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# Toward a self-consistent formulation for predicting bubble nucleation in silicate melts

Helge M Gonnermann (1) and James E Gardner (2)

(1) Rice University, Department of Earth Science, United States (helge@rice.edu), (2) University of Texas at Austin, Department of Geological Sciences, United States (gardner@jsg.utexas.edu)

Magma degassing is a consequence of the pressure-dependent solubility of magmatic gases and significantly affects how volcanoes erupt. During magma ascent the ambient pressure decreases and the melt becomes supersaturated in volatiles. Consequently, bubbles nucleate and then grow by diffusion of volatiles from the melt into existing bubbles. Bubble nucleation is therefore a rate-limiting process for magma degassing, which is exceedingly sensitive to the surface energy (i.e., surface tension) of a nucleating bubble. Thus, the surface energy of a nucleating bubble exerts a fundamental control on the dynamics of volcanic eruptions, by affecting the rate at which bubbles nucleate. The rate at which bubbles nucleate during explosive eruptions, in turn, determines the bubble number density, which is thought to be correlated with magma discharge rate, itself a proxy for explosive intensity. We find, however, that this may not be universally true. To facilitate a deeper assessment of this problem requires an improved understanding of the surface energy during bubble nucleation, which is inaccessible to direct experimental determination. Its effective value can, however, be estimated from nucleation experiments. Because relatively small changes in surface energy result in exceedingly large changes in nucleation rate, accurate estimation requires careful modeling of the nucleation experiments. We show, based on combined decompression-nucleation experiments of rhyolitic melt with dissolved $H_2O$ and $CO_2$, and numerical modeling thereof, that the surface energy between critical bubble nuclei and the surrounding rhyolitic melt depends on the degree of supersaturation. Its value is lower than the macroscopically measureable value, which is consistent with the view that far from equilibrium the interface between a nucleus and the surrounding melt is diffuse, instead of sharp. As a consequence, the dependence of nucleation rate on the degree of supersaturation can significantly differ from the value predicted by classical nucleation theory. We explore the implications of these results for homogeneous bubble nucleation during explosive volcanic eruptions.