# Vesiculation of a rhyolitic melt

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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.

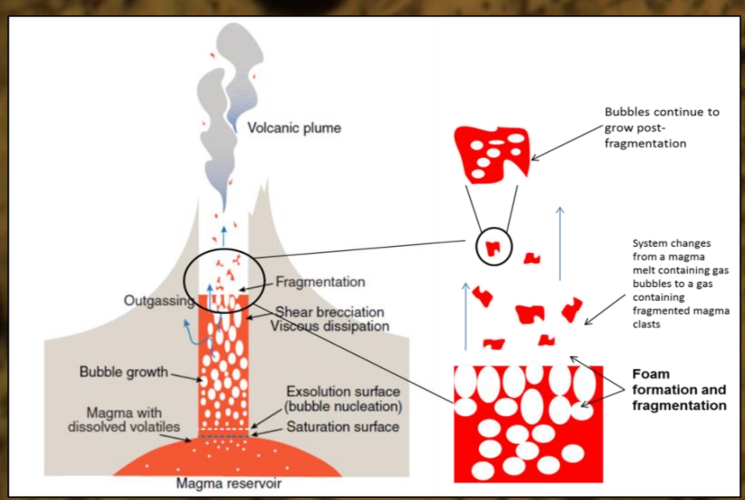


*Fig 1. The stages of bubble nucleation and growth leading to magma fragmentation in a volcanic conduit. Bubbles continue to grow at atmospheric pressure post-fragmentation. Modified from [2].*

## 2. Methods

- Using the technique of Applegarth et al (2013), thin wafers (~ 100 μm thick) of obsidian (0.97 wt% $H_2O$) from the 2008 eruption at Chaitén, Chile were held from 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.

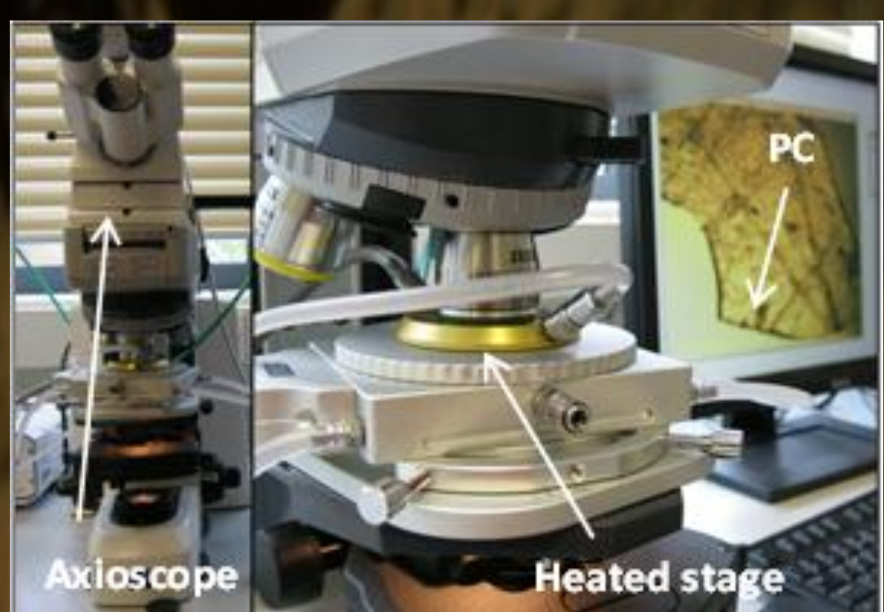


*Fig 2. Hot-stage microscope setup[3]. Sample is placed inside a ceramic furnace (Linkam TS1500 heated stage), mounted on a Zeiss Axioscope.*

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

## 3. 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 = $10^{7.1}$ Pa s)
- Slowest bubble growth rate at 725 °C (0.02 μm $s^{-1}$; η = $10^{9.20}$ Pa s)
- 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.

