SETP35

Shock and Rarefaction Waves in a Heterogeneous Partial Melt

Jordan, J.[1], Hesse, M.[1]
jakejordan@utexas.edu
1. Jackson School of Geosciences, The University of Texas at Austin, Austin, TX

We explore the effect of heterogeneities on partial melting and melt migration in the Earth's mantle. We have constructed simple, explicit nonlinear models in one and two dimensions to examine heterogeneity and its dynamic affects on porosity, temperature and the magnesium number in a partially molten, porous medium comprised of olivine. The composition of the melt and solid are defined by a closed, binary phase diagram for a simplified, two-component olivine system. The two-component solid solution is represented by a phase loop where concentrations 0 and 1 to correspond to fayalite and forsterite, respectively. During a partial melt in the presence of fluid flow, the composition of the melt, the residual solid and the permeability of the system will be linked to transport of chemical components and enthalpy via the fluid. This creates an interconnected system in which chemistry and enthalpy influence porosity and permeability creating variable gradients within the fluid flux field.

For analysis, we examine a purely advective system assuming constant fluid flux with a Riemann initial condition. Chromatographic tools and theory have primarily been used to track large, rare earth elements as tracers. In our case, we employ these theoretical tools to highlight the importance of the magnesium number; enthalpy and heterogeneity in the dynamics of melt migration. We calculate the eigenvectors and eigenvalues in the enthalpy-composition space in order to glean the characteristics of the reactive fronts, or waves, emerging the Riemann step. Analysis on Riemann problems of this nature shows us that the enthalpy-composition waves can be represented by self-similar solutions. The eigenvalues of the enthalpy-composition system represent the characteristic wave propagation speeds of the compositions and enthalpy through the domain. Furthermore, the corresponding eigenvectors are the directions of variation, or "pathways," in enthalpy-composition space that the characteristic waves follow. In the two-component system, the Riemann problem yields two waves connected by an intermediate enthalpy-composition state determined by the intersections of the integral curves of the eigenvectors emanating from both the initial and boundary states. The first wave, "slow path" and second wave, "fast path," follow the aforementioned pathways set by the eigenvectors. The slow path wave has a zero eigenvalue, corresponding to a wave speed of zero, which preserves a residual imprint of the initial condition. Freezing fronts—those that result in a negative change in porosity—feature fast path waves that travel as shocks, whereas the fast path waves of melting fronts travel as spreading, rarefaction waves.

Keywords: Reactive Transport, Porous Media Fluid Flow, Partial Melting, Magma Dynamics, Tectonophysics, Petrology