Observations of bubble growth in rhyolite using hot-stage microscopy

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1. Introduction

- Bubble growth in rhyolitic melts is a primary control on some of the largest explosive eruptions. However, vesiculation remains poorly constrained.
- Few studies have captured in-situ vesiculation of a rhyolitic melt, but have rather relied on interpretation of quenched natural or experimental samples. The previous in-situ study[1] followed vesiculation in water-poor (~0.14 wt%) rhyolitic melt at P = 1 atm.
- This work aims to provide measurements of rapid in-situ vesiculation in more water-rich rhyolitic melt from high resolution imagery. Results are relevant to post-fragmentation magma vesiculation.

2. Methods

- Using the technique of Applegarth et al (2013), thin wafers (~ 100 μm thick) of obsidian (0.97 wt% H₂O) from the 2008 eruption at Chaitén, Chile were held for 5 minutes up to 2 days in the hotstage at between 575 °C and 875 °C. All experiments were conducted at 1 atm and therefore do not consider growth by decompression.
- The in-situ growth of many individual bubbles were recorded directly to PC and then measured using particle tracking code written in MATLAB.

3. Gas loss from sample surface

- The potential for sample dehydration was considered by estimating the extent of diffusive degassing from wafer surfaces using simple diffusion models[4]
- Dehydration was found to be negligible during brief high temperature experiments but became increasingly important for slower, lower-temperature experiments

4. The physical processes of bubble growth

- Five stages of bubble growth were directly observed (Fig. 4).
- Most rapid average bubble growth rate at 875 °C (1.27 μm s⁻¹; η = 10⁻¹³ Pa s⁻¹)
- Slowest bubble growth rate at 725 °C (0.02 μm s⁻¹; η = 10⁻⁴⁰ Pa s⁻¹)
- No bubble growth was noticeable below 725 °C
- Growth rates decreased with time, as reported in [1]. However, growth rate decreases observed here are due to bubble-bubble interactions.

5. Further findings and conclusions

- Water content strongly influences vesicle growth rates, which are ~7 times higher in the water-rich Chaitén rhyolite than the GOVC peralkaline rhyolite (0.14 wt%) used in [1]
- We estimate bubble nucleation rate (J) of ~1.5 x 10¹⁵ m⁻³ s⁻¹ from change in bubble number through time. This matches the lower end of J values from decomposition experiments[6].
- High nucleation rates occurred for ~30 seconds, prior to bubble number reduction due to coalescence during foaming

References


Fig 1. The stages of bubble nucleation and growth leading to magma fragmentation in a volcanic conduit. Bubbles continue to grow at atmospheric pressure post-fragmentation. Modified from [2].

Fig 2. Hot-stage microscope setup. Sample is placed inside a ceramic furnace (Linkam TS1500 heated stage), mounted on a Zeiss Axioscope.

Fig 3. Diffusive degassing from water surface during heating experiments

Fig 4. Five stages of bubble growth

Fig 5. Bubble growth over a period of > 200 seconds at temperatures of 850 °C and 775 °C

Fig 6. Comparison of experimental bubble growth rates compared to those modelled by Navon et al, 1998.