. Super-chondritic U isotopic compositions, as seen in modern N-MORB are likely the result of crustal recycling after the onset of deep ocean oxygenation at ~600Ma [7]. Therefore, E-MORB sources with chondritic U isotopic compositions require formation prior to this time. Together, our Mo and U isotope data help constrain the style and timing of E-MORB formation. We further investigate our preferred scenario using mass balance models of crustal recycling to evolve the U and Mo isotopic compositions seen in mantle derived rocks.