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Silicate melts density, buoyancy relations and the dynamics of magmatic processes in the upper mantle

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Although silicate melts comprise only a minor volume fraction of the present day Earth, they play a critical role on the Earth's geochemical and geodynamical evolution. Their physical properties, namely the density, are a key control on many magmatic processes, including magma chamber dynamics and volcanic eruptions, melt extraction from residual rocks during partial melting, as well as crystal settling and melt migration. However, the quantitative modeling of these processes has been long limited by the scarcity of data on the density and compressibility of volatile-bearing silicate melts at relevant pressure and temperature conditions.

In the last decade, new experimental designs namely combining large volume presses and synchrotron-based techniques have opened the possibility for determining in situ the density of a wide range of dry and volatile-bearing (H_2O and CO_2) silicate melt compositions at high pressure-high temperature conditions. In this contribution we will illustrate some of these progresses with focus on recent results on the density of dry and hydrous felsic and intermediate melt compositions (rhyolite, phonolite and andesite melts) at crustal and upper mantle conditions (up to 4 GPa and 2000 K). The new data on felsic-intermediate melts has been combined with in situ data on (ultra)mafic systems and ambient pressure dilatometry and sound velocity data to calibrate a continuous, predictive density model for hydrous and CO_2-bearing silicate melts with applications to magmatic processes down to the conditions of the mantle transition zone (up to 2773 K and 22 GPa). The calibration dataset consist of more than 370 density measurements on high-pressure and/or water-and CO_2-bearing melts and it is formulated in terms of the partial molar properties of the oxide components. The model predicts the density of volatile-bearing liquids to within 42 kg/m3 in the calibration interval and the model extrapolations up to 3000 K and 100 GPa are in good agreement with results from ab initio calculations. The density model has been applied to examine the mineral-melt buoyancy relations at depth and the implications of these results for the dynamics of magma chambers, crystal settling and the stability and mobility of magmas in the upper mantle will be discussed.