A Simple Model for Trace Element Fractionation during Decompression Melting of a Spatially and Lithologically Heterogeneous Mantle

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Several lines of evidence suggest that the source region of oceanic basalts in the upper mantle is heterogeneous, consisting of chemically and lithologically distinct domains of variable size and distribution. Partial melting of such heterogeneous mantle sources gives rise to diverse isotopic compositions of basalts and residual peridotites. The size and distribution of the enriched blobs in the upper mantle are unknown but may play an important role in controlling variations in isotope ratios and trace element abundances in basalts and residual peridotites. During decompression melting of a two-lithology mantle that consists of blobs of enriched lithology (EM) and the depleted mantle (DM), each EM pocket enters the melting column at a different time. The melting problem is time-dependent. We have recently developed time-dependent batch and fractional melting models for melting a chemically heterogeneous mantle. The purpose of this study is to further expand this model by considering variations in lithology of EM. Such a model will be very useful for studying basalt petrogenesis and the nature of mantle heterogeneity.

During decompression melting of a heterogeneous mantle, both the mineralogy and bulk solid-melt partition coefficient of the lithologically distinct EM and DM varies in the melting column, in accordance with their respective melting rates and melting reaction. In this presentation, I outline a new model that consists a set of evolution equations for the variations of mineral volume fraction, bulk partition coefficient, and trace element concentration in the lithologically heterogenous melting column. I start with mass conservation equations for individual minerals and use them to derive an evolution equation governing the spatial and temporal variations of the bulk solid-melt partition coefficient of a trace element in the melting column. I present a general mass conservation equation for a trace element in the melting column in which partition coefficients of EM and DM vary spatially and temporally. I use simple analytical solutions for mineral modal abundance and bulk partition coefficients in the melting column to construct a time-dependent perfect fractional melting model for melting a lithologically heterogenous mantle column. Finally, I use the new solutions to assess the role of spatially distributed eclogite and garnet pyroxenite (EM) in the petrogenesis of MORB and OIB.