A phenomenological description of stress-driven melt segregation for application to experimental data and geodynamic models: Steady-state viscosity with partitioned deformation

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Experimental studies have demonstrated significant interactions between deformation and melt distribution in partially molten rocks. Driven by pressure gradients that develop when a partially-molten rock is sheared, melt segregates into melt rich bands at a low angle to the macroscopic shear plane and synthetic to the shear direction. The melt-rich bands act as zones of localized deformation, significantly reducing the overall strength of the rock. A major focus of experimental studies has been to constrain the length scales of this process, which depend upon the permeability of the rock as well as the viscosities of the solid and liquid. In this contribution, we explore the effects of melt segregation on the rheological properties of partially molten rocks. In the Earth, the effects of a small amount of melt could vary significantly depending upon the degree of segregation. Quantifying the effects of segregated melt on the rheological properties of Earth materials could be critical to understanding the nature of the lithosphere-asthenosphere boundary and the dynamics of other regions where deformation and magmatism interact. The difficulty in understanding the roles of stress-driven melt segregation in the Earth is that it occurs at the meso-scale. Laboratory-based flow laws describe processes at the grain scale, smaller than the length scales of melt segregation, while geodynamic models describe processes at much longer length scales. Here, we discuss the segregation factor, $S$, that describes melt distribution in an average sense. We also present a framework for the homogenization of viscosity for layered media, which yields effective constitutive equations as a function of $S$. We apply this approach to gain insights from experimental data and discuss settings in the Earth where the possible effects of melt segregation could be explored.