European Geosciences Union
General Assembly 2010
Vienna, Austria, 02 – 07 May 2010

THE USE OF MAGMATIC WATER TO RECONSTRUCT PALAEO-ICE THICKNESSES DURING SUBGLACIAL RHYOLITIC ERUPTIONS

By Jacqueline Owen[1] - a 2nd year PhD student
Supervisors: Dr. H. Tuffen[1], Dr. D.W. McGarvie[2], Prof. H. Pinkerton[1] & Prof. L. Wilson[1]
[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

1. Water as a palaeo-environment indicator

Figure 1: A photograph of the subglacially erupted Bláhnúkur (Photograph looking ~SW)

1.1: Introduction

The solubility of volatiles is dependent on 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 elevation it is possible to reconstruct the thickness of ice above a volcano at its time of eruption[1].

1.2: 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 which is part of the Torfajökull central volcano, in southern Iceland[2] (Fig. 2). The results can be seen in Figure 3 (see section 2).

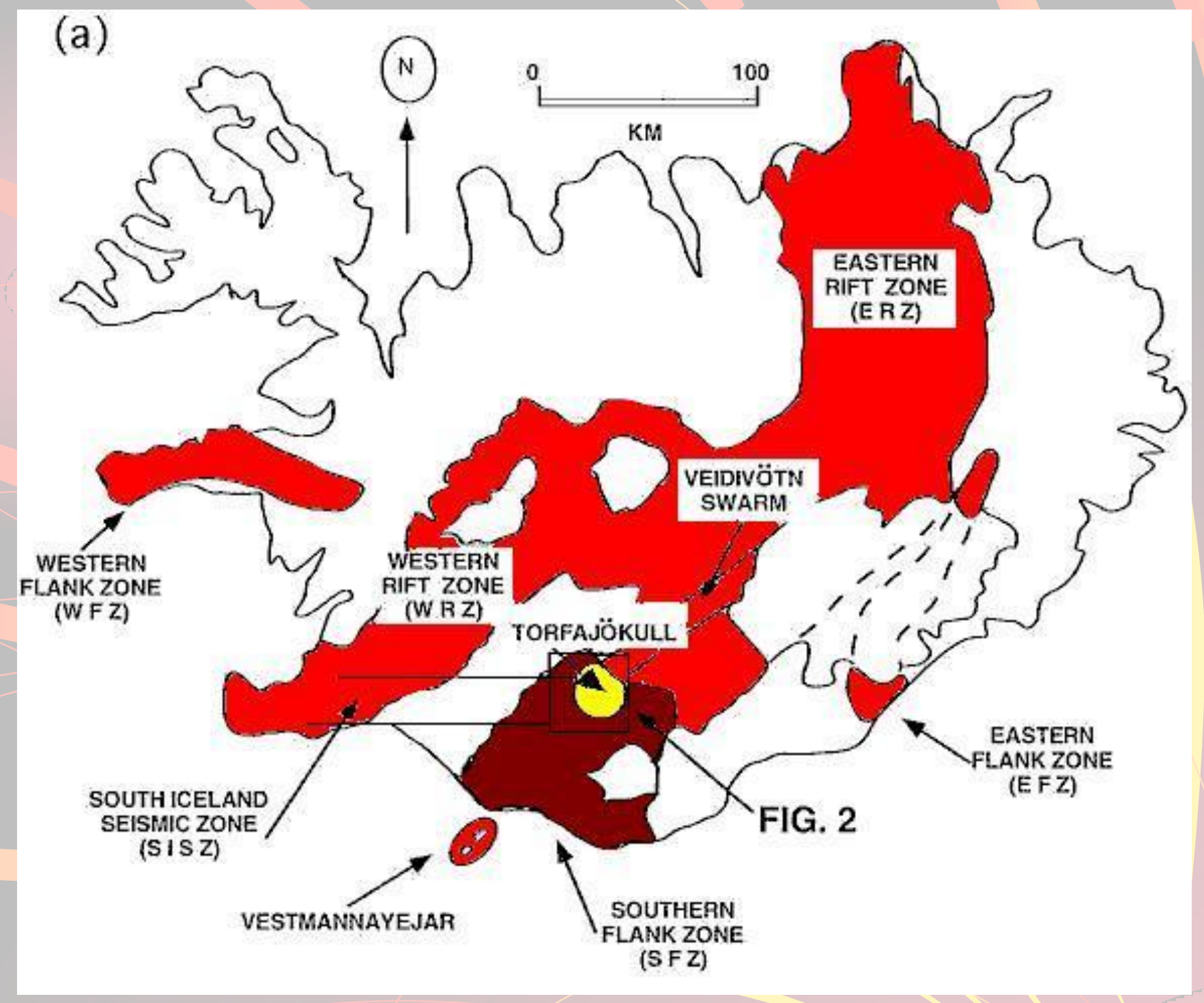

Figure 2: A map showing the location of Torfajökull within the neovolcanic zones of Iceland. Modified[3].

2. My results: reconstructing the palaeo-ice thickness at Bláhnúkur

2.1: My results

My results (Fig. 3) suggest that when Bláhnúkur erupted, ~95 ka (Clay, unpublished data), the ice surface elevation was ~1050 m a.s.l. in this part of Iceland.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[4]. However, 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' and 'Brandsgil' (Fig. 5) are water-rich.

