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Experimental investigation of stress-driven melt segregation and electrical conductivity of partially molten mantle rocks with low carbonated melt fractions

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The mechanical and thermal properties of the mantle are of prime concern since they play a major part in Earth's global geodynamics such as mantle convection, crustal flow and plate shifting. Several magnetotelluric and seismic campaigns, such as the MELT experiment, have shown high conductivity and low velocity zones that can be interpreted in terms of partial melting. Depending on the geological context, interactions between partial melting, deformation and melt-rock reactions can influence the nature of the produced melt and its segregation from the host rock. Recent experimental studies have shown that the high conductivity zones beneath mid-ocean ridges are best explained by low carbonated melt fractions (< 1 wt.%). Although recent experimental and theoretical studies have shown that shear stress gradients in initially homogeneous basaltic melt-bearing aggregates promote melt redistribution (Takei and Holtzman, 2009; Caricchi et al., 2011), little is known on the impact of shear stress gradients in samples containing less than 1 wt. % carbonated melts. All these studies lead to unanswered questions: how do these gradients influence melt mobility and therefore melt interconnectivity in partially molten samples with < 1 wt. % melt? How do low melt fractions impact on physical properties such as the bulk viscosity of partially molten rocks, on the deformation regime? How does melt segregation resulting from an applied shear stress impact on electrical and seismic anisotropy?
To answer these questions, we have synthesized by spark plasma sintering large volume samples of forsterite and enstatite aggregates containing an initial homogeneous distribution of Na-rich carbonated melts (1 wt. %), which will be deformed under torsion in an internally heated Paterson-type apparatus coupled to an impedance spectrometer. These experiments will enable us to directly measure the bulk viscosity of these partially molten samples as well as collect continuous electrical measurements during deformation.
We will similarly investigate carbonated melt migration velocities by deforming samples under torsion in a source/sink geometry. The source consisting of Na-rich carbonated melt, which will form the inner core, will be coupled with a nominally melt-free sink of forsterite and enstatite forming the outer ring.
Our novel approach consisting in an internally coherent set of petrological-geophysical-rheological constraints will enable us to better interpret the anomalies detected by geophysical probing beneath mid-ocean ridges.

Takei, Y., Holtzman, B., 2009. Viscous constitutive relations of solid-liquid composites in terms of grain boundary contiguity: 3. Causes and consequences of viscous anisotropy, J. Geophys. Res. 114, B06207, doi:10.1029/2008JB005852.
Caricchi, L., Gaillard, F., Mecklenburgh, J., Le Trong, E., 2011. Experimental determination of electrical conductivity during deformation of melt-bearing olivine aggregates: Implications for electrical anisotropy in the oceanic low velocity zone. Earth Planet. Sci. Lett. 302, 81-94.