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Can volcanic gases be used to reconstruct palaeo-environments?

By Jacqueline Owen - a 1st year PhD student (j.owen2@lancaster.ac.uk)
Lancaster University, Environmental Science
Supervisors: Dr. H. Tuffen, Dr. D.W. McGarvie, Prof. H. Pinkerton & Prof. L. Wilson

NATURAL ENVIRONMENT RESEARCH COUNCIL

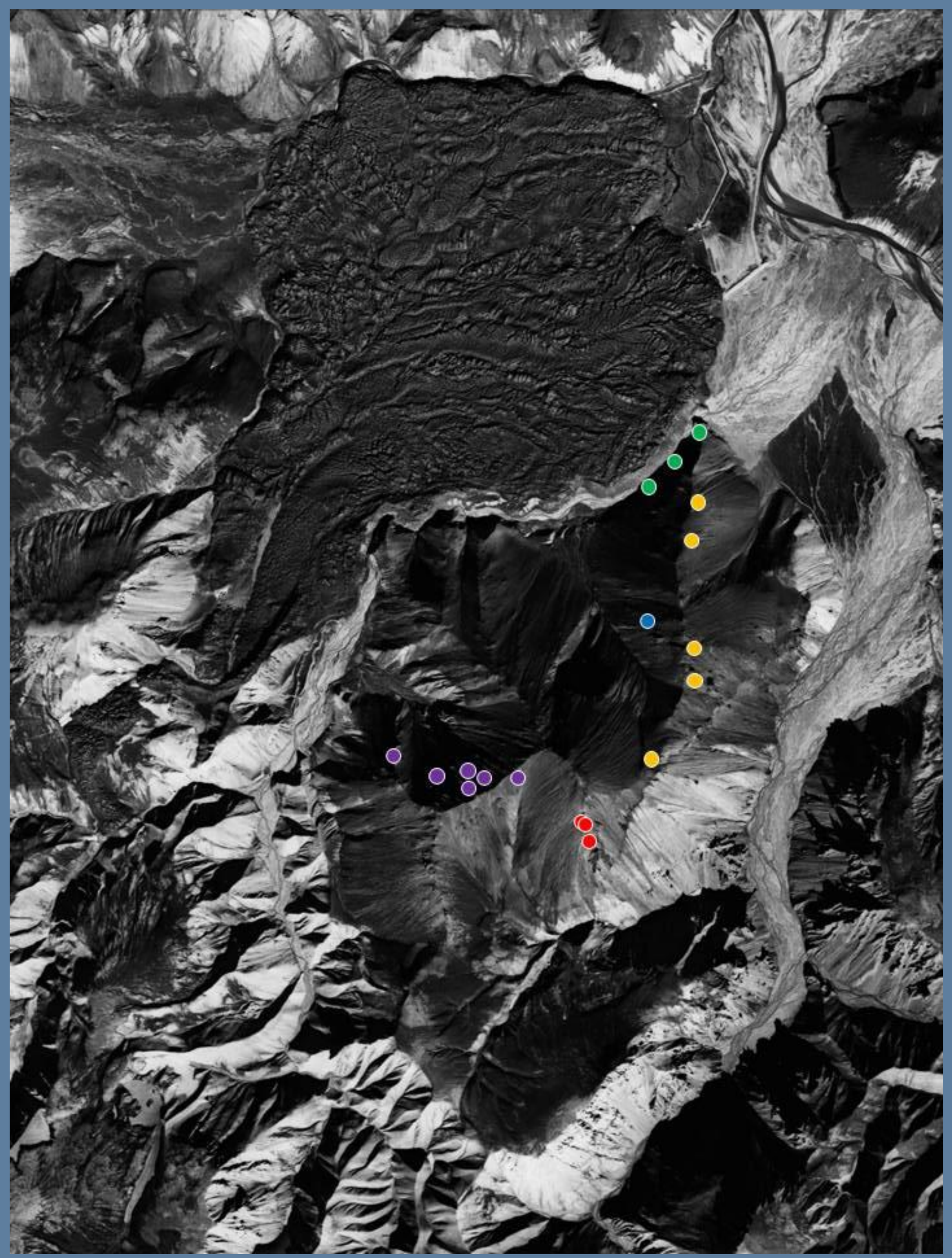

Figure 4: A location map showing where the samples were collected from. Green: Graenagil, Orange: A ridge, purple: lobe slope, red: feeder dyke, blue: no man's land