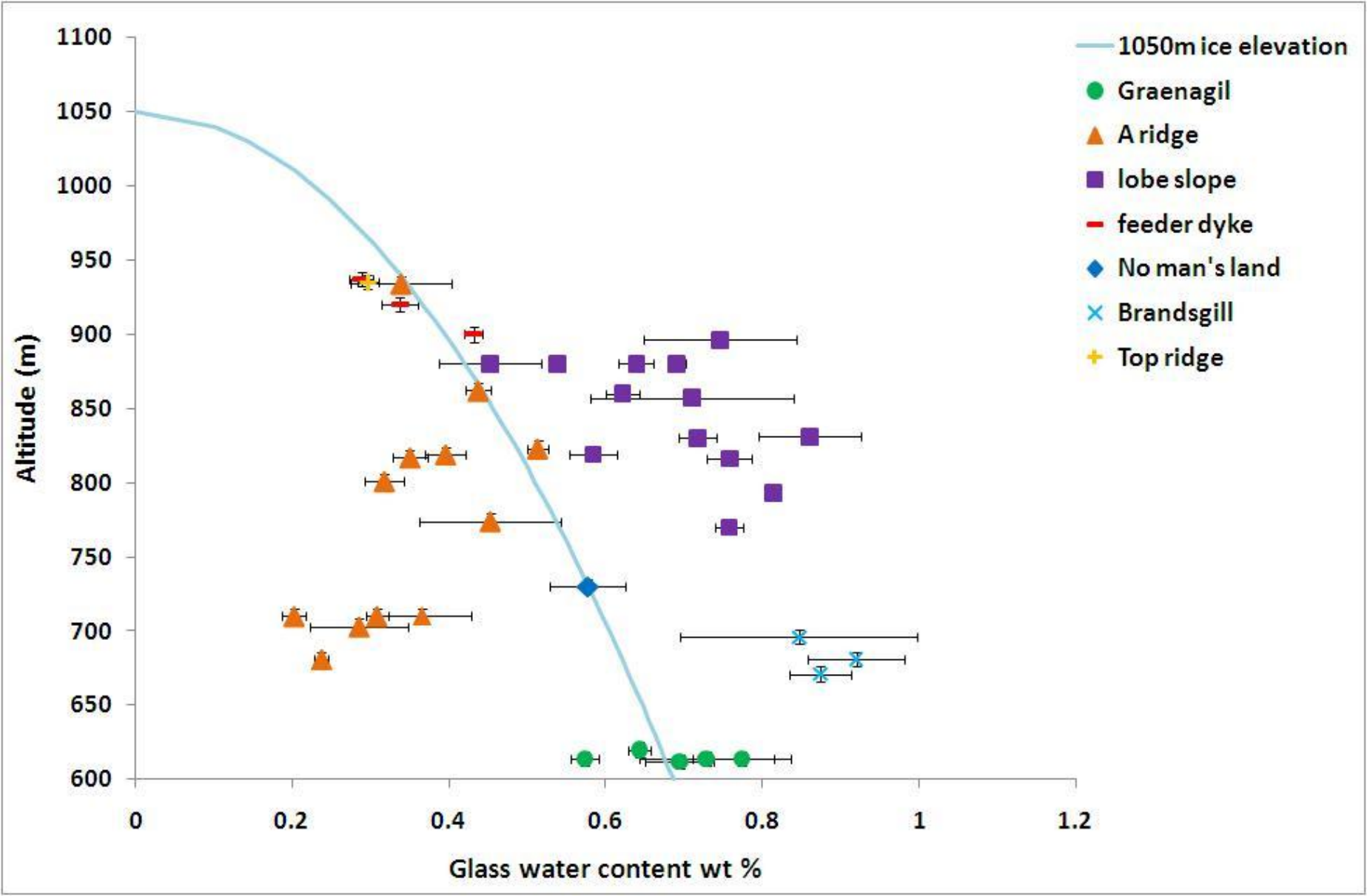

Figure 3: A theoretical ice thickness curve (blue line), representing an ice surface level of 1050m, calculated using VolatileCalc[5] with the assumption that the lava was erupted at 850°C and with 0 ppm CO_2. Also plotted is data from my Bláhnúkur samples (symbols)

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

2.2: Explanations for the 'lobe slope' and 'Brandsgil' being water rich

1) The ice was ~300 m thicker here than it was elsewhere.
2) There are small (below detection limit) amounts of CO_2 present elsewhere (see section 3.3), meaning that the ice is ~300 m thicker everywhere.
3) The lobes formed intrusively where they experienced loading from both rock and ice and therefore a greater quenching pressure. Since then, there has been >200 m of erosion from here but nowhere else
4) There has been endogenous growth, therefore the lobes quenched at a lower elevation and have been uplifted ~170 m to their current position.
5) A combination of the above.

2.3: Explanations for 'A ridge' being water poor

1) Meltwater drainage has caused an under pressure.
2) The lobes formed at a higher elevation and have been remobilized.
3) There were originally, only negligible amounts of water within the rocks for it to lose.

Option 3 is a preferred option considering the results shown in Fig. 7. (see section 3.4)