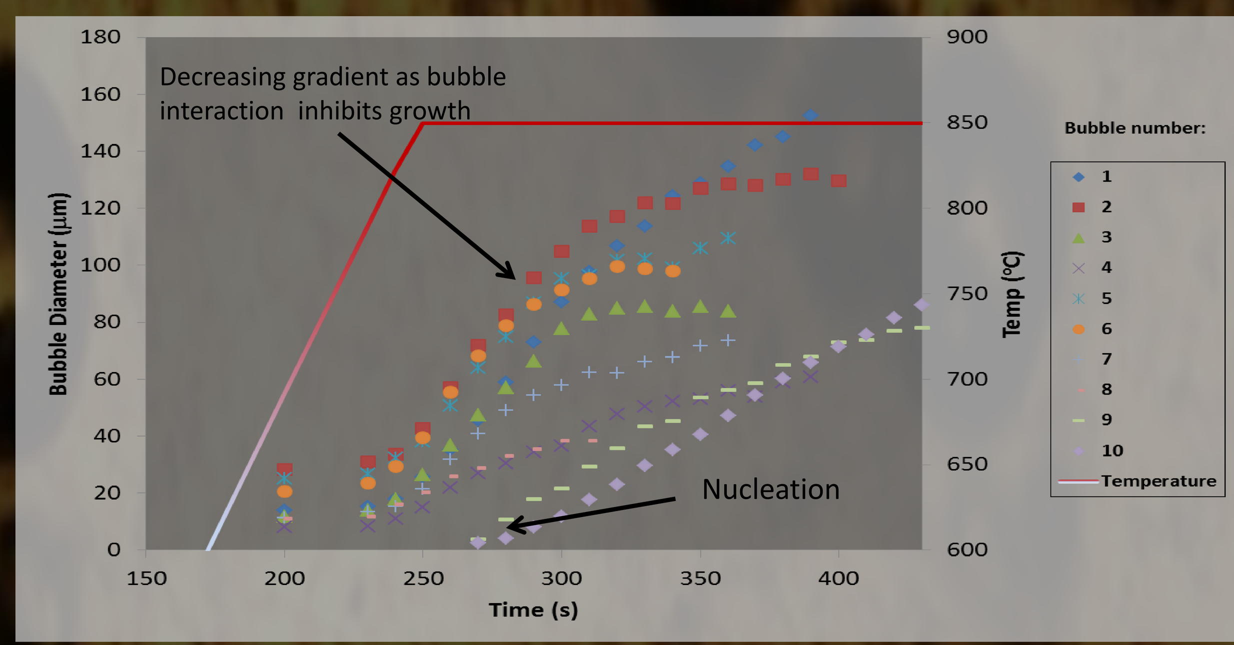


*Fig 3. Bubble growth over a period of > 200 seconds at temperatures of 850 °C and 775 °C.*

- Experimentally obtained bubble growth rates were compared to the predicted growth rates modelled by Navon et al (1998), Fig. 6, using: $P_g - P_f = \frac{2\sigma}{R} + 4\eta\frac{V_r}{R}$

Where the bubble overpressure ($P_g$) - ambient pressure ($P_f$) is assumed to be initially constant, and the effect of surface tension (σ) is ignored for bubble radius > 5.5 μm

∴ Growth rate (**$V_r$**) **= R/4η**

- Viscosity (**η**) was estimated using the model of [7].
- At all temperatures modelled growth rates exceed those determined experimentally; there is a closer fit at higher temperatures.
- This finding is contrary to [1], whose modelled growth rate fitted better at lower temperatures. This discrepancy may relate to the varied water contents of samples studied.