Water as a palaeo-environment indicator

The exsolution of volatiles is a function of pressure. Therefore, at a subglacial volcano, the quantity of volatiles that remain in the residual melt is dependent on the thickness of ice above the edifice. In most magmas water is the primary volatile and the pressure dependence of water solubility is reasonably well understood. Therefore, by studying the relationship between dissolved water content and altitude it is possible to reconstruct the thickness of ice that was overlaying a volcano at its time of eruption[1].

Case study

I have used Fourier Transform Infra-red (FTIR) spectroscopy to determine the water content of a series of rocks collected at different elevations from Bláhnúkur (Fig. 1), a small volume, rhyolitic subglacial volcano, part of the Tofajökull complex, in southern Iceland[2] (Fig. 2). Figure 3 plots these results against theoretical ice thickness curves.

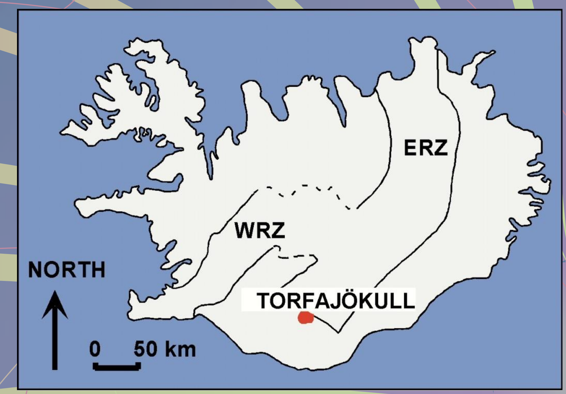

Figure 2: A map showing the location of Torfajökull (red dot) within Iceland. ERZ: East Rift Zone, WRZ: West Rift Zone

My results

My results (Fig. 3) suggest that when Bláhnúkur erupted, ~95 ka (unpublished data), the ice surface elevation was ~1050 m a.s.l. in this part of Iceland. This result is plausible as it corresponds well with the inferred ice thickness from tuyas in the same region.

