The Influence of Partial Melt Generation on Mantle Density and Viscosity: Consequence for the Mantle Dynamics

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Melt generation in a planetary mantle is a complex process that has a strong influence on the thermo-chemical evolution of terrestrial planets, being present during some period of planetary evolution [Solomatov and Moresi, 2000]. In most earlier thermal evolution and convection models, melt generation has been considered by the consumption and release of latent heat, the associated formation of crust and the redistribution of radioactive heat sources [e.g. Hauck and Phillips, 2002; Breuer and Spohn, 2003; Schumacher and Breuer, 2006].

However, when modeling partial melt it is important to consider also the effects on mantle (1) density and (2) viscosity. Here we discuss the influence of partial melt on mantle density and viscosity assuming fractional melting, i.e., melt leaves the system as soon as it is formed, and a wet planetary interior as it has been suggested for the Martian mantle [e.g., Hauck and Phillips, 2002; Grott and Breuer, 2008].

First, the density of the mantle material decreases with increasing degree of depletion due to compositional changes. The extraction of partial melt leaves behind a residuum depleted in incompatible elements and modified in modal mineralogy, which is expected to be more buoyant than its fertile parent material [e.g., Morgan, 1968; Schutt and Lesher, 2006]. This process can lead to the formation of a buoyant upper mantle, having a stabilizing effect on the mantle dynamics and preventing efficiently the planet from cooling.

Second, melt can also indirectly impact the viscosity of partially molten rocks through its influence on the water content [Hirth and Kohlstedt, 1996]. Mantle material will be dried out due to partitioning of water from the minerals into the melt during the melting process. As a result, the viscosity of water depleted regions increases more than two order of magnitude compared to the water-saturated rocks [Korenaga, 2009].

Using a 2D spherical convection model that can handle radial and lateral variations in the viscosity [Hüttig and Stemmer 2008a; Hüttig and Stemmer, 2008b], we investigate systematically the effects of partial melt on mantle dynamics and thermal evolution of a one-plate planet. We assume Mars-like parameters, a cooling core boundary condition and decaying heat sources.

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