

Determination of water solubility in the rhyolitic melt at 650°C and its interpretation by "hydrogen bonding model"

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We experimentally determined the water solubility in the rhyolitic melt at 650°C with pressures of 30, 90, and 150 MPa. First, we hydrated a clear rhyolitic obsidian glass pellet with water of ~10 wt%, at 800 or 900°C with arbitrary pressures for 21-48h in a cold-seal pressure vessel. Subsequently, we lowered the temperature to 650°C at the isobaric condition and kept it for 0-120h. Then, the system was instantaneously decompressed to the pressures of 30, 90, and 150 MPa, and put for 24-96h to induce vesiculation. The run products, which did not contain any microlite or nanolite, were sliced into several pieces and double-polished. The content and distribution of water species of the run products were measured by using the doubly-polished thin sections and Fourier transform infrared (FT-IR) micro-spectroscopy (JASCO FT/IR-660 Plus spectrometer and a JASCO IRT-30 microscope in ERI, University of Tokyo). The total water contents ($H_2O_m + OH^-$) and its gradients around the bubbles were determined by transmittance and reflectance spectra, respectively. H_2O_m means H_2O molecule.

As a result of the experiment, we found the obtained solubility (2.70 ± 0.25 wt% at 30 MPa, 5.84 ± 0.54 wt% at 90 MPa, and 6.84 ± 0.63 wt% at 150 MPa) is significantly higher than that calculated by the "Burnham model" (Burnham, 1979). In the Burnham model, the whole water is dissolved into melt as OH^- groups through the hydrolysis of Si-O bondings, despite the contribution of H_2O_m cannot be neglected in low temperature. Therefore we developed a new solubility model accounting for the dissolution of H_2O_m into the rhyolitic melt by considering a hydrogen bonding between hydrogen of H_2O_m and oxygen of the Si-O network. We analytically derived the pressure-temperature dependence of H_2O_m solubility in melt and substituted the molar enthalpy of formation of hydrogen bonding in water-saturated aluminosilicate melt $\Delta H = 10$ kJ/mol (Mysen, 2012). The solubility of total water is evaluated from the sum of the solubilities of H_2O_m and OH^- which is calculated from the equilibrium constant between H_2O_m and OH^- ($K = [OH^-]^2/[oxygen][H_2O_m]$). This new "hydrogen bonding model" can explain our experimental data very well when $K \cong 0.040-0.10$.

Our new theoretical model can calculate the water solubility in low-temperature melt below 700°C, in that region extrapolation of conventional theoretical equations has not yielded reliable values until now. A precise study of the physicochemical properties of low-temperature magma, including the water solubility determined in this study, may provide further insights into the cooling process near the walls of magma reservoirs and volcanic conduits, the formation process of dikes and sills, and the behavior of obsidian lava flows.

Keywords: water solubility, 650°C, rhyolitic melt, vesiculation, hydrogen bonding model