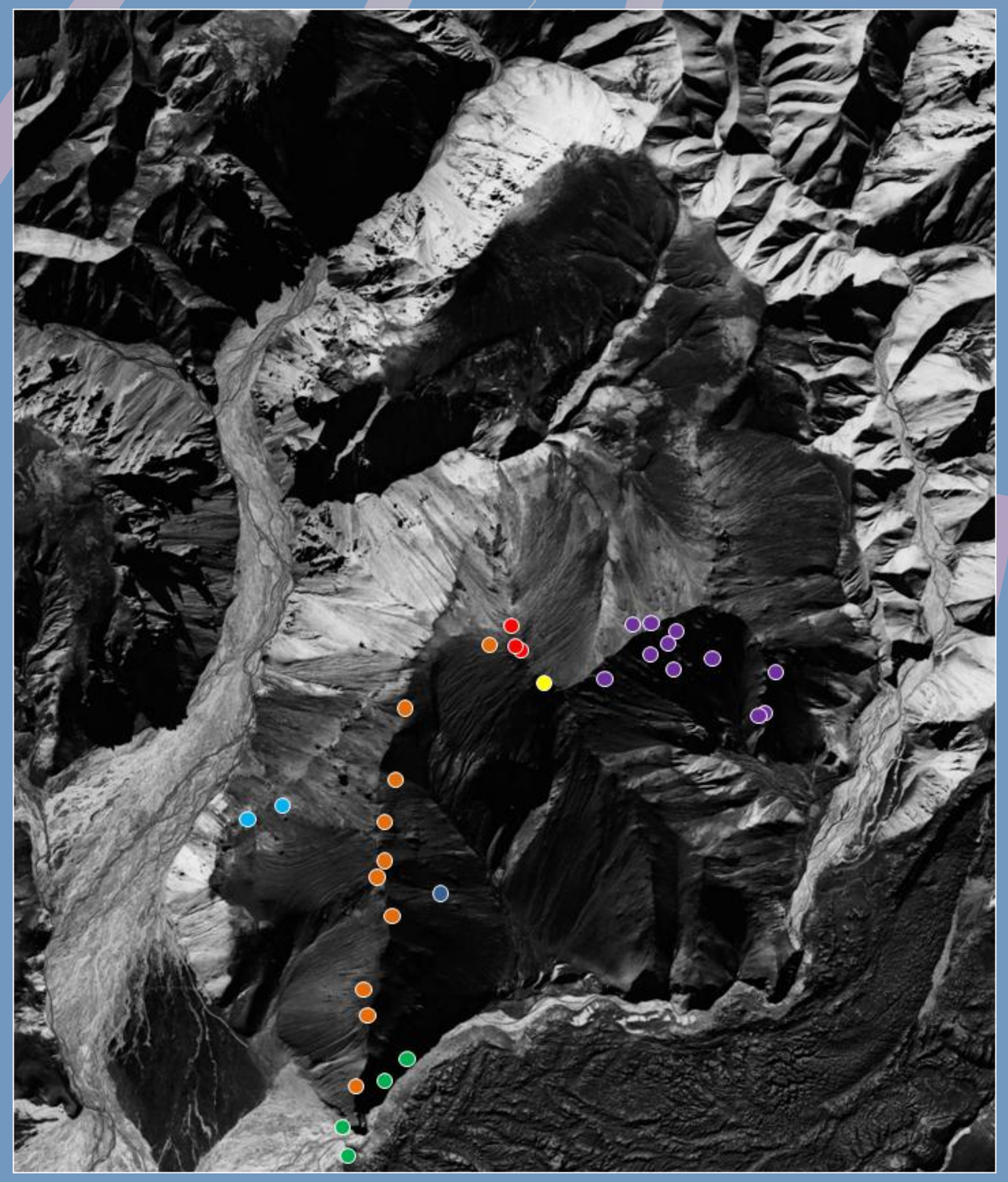

Figure 4: An aerial photograph[6] showing where the samples were collected from. Green: Graenagil, orange: A ridge, purple: lobe slope, red: feeder dyke, dark blue: no man's land, light blue: Brandsgill, yellow: top ridge

3. Some important considerations

3.1: Has water been added at a later date?

Volcanic rocks absorb water post eruption through cracks and fractures[8]. 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. The speciation can be easily determined through spectroscopy[9]. Spectroscopic studies of my samples reveal that alteration has not been a significant process with my rocks; only two samples have been dismissed (Fig. 7).

3.2: Equilibrium degassing

In order to be able to infer quenching pressures from the dissolved water content, equilibrium degassing needs to be achieved. For rhyolitic eruptions, this means that the eruption rate needs to be < 1 m s^{-1} [7]. However, it is believed that the eruption rate of Bláhnúkur meets these requirements[4].

3.3: 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[4]. 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 cannot detect if there is below 30 ppm of CO_2[7]. However, if there has been significant H_2O degassing it is likely that the $C0_2$ content will be 0 ppm[1].

