Constraints on deep, CO₂-rich degassing at arc volcanoes from solubility experiments on hydrous basaltic andesite of Pavlof Volcano, Alaska Peninsula, at 300 to 1200 MPa

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ABSTRACT

The solubility of CO_2 in hydrous basaltic andesite was examined in f_{O_2}-controlled experiments at a temperature of 1125 °C and pressures between 310–1200 MPa. Concentrations of dissolved H_2O and CO_2 in experimental glasses were determined by ion microprobe calibrated on a subset of run glasses analyzed by high-temperature vacuum manometry. Assuming that the solubility of H_2O in mafic melt is relatively well known, estimates of $X_{H_2O}^{fluid}$ and $P_{H_2O}^{fluid}$ in the saturating fluid were modeled, and by difference, values for $X_{CO_2}^{fluid}$ and $P_{CO_2}^{fluid}$ were obtained (X_{CO_2} ~0.5–0.9); f_{CO_2} could be then calculated from the fluid composition, temperature, and pressure.

Dissolved H_2O over a range of 2.3–5.5 wt% had no unequivocal influence on the dissolution of CO_2 at the pressures and fluid compositions examined. For these H_2O concentrations, dissolved CO_2 increases with f_{CO_2} following an empirical power-law relation: dissolved CO_2 (ppmw) = $14.9_{-3.3}^{+4.5}[f_{CO_2}$ (MPa)$]^{0.7\pm0.03}$. The highest-pressure results plot farthest from this equation but are within its 1 standard-error uncertainty envelope.

We compare our experimental data with three recent CO_2-H_2O solubility models: Papale et al. (2006); Iacono-Marziano et al. (2012); and Ghiorso and Gualda (2015). The Papale et al. (2006) and Iacono-Marizano et al. (2012) models give similar results, both over-predicting the solubility of CO_2 in a melt of the Pavlof basaltic andesite composition across the f_{CO_2} range, whereas the Ghiorso and Gualda (2015) model under-predicts CO_2 solubility. All three solubility models would indicate a strong enhancement of CO_2 solubility with increasing dissolved H_2O not apparent in our results. We also examine our results in the context of previous high-pressure CO_2 solubility experiments on basaltic melts. Dissolved CO_2 correlates positively with mole fraction (Na+K+Ca)/Al across a compositional spectrum of trachybasalt-alkali basalt-tholeiite-icelandite-basaltic andesite. Shortcomings of current solubility models for a widespread arc magma type indicate that our understanding of degassing in the deep crust and uppermost mantle remains semi-quantitative. Experimental studies systematically varying concentrations of melt components (Mg, Ca, Na, K, Al, Si) may be necessary to identify solubility reactions, quantify their equilibrium constants, and thereby build an accurate and generally applicable solubility model.

Keywords: Experimental petrology, magmatic CO_2, volcanic degassing, volatile solubility