The surface tension of rhyolite from combined experiments and numerical modeling

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Bubbles provide the driving force for volcanic eruptions. Consequently, it is critical to understand their nucleation, which strongly depends on volatile supersaturation in the melt and is even more sensitive to surface tension. The latter can be constrained from experiments, wherein small volumes of volatile-saturated melt, typically of the order of 0.01-0.1 cubic centimeter, are rapidly decompressed. Here, we present the results of such bubble nucleation experiments in hydrated rhyolite, together with numerical modeling of the experiments. The numerical model combines classical nucleation theory with diffusive bubble growth and is constrained by the bubble number densities and size distributions measured in the experimental charges after quenching.

From the integrated bubble nucleation and growth modeling we find that surface tension may not be constant during the experiments, but instead increases as water diffuses from the melt into existing bubbles. This is consistent with previous results and indicates that surface tension decreases with water content. The resultant estimates of surface tension range between approximately 65 and 85 mN/m and are remarkably consistent across a wide range of water saturations and melt temperatures. Bubble nucleation in experiments with high decompression rates and low final pressures peaks, at some time during the experiment. Subsequently nucleation rates decrease rapidly and nucleation ends before the experimental charge is quenched. This is a consequence of high nucleation rates and efficient water diffusion from melt into numerous existing bubbles. Once supersaturation starts to diminish for the entire melt volume, nucleation rates plummet and nucleation ceases. In contrast, during experiments with a high final pressure, nucleation rates and bubble number density remain sufficiently low for most of the melt to remain fully supersaturated and bubble nucleation to continue at an almost constant rate, until the sample is quenched. It is therefore important that the estimation of surface tension from nucleation experiments is based on the actual time interval during which bubble nucleation takes place, and that it accounts for possible changes in surface tension during the experiment.