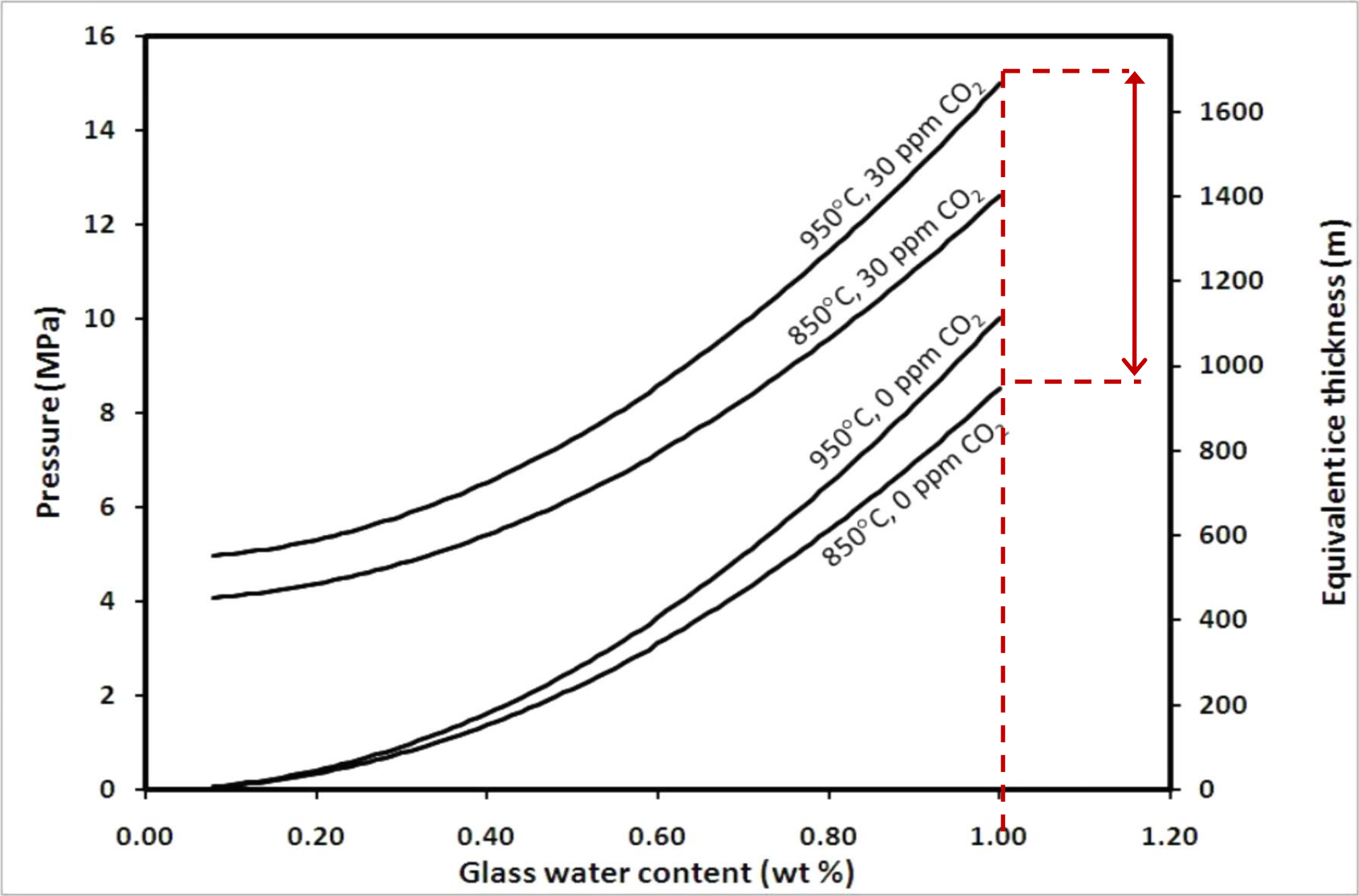

Figure 6: Graphs showing the effects of CO_2 and temperature on water solubility within rhyolitic melts based on calculations made in VolatileCalc[5]. The dashed lines depict how a rock with a water content of 1 wt %, could equate to an ice thickness anywhere between ~950 m (if the lava was erupted at 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).

