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Rhyolite eruptions under ice:
An interconnected web of volatiles, pressure, degassing and eruptive behaviour

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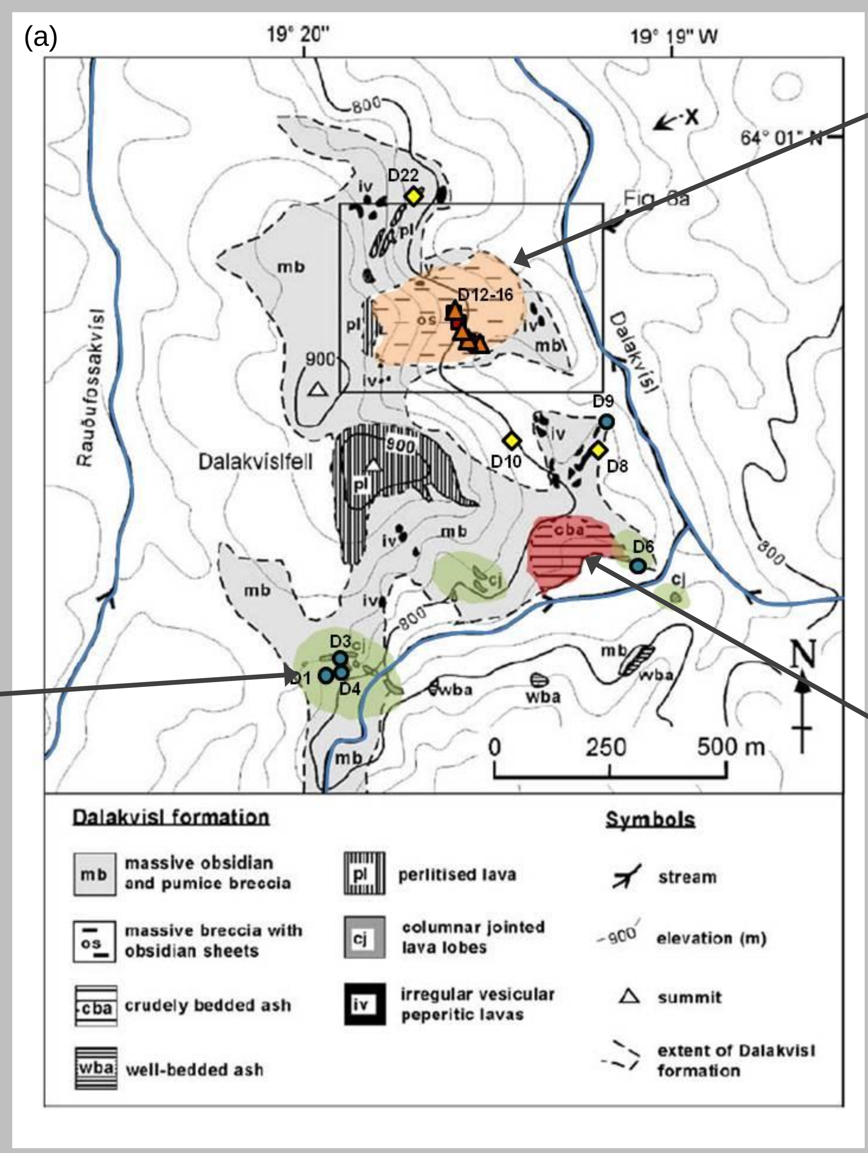
By Jacqueline Owen*[1] - a 4th year PhD student
Supervisors: Dr. H. Tuffen[1], Dr. D.W. McGarvie[2]
[1] LEC, Lancaster University, Lancaster LA1 4YQ, UK (* j.owen2@lancaster.ac.uk)
[2] Department of Earth and Environmental Sciences, The Open University, Milton Keynes MK7 6AA, UK

