Mobility of carbonate-rich melts in the upper mantle and the deep carbon cycle

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Carbonate-rich melts produced by incipient melting of mantle lithologies are primary conveyors of carbon and other incompatible elements in the deep Earth. Their mobility in the mantle thus controls the exchanges of carbon (and H_2O) between deep and surficial reservoir and ultimately, the recycling of carbon and the fluxes to the surface. A quantitative understanding of these processes has been largely limited however by poor knowledge of the physical properties, i.e. density and viscosity, of carbonate melts at relevant mantle conditions. Here we discuss new results on the density and viscosity of dry and hydrous carbonate melts that mimic incipient melts from subducted metapelites and carbonated eclogites and peridotites in the upper mantle. Densities were determined by the synchrotron X-ray absorption method in a Paris-Edinburgh press to 4 GPa-1800 K, while viscosities were computed up to 12 GPa and 2000 K by classical Molecular Dynamic simulations using optimized interaction potentials for carbonate species. Our results provide the first experimental equations of state for carbonate melts at upper mantle conditions, constrain the effect of hydration on the density/mobility of carbonate melts and the compressibility of dissolved volatiles in the melt (*Ritter et al., 2020*). Moreover, we report evidence for non-Arrhenian temperature dependence of the viscosity of mixed alkali/alkaline earth carbonate melts at upper mantle conditions, which may arise from the formation of low-dimensional structure in the carbonate network (*Ritter et al., 2021*). This behaviour may be extensible to other carbonate melts regardless of the composition and hence, it should be taken into account when modelling their mobility in the upper mantle. Finally, we present a global density model for mantle-derived carbonate-rich melts in the system MgO-Ca-Na_2O-K_2O-K_2O-Li_2O-H_2O-CO_2 in the upper mantle calibrated by > 880 density data points from experiments and simulations. The model, based on a simple Murnaghan equation of state and the assumption of linear mixing of volume between the different components, permits density and sound velocity predictions down to the mantle transition zone, 2300 K and 30 GPa. The applications of the new data and model to constrain the timescales of carbonate melt extraction from subducting slabs, buoyancy relations between mantle lithologies and carbonate-rich melts and their geodynamic signature within the deep carbon cycle will be discussed.

Keywords: carbonate melts, physical properties, melt mobility, high pressure, deep carbon