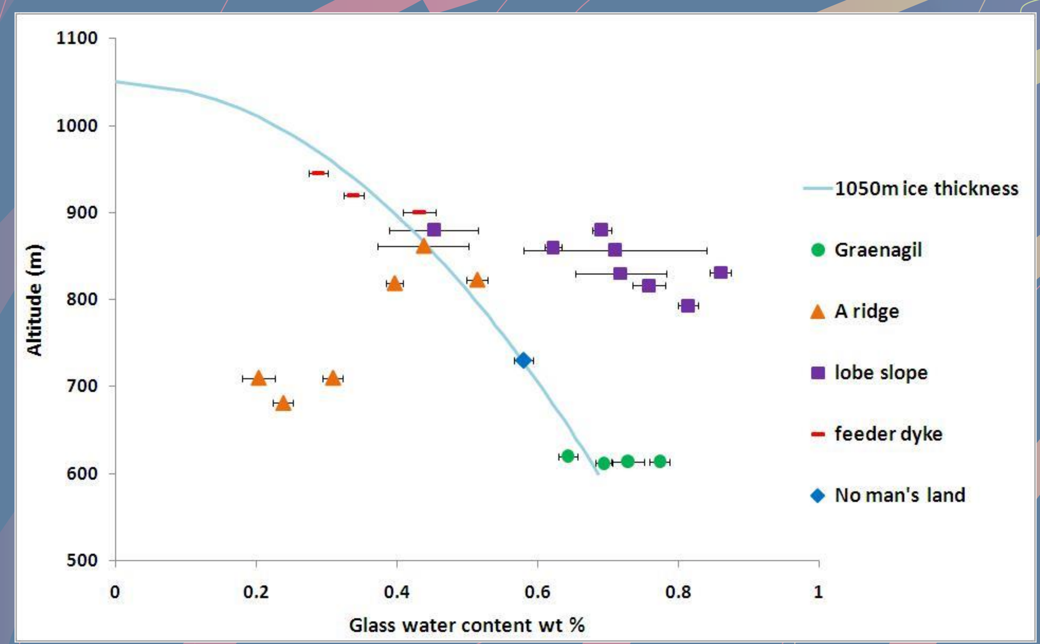

Figure 3: A theoretical ice thickness curve (blue line), representing an ice surface level of 1050m, calculated using VolatileCalc[3] with the assumption that the lava was erupted at 850°C and with 0 ppm CO_2. Also plotted is data from my Blahnukur samples (shapes).

Figure 1: A photograph of Bláhnúkur, a small volume, subglacial rhyolitic volcano in South Iceland (Photograph looking ~SW)

Anomalies

There are two anomalous areas within Figure 3. Many of the lobes from 'A ridge' (Fig. 4) are more water-poor than expected, whereas the lobes from the 'lobe slope' (Fig. 5) are water-rich. Are these errors - do they disprove the theory, or is there a scientific explanation? Perhaps, meltwater was able to drain away from 'A ridge', thereby reducing the pressure, whereas the lobes on the 'lobe slope' formed intrusively where they experienced loading from both rock and ice and therefore a greater quenching pressure.

Further work

✓I am currently testing out various hypotheses in an attempt to explain the results seen in figure 3.
✓I also intend to collect more samples from Bláhnúkur in an attempt to better define the individual trends seen in figure 3.
✓This summer I will also study magma degassing in other subglacial volcanoes in the Torfajökull district, in the hope of better understanding the role that degassing plays in controlling the explosivity of subglacial rhyolitic eruptions.

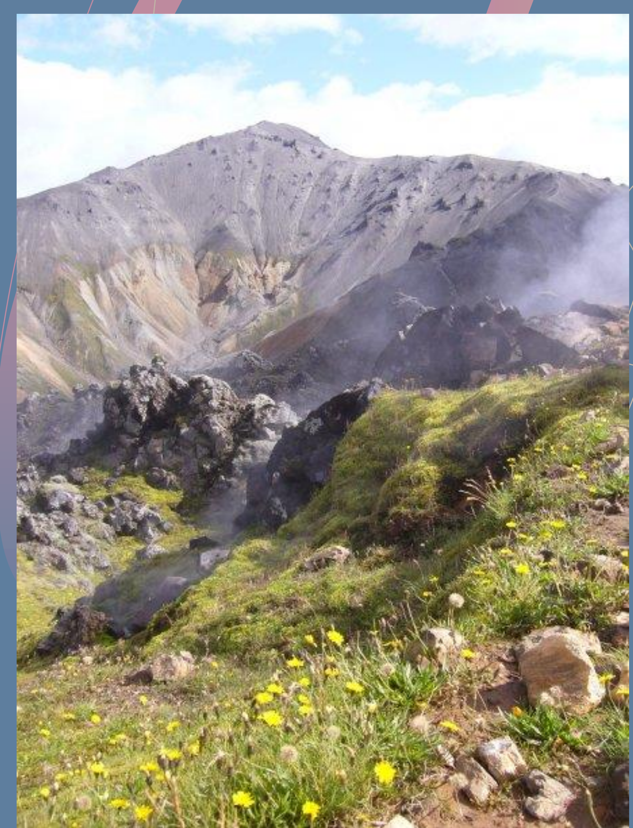

Figure 5: A photograph of the lobe slope on Bláhnúkur, with fumaroles in the foreground (Photograph looking ~E)

Some important considerations

Has water been added at a later date?