Dalakvísl – a volcanic Jekyll and Hyde

Dalakvísl is part of the Torfajökull central volcanic complex in Southern Iceland. It erupted under an ice sheet ~70 ka ago[1] as part of a massive ring fracture eruption that altogether produced 26 km^3 of rhyolite; the largest rhyolitic eruption in Icelandic history[2,3]. Dalakvísl's contribution to this was tiny; a measly 0.2 km^3 [4]. However, Dalakvísl also proved that size is not everything, displaying a diverse mixture of products (Fig. 1a), from effusive columnar jointed lava lobes (Fig. 1b) to explosive fine-grained ash deposits bearing highly vesicular pumice (Fig. 1d). The interpretation is that there was a transition in style during the eruption[4]. This behavioural transition is thought to be captured within a deposit of obsidian sheets, where the lava bodies have dense obsidian cores but vesicular margins [4] (Fig. 1c). These will hereafter be referred to as 'sheet cores' and 'sheet margins' respectively.

Aim of project

The aim of this project was merely to reconstruct the palaeo-ice thickness using the magma degassing technique (see next section). However, we got far more than we bargained for when we realised that changing loading pressures could also help to explain the transition in style demonstrated at Dalakvísl.



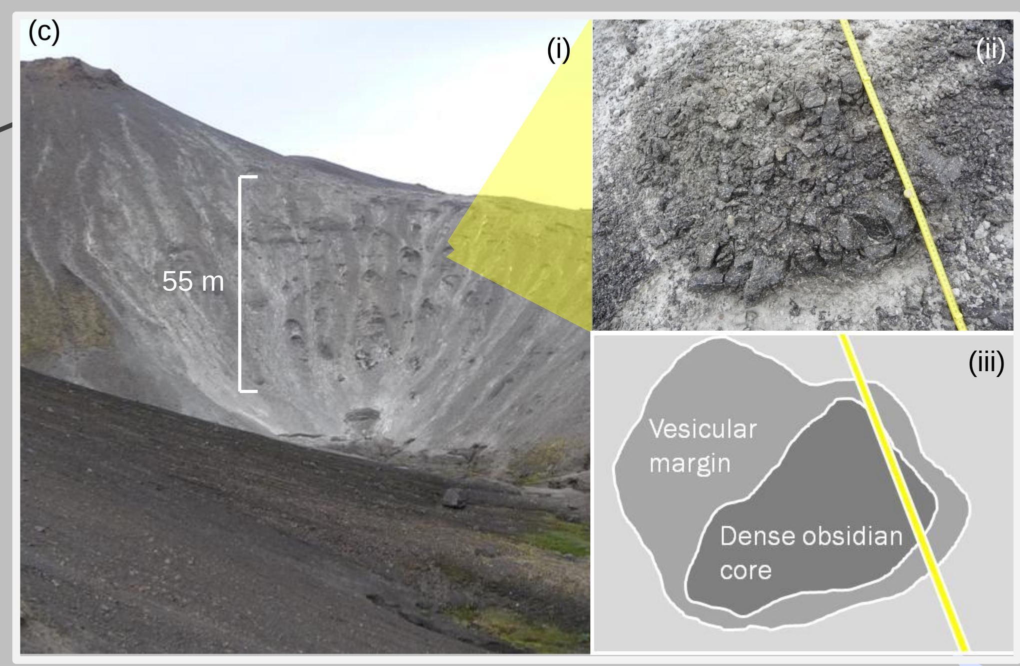


Figure 1: (a) A geological map of Dalakvísl[4] with sampling locations marked according to the legend in Fig. 3. Green, orange and red areas indicate effusively , transitional and explosively produced deposits respectively; (b) an example of an effusively produced lava lobe with columnar jointing; (c) obsidian sheets thought to have captured the transition in style (i) the whole deposit looking North, (ii) a single sheet (iii) a schematical representation of a single sheet and (d) pale, explosively produced, fine grained, layered ash with pumiceous clasts

