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Melt modeling of U-series disequilibria in mid-ocean ridge basalts

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Recent model development in calculating uranium-series disequilibria during partial melting has produced new open-source, one-dimensional, steady-state porous flow calculators that determine (^{230}Th/^{238}U), (^{226}Ra/^{230}Th), and (^{231}Pa/^{235}U) activity ratios under a range of chemical equilibrium and disequilibrium transport scenarios [1]. However, a more thorough assessment of basalt compositions in mid-ocean ridge settings requires additional scenarios and variables, including the effects of aging during lithospheric transport for segregated magmas under colder (slower-spreading) ridges, and two-dimensional, triangular flow regimes. We present two new melt calculation tools written using open-source Python code. The first applies the U-series age decay equations to porous flow melt products determine the effects of aging during lithospheric transport, during magma chamber storage, or after eruption. The second, a two-dimensional melting tool, is a streamline integration calculator that considers the rate of segregated melt transport along the top surface of a triangular melting regime. These calculators can be used in a modular fashion to simulate a range of scenarios, and are integrated with the existing pyUserCalc porous flow model.

Preliminary results suggest that for a given melting and transport model, the transport times required to pool partial melts from the far corners of a triangular melting regime place a limit on the extent to which U-series disequilibria can record two-dimensional melt integration, potentially decoupling shorter-lived U-series nuclides from trace elements that record the pooling of melts from triangular systems. For the slowest melt transport rates after melt segregation, integrated melt compositions approach one-dimensional outcomes, because melt increments from the outer portions of the triangle experience enhanced decay towards secular equilibrium prior to pooling. Very rapid transport after melt segregation, on the other hand, can enhance the isotopic signatures derived from the outer triangle corners (and, thus, the deeper melting regime) for shorter-lived nuclides like ^{226}Ra and ^{231}Pa. This rapid transport effect is particularly observed for colder mantle scenarios (lower potential temperatures) with shallow solidi, which have smaller triangular regimes and thus shorter melt transport paths.

[1] Elkins & Spiegelman (2021), *Earth and Space Science* 8, https://doi.org/10.1029/2020EA001619.