It is possible that volcanic rocks can absorb water post eruption, through cracks and fractures[4]. However, these later additions tend to leave the H_2O in the form of molecular water, whereas water retained within the melt tends to be in the form of hydroxyl ions which are intricately bonded with the other atoms. The percentage in the two different forms can be quite easily determined through spectroscopy[5] or through thermal analysis[6]. Spectroscopic studies of my samples reveal that alteration has not been a significant process with my rocks.

Other influences on water solubility

A major problem with the simple ice thickness model is that factors other than pressure, affect the water solubility. These include the CO_2 content and the eruptive temperature[3]. As figure 6 illustrates, if a rock has a water content of 1 wt %, it could equate to anywhere between ~950 and ~1700 m of ice depending on the temperature and CO_2 content. The problem is intensified because the majority of analytical techniques can not detect if there is CO_2 below 30 ppm[7]. However, if there has been significant H_2O degassing it is likely that the CO_2 content will be 0 ppm[1].

The good news is that the effects of CO_2 and temperature are quite well known, so the model[3] can be used. The bad news is that there are other influences which have not been considered and are poorly understood. E.g. F has the potential to significantly influence water solubility[8] and in my rocks it is seen to vary considerably within a very small spatial scale[7] (Fig. 7).

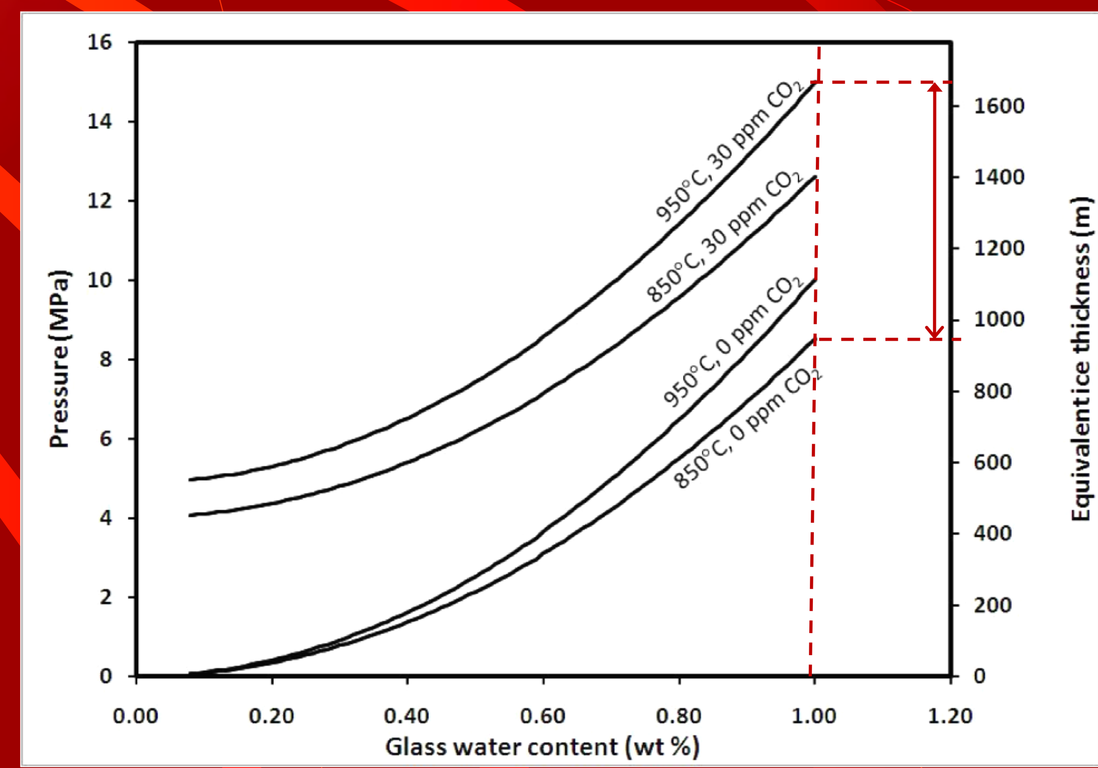

Figure 6: Graphs showing the effects of CO_2 and temperature on water solubility within rhyolitic melts based on calculations made in VolatileCalc[3]. The dashed lines depict how a rock with a water content of 1 wt %, could equate to an ice thickness anywhere between ~950 m (if the lava was erupted at 850°c with a CO_2 content of 0 ppm) and ~1700 m (if the lava was erupted at 950°C and had a CO_2 content of 30 ppm).

