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SPECIAL COLLECTION: RATES AND DEPTHS OF MAGMA ASCENT ON EARTH

Degassing of hydrous trachytic Campi Flegrei and phonolitic Vesuvius melts: Experimental limitations and chances to study homogeneous bubble nucleation

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Abstract

Melt degassing by bubble nucleation and growth is a driving mechanism of magma ascent. Therefore, decompression experiments with hydrous silicate melts were used to investigate the onset and the dynamics of H_2O degassing. Nominally H_2O-undersaturated trachytic Campi Flegrei and phonolitic Vesuvius melts representative for the magma compositions of the Campi Flegrei volcanic system were decompressed at a super-liquidus temperature of 1050 °C from 200 MPa to final pressures (P_{final}) of 100, 75, and 60 MPa using continuous decompression rates of 0.024 and 0.17 MPa/s. Experiments started from either massive glass cylinders or glass powder to demonstrate the influence of the starting material on melt degassing. Glass powder can be used to shorten the equilibration time (t_{eq}) prior to decompression for dissolution of H_2O in the melt. The decompressed samples were quenched and compared in terms of bubble number density (N_V), porosity, and residual H_2O content in the melt.

Decompression of all glass cylinder samples led to homogeneous bubble nucleation with high N_V of ~10^5 mm^{-3}. The supersaturation pressures for homogeneous bubble nucleation were estimated to be <76 MPa for the trachytic and <70 MPa for the phonolitic melt. In contrast to glass cylinders, the usage of glass powder equilibrated for 24 h before decompression prevented homogeneous bubble nucleation during decompression. We suggest that trapped air in the powder pore space resulted in the formation of tiny H_2O-N_2 bubbles throughout the samples prior to decompression. Degassing of these glass powder samples was facilitated by diffusive growth of these pre-existing bubbles and thus did not require significant H_2O supersaturation of the melt. This is evidenced by several orders of magnitude lower N_V and lower residual H_2O contents at correspondingly higher porosities compared to the glass cylinder samples. However, a significant extension of t_{eq} to 96 h in the glass powder experiments led to degassing results comparable to the glass cylinder samples. This effect is probably due to Ostwald ripening, coalescence, and the ascent of the pre-existing bubbles during the extended t_{eq} prior to decompression.

The N_V of the glass cylinder samples were used to test the applicability of the vesiculation model provided by Toramaru (2006). For the applied decompression rates, the experimental N_V are up to 5 orders of magnitude higher than the values predicted by the model. This may be mainly attributed to the usage of the macroscopic surface tension and the total H_2O diffusivity in the model to describe the molecular process of bubble nucleation. A significant increase in modeled N_V can be achieved by application of a reduced surface tension in combination with the lower diffusivity of network formers as a limiting parameter for the formation of a bubble nucleus.

This study demonstrates that the investigation of homogeneous bubble nucleation necessitates an optimized experimental protocol. We strongly recommend performing experiments with massive glass cylinders as starting material. The timescale of decompression is a limiting parameter and must be short enough to minimize the opportunity for a reduction of N_V by bubble coalescence. Considering our comparably high N_V, the samples of many previous experimental studies that were used to calibrate models for homogeneous bubble nucleation were probably subject to significant N_V reduction. Newly derived data from optimized experiments will require improved models for homogeneous bubble nucleation during magma ascent.

Keywords: Campi Flegrei, magma ascent, decompression experiment, homogeneous bubble nucleation, H_2O degassing, bubble number density