

Experimental constraints on deep CO₂-rich fluid degassing at arc volcanoes

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Several petrologic and geophysical studies suggest that basaltic magmas residing deep in the roots of many volcanic systems are saturated with an exsolved, CO₂-rich vapor. These CO₂-rich fluids help to form magma pathways by penetrating and pressurizing tensile micro-cracks at the tips of propagating dikes and sills in advance of rising magma.

To estimate the pressure (depth) of deep CO₂-rich degassing under arc volcanoes, solubility experiments on basaltic andesite with 2-6 wt% H₂O and 1 wt% CO₂ (from Ag oxalate) were conducted using a piston cylinder apparatus at 1125°C and pressures of 400-1200 MPa. A welded inner AuPd capsule containing hydrated rock powder and Ag oxalate was placed in an outer Pt capsule in which Ni-NiO buffer and oxalic acid plus Ag oxalate were added. Proportions of oxalic acid to Ag oxalate were set to mimic the anticipated composition of the excess fluid in equilibrium with the melt to reduce the diffusion of hydrogen through the inner capsule (mol fractions CO₂ of 0.70-0.95).

Concentrations of dissolved CO₂ and H₂O in the quenched glasses were determined by manometry at the University of Lausanne and by ion microprobe at the Northeast National Ion Microprobe Facility. The experimental uncertainties are $\leq 10\%$ for CO₂ and $\leq 7\%$ for H₂O. In contrast to published experiments at lower pressure (<400 MPa), no systematic dependence of CO₂ on H₂O was noted in glasses over dissolved water concentrations between 2.3-5.3 wt%. Instead, the data demonstrate the over-riding influence of pressure on CO₂ solubility in deep-crustal, moderately-hydrated basaltic magma. A power law decrease in dissolved CO₂ with decreasing pressure given by $\text{CO}_2(\pm 480 \text{ ppm}) = 0.0008(P(\text{MPa}))^{2.36}$ with $r^2 = 0.95$ best describes the relation. This result is consistent with the numerical model of Papale et al. (Chem. Geol. 2006) which predicts flattening of the H₂O-CO₂ isobaric saturation surface for basaltic magma containing ~2-6 wt% H₂O at pressures above 400 MPa. However, the absolute concentrations of dissolved CO₂ in the quenched glasses suggest that the Papale et al. model under-estimates pressures of fluid saturation by ~20%. Solubility data from mixed H₂O-CO₂ experiments of Shishkina et al. (Chem. Geol. 2008) show similar results for tholeiitic basalt at 500 MPa and H₂O ≤ 4.0 wt%.

In broad terms, the results of these experiments imply that 80-90% of the CO₂ initially dissolved in basaltic magma below arc volcanoes can be released by decompression exsolution at levels deeper than ~20 km.