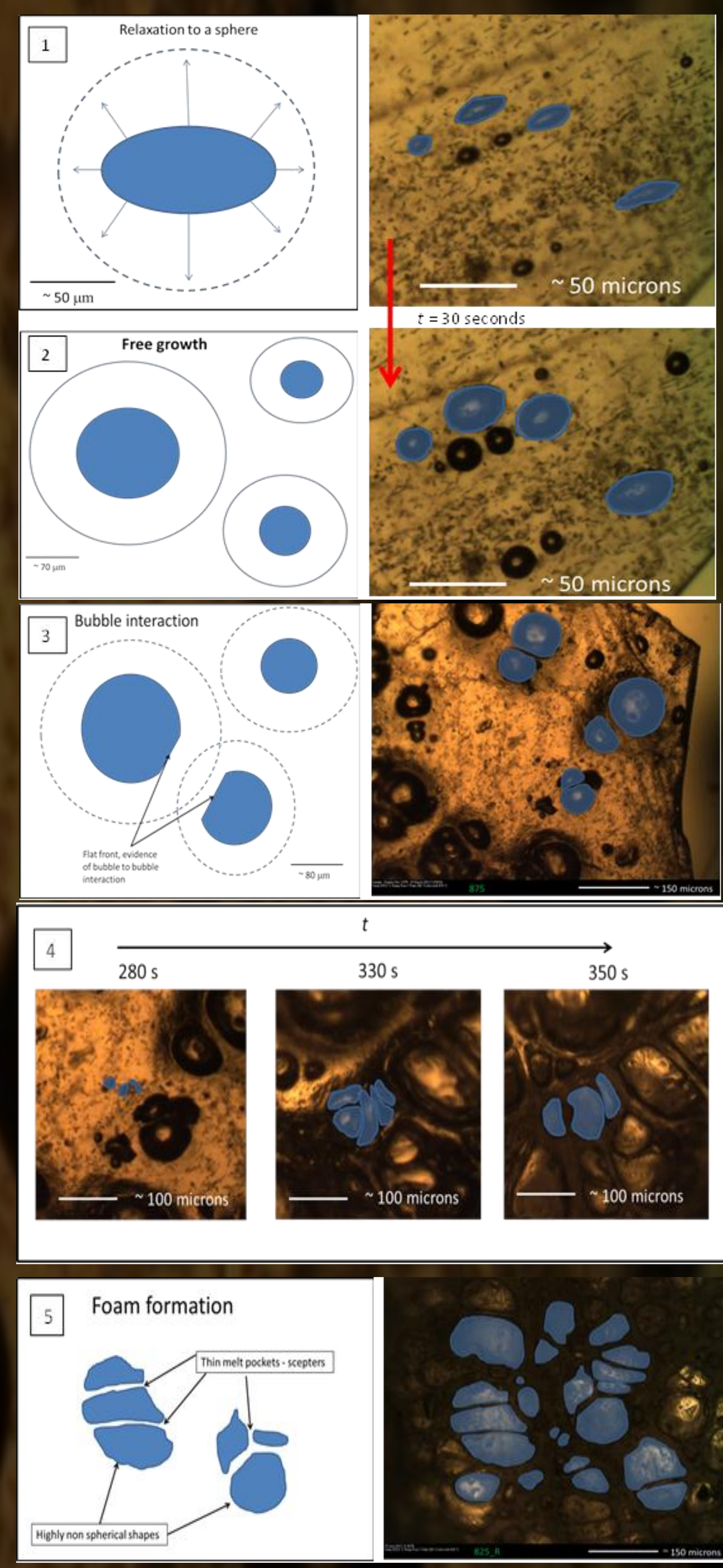


*Fig 4. Bubble growth morphology*

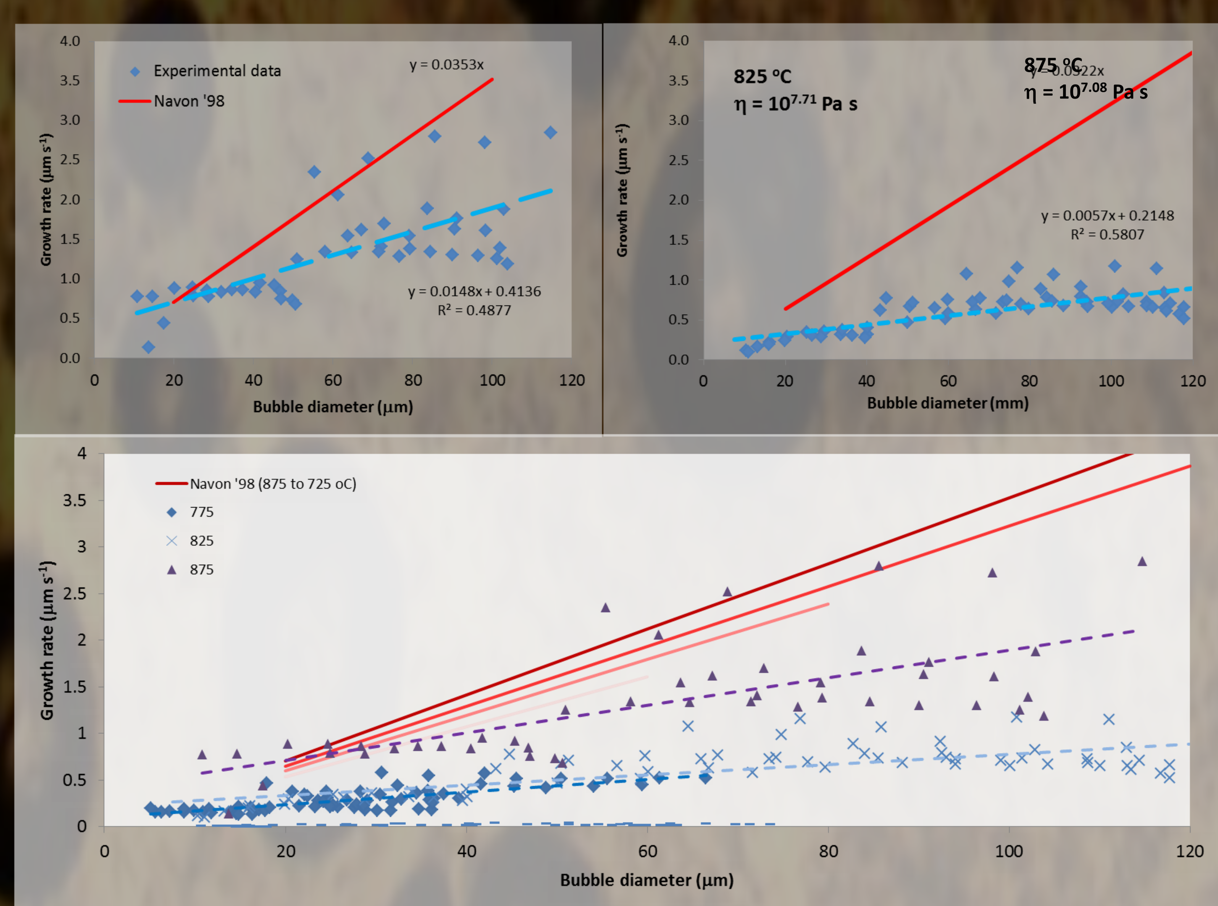


*Fig 5. Comparison of experimental bubble growth rates compared to those modelled by Navon et al, 1998.*

Using the techniques described it is also possible to track bubble size distributions and bubble number densities through time.

