Reconstructing palaeo-ice thicknesses:
On what type of volcano can the magma degassing technique be used?

INTRODUCTION

Why reconstruct palaeo-ice thicknesses?
They provide a clear proxy to reconstruct palaeo-environmental change and help us to better understand the link between:
1) Ice thickness and eruption behaviour
2) Ice thickness and subglacial deposits, such as jökulhlaups and tephole dispersal
3) Ice thickness and eruption frequency. Can the 21 st century expect an increase in volcanism if anthropogenic climate change continues to cause deglaciation?

What is the magma degassing technique?
Samples are collected from a range of elevations and analysed for their dissolved H2O content. Towards the top of a subglacial edifice, the ice will be thinner; less loading pressure will allow more H2O to escape. Consequently erupted products should show a decreasing trend of dissolved H2O with elevation. Solubility pressure curves (SPCs) can be drawn to show the dissolved H2O content one would expect at each elevation for a given palaeo-ice thickness. This provides a quick and easy way to compare actual data to theoretical palaeo-ice surfaces, until the best match is found.

So, what’s the problem?
There has not been a single study to date, where all the data has fitted convincingly to a single SPC. For the majority of cases, an explanation has been provided for the discrepancy; samples include, under-saturated magma, underpressured cavities due to meltwater drainage, and additional loading from hydrostatic stress.

Our aim
To determine the type of rhythmic edifice for which the magma degassing technique can effectively reveal palaeo-ice thicknesses

Dalvikvíl
Dalvikvíl was a small (0.2 km²) mixed explosive-effusive eruption. 
Lithofacies interpretation suggests an entirely subglacial eruption environment but there is potential submersed lava [8]. However, at 810 m this would suggest a considerably lower ice surface than the other ring fracture lithofacies [9].

Samples collected from the full range of lithofacies including effusive lava lobes [10] and obsidian sheets thought to have formed during the transition in style [11].

Kakafjall
Kakafjall formed during an entirely subglacial eruption (Fig. 6). Abundant columnar-jointed lava with close fracture spacing suggests ice contact [12].

METHOD

Samples were collected from SE Raudfossáfljót, Dalvikvíl and Kakafjall; three subglacial rhythmic edifices, that formed contemporaneously, but with contrasting styles [13]. During the 70 ha ring fracture eruption at Torfajökull [14].

1. Dissolved H2O was measured using FTIR
For each edifice, H2O data was compared to SPCs, to find the most representative palaeo-ice thickness
Subglacial-subarctic lithofacies transitions from ring fracture tuyas indicate an ice surface at ~1090 m a.s.l. [15], does the magma degassing technique agree?

Observations from the data (Fig. 5)[15]
1. Plotting graphs in terms of lithofacies, the data fits well to SPCs that represent loading from both fragmental material and ice
2. Effusive lava lobes fit well to SPC-B
3. The more explosively produced sheet margins fit to SPC-A which represents a lower pressure environment
4. Sheet cones (from same sheet) plot between these two SPCs and show a particularly rapid decrease in H2O with elevation

However, it should be noted that SE Raudfossáfljót views the scarcity of suitable obsidian for FTIR analysis amongst the subglacial deposits. Fine-grained, vesicular material, such as that which formed during the subglacial eruption phase of the eruption [16], has a tendency to become hydrated and is thus unsuitable for the magma degassing technique.

Reconstructing a palaeo-ice thickness
Our best fit SPCs (Fig. 5) require loading from fragmental material, ice and meltwater. This makes it impossible to provide a single value for the palaeo-ice surface; the dissolution of organic material is unknown. Furthermore, the data fits onto two SPCs.

CONCLUSION
On what type of volcano can the magma degassing technique be used?

Unsuitable edifices
1. Due to the emergence of the edifice the load may become degassing
2. Subglacially erupted edifices where they tend not to preserve suitable obsidian
3. Well-eroded edifices where the samples exposed today originally formed intrusively

Lithofacies that suggest a change in cavity pressure may produce multiple SPCs

Favourable edifices
1. Useful eruptions because this favours the production of in situ, non-eroded obsidian lava bodies
2. Entirely subglacial edifices due to the continuous pressure (i.e. magma loading) rather than atmospheric pressure
3. Edifices that show strong evidence for ice contact because then loading pressure can be solely attributed to ice

However, it should be noted that although SE Raudfossáfljót and Dalvikvíl showed good results for reconstructing palaeo-ice thicknesses, use of the magma degassing technique has provided useful additional insights into loading material, erosion quantities and subglacial regime pressures; the latter possibly being connected to changes in eruptive styles [17] which have significant consequences for subglacial hazards.

References