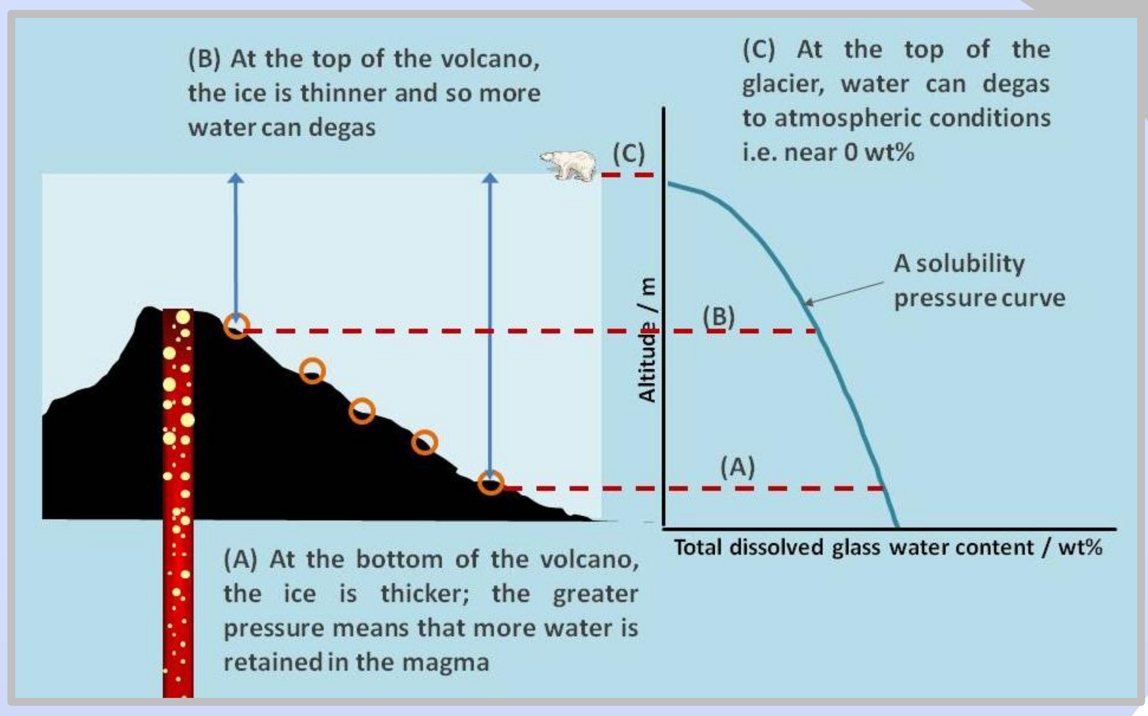


Figure 2: A schematical illustration explaining the magma degassing technique

The magma degassing technique

During a volcanic eruption, the extent to which water degasses depends on pressure. Quenching pressure is dependent on the degree of loading from overlying material. In subglacial eruptions, this loading will be due to the presence of overlying ice. Therefore, glass water content can be used to infer palaeo-ice thicknesses[5].

Assuming that the volcano erupts under an ice sheet with a relatively flat surface then one should expect the ice thickness to decrease with increasing elevation. However, the solubility-pressure relationship is not linear and so there is a curving trend known as a 'solubility pressure curve'. A solubility pressure curve (Fig. 2) shows the water content one would expect, at each elevation, for a given palaeo-ice thickness[5].

The results

When plotting our water contents against elevation it became clear that a simple palaeo-ice thickness reconstruction would not be possible and that the degassing story was actually quite a complicated affair (Fig. 3). However, a number of observations were made...