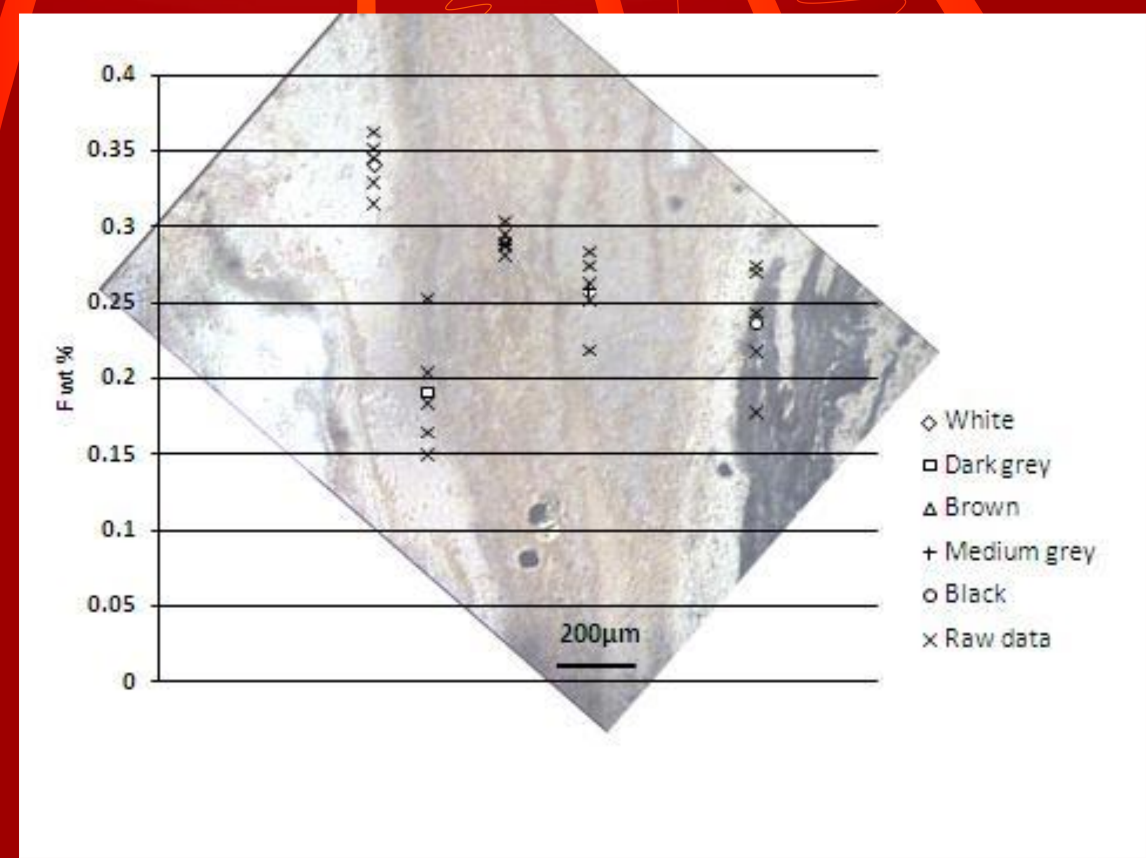

Figure 7: A plot showing fluorine data for different coloured bands within a sample of obsidian taken from Bláhnúkur. The x's show the raw data and the solid shapes show the average values for each band.

Equilibrium degassing

For the model, to work there needs to be equilibruim degassing, which means that the eruption rate needs to be slow enough to allow this to happen[7].

A potential link with vesicularity

Preliminary studies have revealed a potential link between the volatile content and the vesicularity of my samples. Further investigation is required to better understand this link and the extent to which different textures can influence the magmatic water content.

References
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