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Global trends in novel stable isotopes in basalts: theory and observations

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The geochemistry of global mantle melts suggests that mid-ocean ridge basalts (MORB) sample a broadly homogenous upper mantle lithology, with temperature variations causing melt variability [1,2]. By contrast, ocean island basalts (OIB) provide a more heterogenous view of the mantle, proposed to sample both lithological and temperature heterogeneities relative to MORB [3,4].

Recently, non-traditional stable isotopes have been suggested as a tool to complement existing tracers of mantle heterogeneity, because mineral- and redox-specific equilibrium fractionation effects link melt isotopic composition to source mineralogy and melting degree. Here, we choose five stable isotope systems (Mg-Ca-Fe-V-Cr) that have shown promise in models or natural samples as tracers of mantle temperature and/or lithological heterogeneity [5,6,7,8,9]. We use a quantitative combined phase equilibria and equilibrium mantle melting isotope fractionation model [10] to explore isotopic behaviour during melting of three mantle lithologies (peridotite, silica-excess and silica-deficient pyroxenite), aiming to address:

1) Which stable isotope systems are predicted to have resolvable sensitivity to mantle temperature and lithological heterogeneity; improvements to which analytical uncertainties and model parameters could be most useful with these questions in mind?

2) What can the modelled melt isotopic compositions tell us about the origins of erupted MORB and OIB?

We find that redox-sensitive isotope systems (Fe, V, Cr) show most variability in modelled melt isotopic composition with potential temperature. However, analytical precision improvements are necessary for variability to be resolved in erupted basalts. Mg and Ca isotopes show most sensitivity to a garnet-bearing source lithology. Cr is also potentially sensitive to source lithology, but Cr isotopic behaviour is understudied and requires further work to be used with confidence on mantle melts.

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