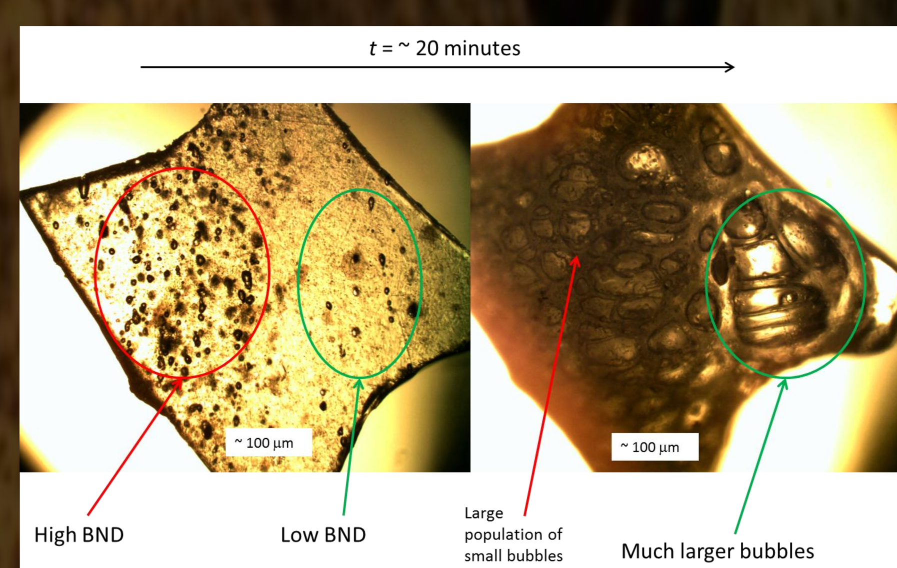


*Fig 6. Contrasting initial and final bubble size distributions, the hold temperature here is 775 °C*

## 4. 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 rates (J) of >1.5 x $10^{10}$ $m^{-3}$ $s^{-1}$, from change in bubble number through time. This matches the lower end of J values from decompression experiments[6]. High nucleation rates occurred for ~30 seconds, prior to bubble number reduction due to coalescence during foaming.
- Bubble growth rates in our experiments were poorly represented by the Navon et al ('98) model, with worst fits at low temperature (high viscosity). However, we found a good correlation between measured growth rates and modelled diffusivity, implying that volatile diffusivity may have been a limiting factor.

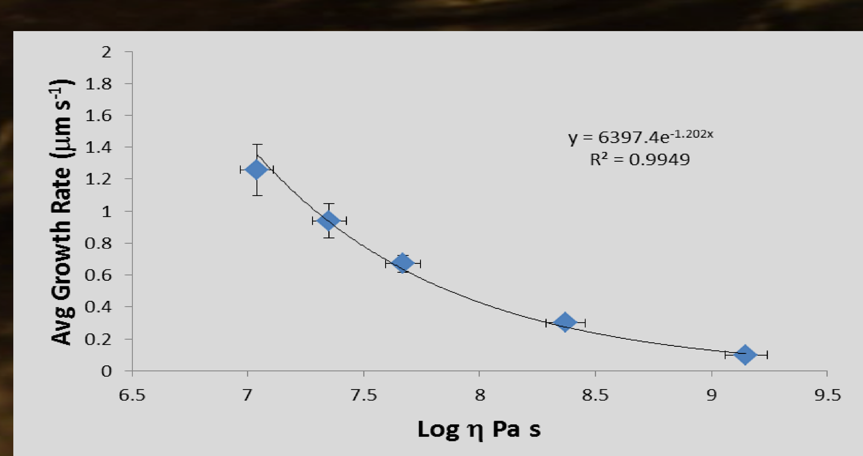


*Fig 7. Bubble growth rate ($V_r$) increases with decreasing melt viscosity(η) where: $V_r \approx \exp(-1.202\eta)$.*

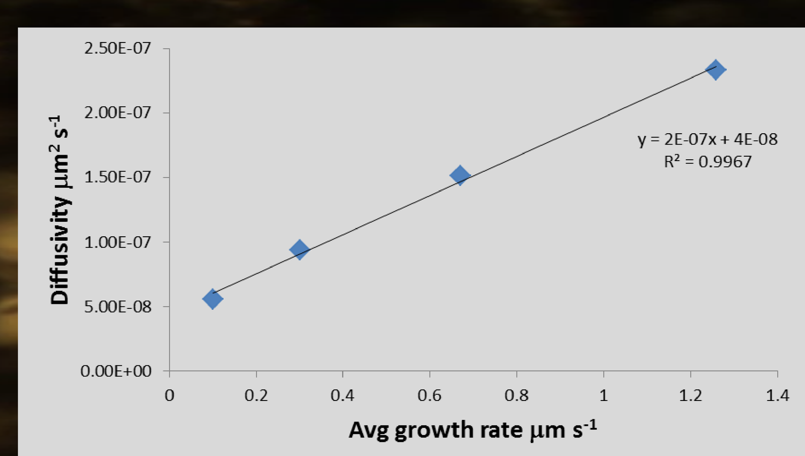


*Fig 8. At higher temperatures (> 725 °C) there is a positive linear relationship between bubble growth rate and modelled diffusivity.*

References

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