Enriched continental basalts from depleted mantle melts: the issue of lithospheric contamination

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Magma-wallrock interaction (assimilation) is critical to the thermodynamic and chemical evolution of a magmatic system. While the most widely used quantification of AFC (assimilation-fractional crystallization) is DePaolo (1981), this approach is limited because it is not thermodynamically feasible. It mixes a compositionally fixed bulk contaminant into a magma body despite excellent documentation of partial melting processes at the contacts of intrusive rocks. Such limitations may significantly impact the mass balance of different sources in models of magmatic systems.

In our case study, we present contamination modeling of highly heterogeneous (e.g., initial ε_{Nd} from -15 to +2) continental flood basalts from Vestfjella mountain range, Antarctica, which belong to the Jurassic ~180 Ma Karoo large igneous province. Previously presented AFC models implied that high amounts of crustal contribution (~20 wt. %) would be needed to explain the most enriched geochemical signatures. We show that by selecting viable representatives for crustal and mantle contaminants (Archean and Proterozoic crust and SCLM-derived melt i.e. lamproite) and by using the energy-constrained AFC (EC-AFC) modeling (Spera and Bohrson, 2001), all Vestfjella lava types can be produced from a MORB-affinity parental melt with less than 5% of lithospheric contamination. This suggests an important role for a long-term depleted sublithospheric mantle source in their petrogenesis.

We encourage all igneous petrologists to learn to use EC-AFC equations in any model that involves contamination of a magma body with lithospheric components.

References:

DePaolo, D.J., 1981. Trace element and isotopic effects of combined wallrock assimilation and fractional crystallization. Earth Planet. Sci. Lett. 53, 189-202.

Spera, F.J. and Bohrson, W.A., 2001. Energy-constrained open-system magmatic processes I: General model and energy-constrained assimilation and fractional crystallization (EC-AFC) formulation. J. Petrol. 42, 999-1018.