The fate of heterogeneous blobs during melting and melt migration in an upwelling mantle

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The source region of MORB is heterogeneous, consisting of depleted mantle (DM) and blobs of enriched mantle (EM) of variable size and and shape. The chief objectives of this study are to examine the fate of EM and how the size and distribution of blobs of EM in the MORB source region affect the variation and distribution of isotope ratios observed in basalts and abyssal peridotites. We consider time-dependent double-porosity models for near fractional melting and channelized melt migration in an upwelling mantle. We use time-dependent boundary conditions to simulate heterogeneities of different size and distribution feeding into the melting column and linear kinetics to model chemical disequilibrium between the melt and the solid. We use analytical solutions to study fractionations of Sr-Nd-Hf isotope ratios during equilibrium melting and melt transport and numerical models to study cases involving chemical disequilibrium.

Results from this study show that the size, shape, and distribution of enriched blobs are systematically transformed during melting and melt migration in the mantle. Chemical disequilibrium is needed to preseve correlations of isotope ratios in residual peridotites. Upon entering melting column, a blob of EM, represented by a layer of Gaussian-shaped isotope heterogeneity, is gradually deformed into asymmetric figures by upward acceleration of the melt and by continuous chemical exchange between the matrix melt and residual solid. The width of the enriched layer spreads upward while the amplitude of isotope heterogeneity decreases, giving rise to dispersion fronts in the melt and the solid. The extents of dispersion and decoupling among Sr-Nd-Hf isotopic signals in the melt and the solid depend on the degree of chemical disequilibrium: greater disequilibrium results in broader dispersion and smaller decoupling. Using a boundle of column model for melting in a trianglar region, we show that the scattered correlations in Sr-Nd and Nd-Hf isotope ratio diagrams for MORB samples can be reproduced by melting and melt migration in a two-component mantle consisting of km-size EM (7%) imbedded in DM (93%). Significant mixing takes place during melt migration in the mantle. This model can also explain the observed Nd-Hf isotope variations in abyssal peridotites and the slight decoupling between MORB and abyssal peridotites in their Nd isotope ratios.