

SPECIAL COLLECTION: GLASSES, MELTS, AND FLUIDS, AS TOOLS FOR UNDERSTANDING VOLCANIC PROCESSES AND HAZARDS

Experiments and models on H₂O retrograde solubility in volcanic systems†

AMY G. RYAN^{1,*}, JAMES K. RUSSELL¹, ALEXANDER R.L. NICHOLS², KAI-UWE HESS³
AND LUCY A. PORRITT¹

¹Centre for Experimental Studies of the Lithosphere, Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver, British Columbia V6T-1Z4, Canada

²Research and Development Center for Ocean Drilling Science, Japan Agency for Marine Earth Science and Technology (JAMSTEC), 2-15 Natsushima-cho, Yokosuka, Kanagawa 237-0061, Japan

³Department of Earth and Environmental Sciences, Ludwig-Maximilians-Universität, Theresienstrasse 41, 80333 Munich, Germany

ABSTRACT

We present a suite of 36 high-temperature (900–1100 °C) experiments performed on 10 × 10 mm unjacketed cores of rhyolitic obsidian from Hrafnattinnuhryggur, Krafla, Iceland, under atmospheric pressure. The obsidian is bubble- and crystal-free with an H₂O content of 0.11(4) wt%. The obsidian cores were heated above the glass transition temperature (T_g), held for 0.25–24 h, then quenched. During each experiment the volume of the samples increased as H₂O vapor-filled bubbles nucleated and expanded. Uniquely, the bubbles did not nucleate on the surface of the core, nor escape, conserving mass during all experiments. Within each isothermal experimental suite, the cores increased in volume with time until they reached a maximum, after which continued heating caused no change in volume (measured by He-pycnometry). We interpret these T - t conditions as representing thermochemical equilibrium between the melt and exsolved vapor. These experiments are modeled to recover the 1-atm, temperature-dependent solubility of water in the rhyolite melt. Our results define the magnitude of retrograde solubility (-7.1×10^{-3} wt% H₂O per 100 °C) and provide estimates of the enthalpy and entropy of the H₂O exsolution reaction [$\Delta H^\circ = 17.8$ kJ/mol, $\Delta S^\circ = 107$ J/(K·mol)]. We conclude by modeling the implications of retrograde solubility for the glass transition temperatures (T_g) of cooling volcanic systems at pressures relevant to volcanic conduits and the Earth's surface. All volcanic systems cool; the effects of retrograde solubility are to allow melts to rehydrate by H₂O dissolution as they cool isobarically, thereby depressing T_g and expanding the melt window. Ultimately, the melt is quenched at higher H₂O contents and lower temperatures where the isobaric retrograde solubility curve “catches” the evolving T_g .

Keywords: Rhyolite, hydrous, H₂O-solubility, volcanic, experiment, modeling, glass transition, retrograde