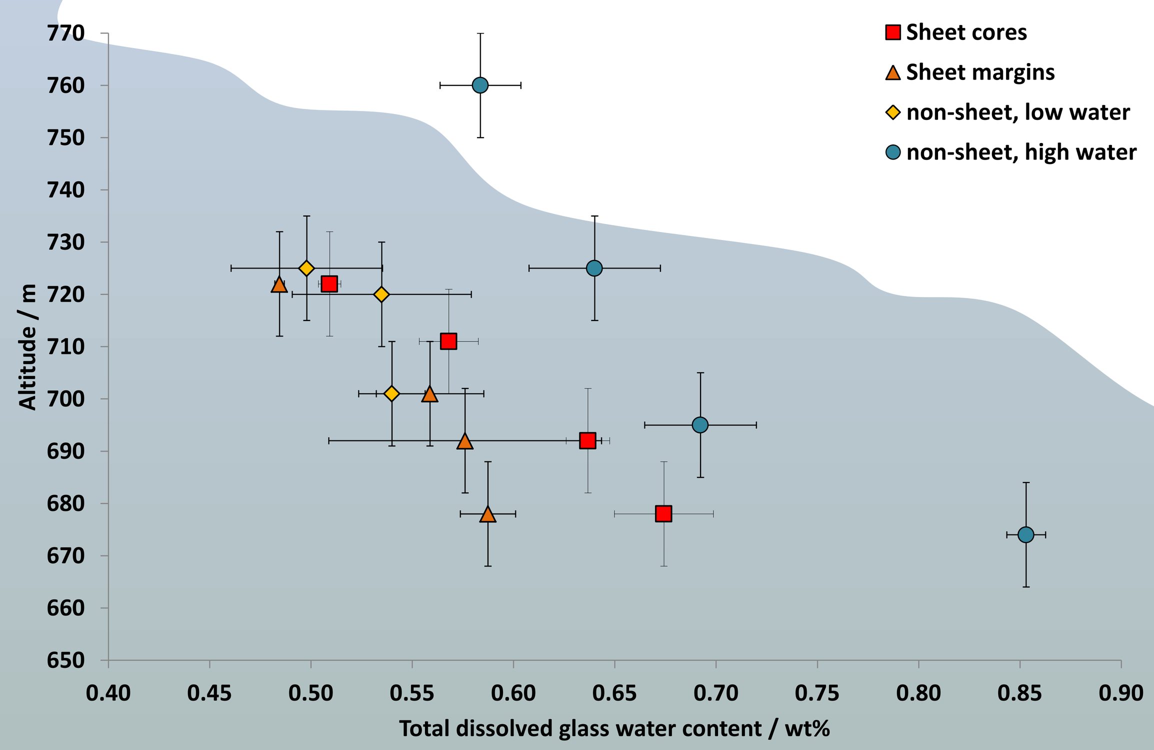
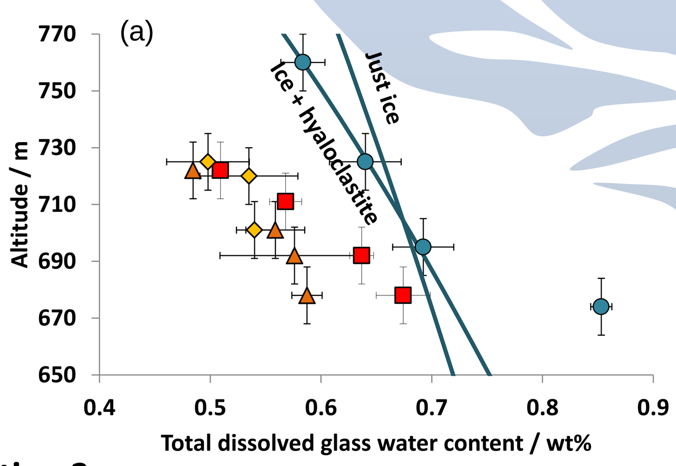


Figure 3: Water content of the Dalakvísl samples, plotted again elevation. Each data point represents the average from 5 FTIR measurements. The x error bar is the standard deviation of these measurements; the y error bar is ± 10 m

