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The density and the compressibility model of hydrous silicate melts at crustal and upper mantle conditions

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The density of hydrous melt is the primary control of various igneous processes, such as the rates of melt separation and upwards migration, and the efficiency of the crystal fractionation and the magma mixing. Despite these importances, the density of hydrous melt is poorly constrained, especially at the pressure range corresponds to crust to wedge mantle (~5GPa). Recently, new precise experimental determined relationship between density and pressure of hydrous silicate melt have been determined using X-ray absorption method (e.g., Sakamaki et al., 2009). In this study, we compile and calibrate the volumetric parameters of dry and hydrous basaltic-rhyolitic melts and construct the density model that describes the density of the silicate melt as a function of T, P, H_2O content and the and composition of the melt.

The Birch-Murnaghan equation is used for the equation of state of the silicate melt. The partial molar volume and the bulk modulus of the dry silicate melt are calculated based on the parameters provided by Lange and Carmichael (1990). K′ (the pressure derivative of bulk modulus) is newly parameterized as a function of SiO_2 content. A set of the partial molar volume, compressibility, and K′ of the H_2O component in the silicate melt are newly compiled and calibrated based on the results of high pressure experiments that have been reported in previous literature.

The combination of the Birch-Murnaghan equation and the set of parameters well reproduces the experimentally determined pressure-density relations of various dry and hydrous melts such as komatiite, phonolite, andesite and rhyolite between the pressure range of 0-5 GPa. The model covers the pressure, H_2O content and compositional ranges of the entire melting region of the subduction zone. The model and the parameter set will be useful for the calculations of density contrasts between hydrous melt and minerals/wall rock, prediction of physical and chemical state of subduction zone mantle and crust based on inversion of geophysical observations, and the construction of a thermodynamic model for the calculation of phase relations of hydrous melt bearing system. Volume and compressibility of the hydrous melt is well reproduced assuming linear combinations between volumes and compressibility's of dry melt and H_2O component in the melt, indicating H_2O component in silicate melt shows an ideal mixing behavior in terms of volume during dissolution into silicate melt along the entire pressure range tested. This result will be a strong constraint during constructing a thermodynamic model for the calculation of phase relation of the hydrous melt.

Keywords: magma, density, hydrous