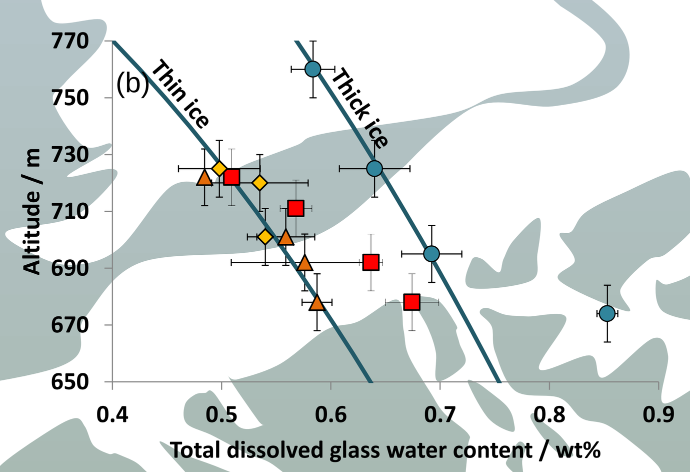
Observation 1

None of the data can be fitted to a solubility pressure curve when ice is the only loading medium – some loading from hyaloclastite is also needed to get the right gradient (Fig. 4a).



Observation 2

More than one solubility pressure curve is required to meet the data (Fig. 4b), with the more effusive samples suggesting thicker ice than the more explosive samples (Fig. 1a). Ice thinning of ~140 m could explain the difference.



Observation 3

The obsidian sheet samples, which were thought to have formed during the transition in style (Fig. 1c),

1. Plot between then thick and thin ice estimates
2. Show variation in water content, with the sheet cores always having more water than the sheet margins, suggesting that the different zones of the sheets have formed under different pressure conditions
3. Both the sheet core samples and sheet margin samples decrease in water content with elevation, however they have different gradients and seem to be converging to a point. i.e. the difference between the sheet core and sheet margin water contents decreases with elevation

(see Fig. 4c)

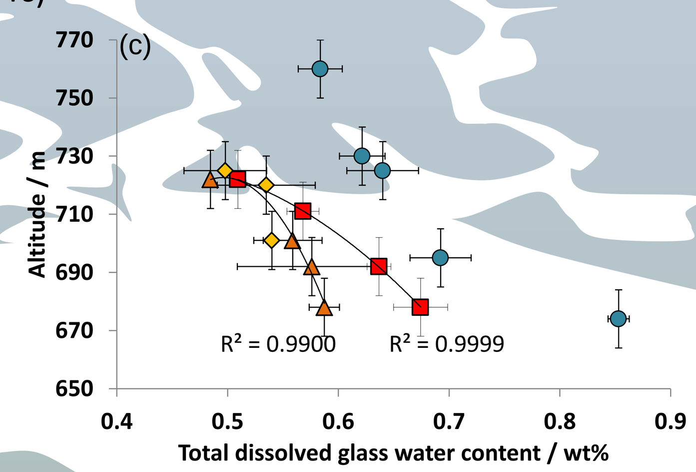


Figure 4: Reproductions of Figure 3 (using the same legend) with the addition of (a) solubility pressure curves representing loading by just ice and ice plus hyaloclastite, (b) solubility pressure curves representing thick and thin ice and (c) trend lines showing the trends of the sheet data

Conclusions

We believe that Figure 3 shows that a jökulhlaup occurred during the eruption of Dalakvísl and that the resultant pressure change triggered a change in style from effusive to explosive behaviour. This would be achieved if meltwater was unable to drain away from the eruption site, thus maintaining a high pressure in the early part of the eruption. We believe that the effusive samples are recording these pre-jökulhlaup loading conditions whereas the large degree of variation in the sheet samples are recording rapidly changing pressure conditions due to a sudden drainage of meltwater as the jökulhlaup occurred. These sheet samples have been interpreted as recording the transition in style[4], therefore we interpret that the depressurisation from the jökulhlaup led to a more explosive regime. The palaeo-ice thickness has been inferred to have been between 70 and 210 m. The range taking in the unknown degree of hyaloclastite loading that is associated with all samples. This also suggests that what we see today formed intrusively and that there has been considerable erosion of Dalakvísl since it formed 70 ka years ago. Maybe it wasn't such a little eruption after all...

References

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