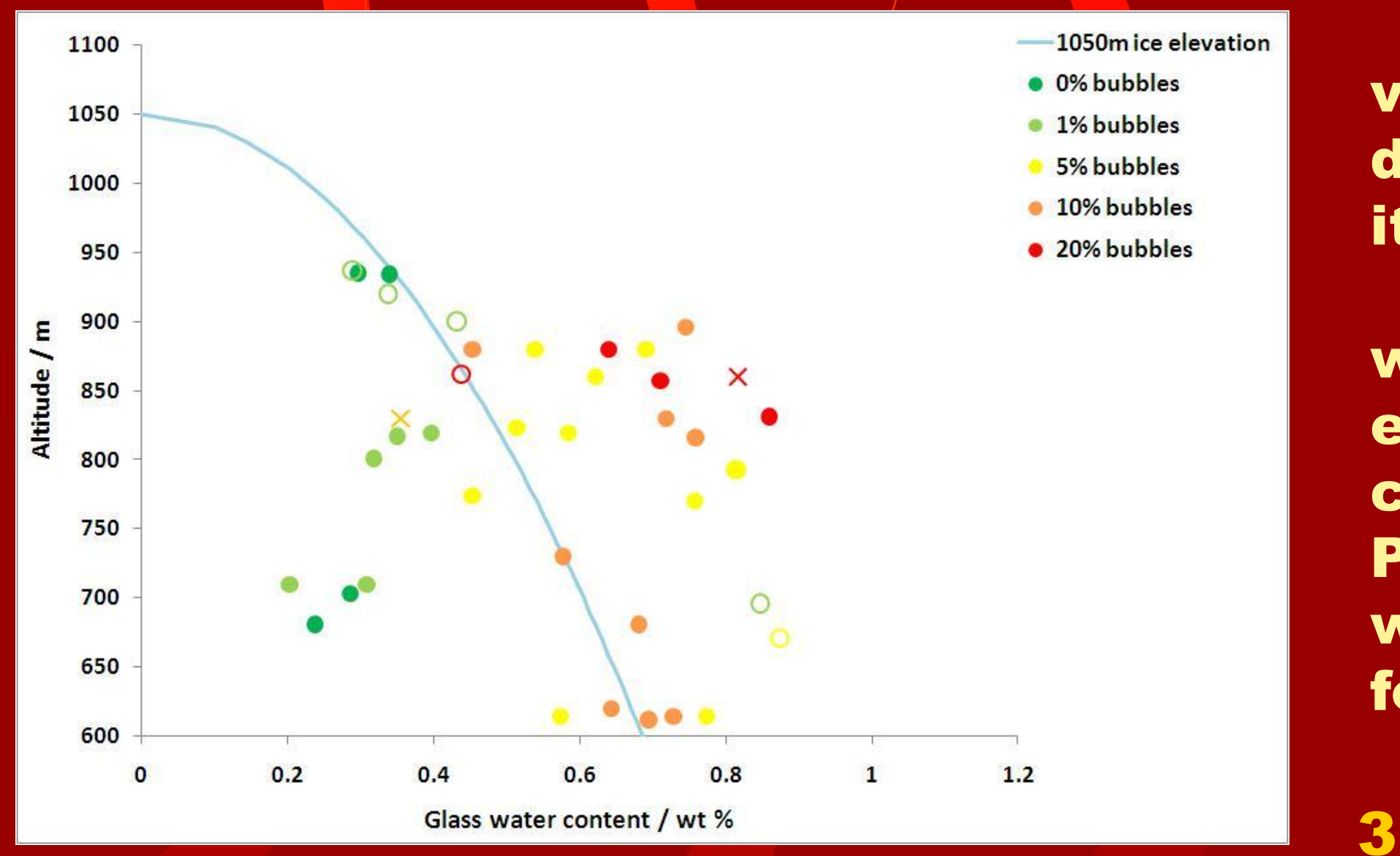

Figure 7: A reproduction of figure 3, this time colour coded according to vesicularity (based on estimations by eye). Filled in circles represent lobes, empty circles represent lava bodies / dykes. The crosses represent data dismissed because they have a high ratio or molecular water (see section 3.1).

3.4: A link with vesicularity

The presence of vesicles is of fundamental importance when reconstructing quenching pressures. They show that some degassing has taken place which is an essential requirement for the dissolved volatiles to be recording the confining pressure. An absence in volatiles suggests that the melt was undersaturated and therefore only a minimum quenching pressure can be determined. However, it is possible that vesicles may collapse and completely heal; therefore a vesicle-free melt may not necessarily show undersaturation[7].

My samples from 'A ridge', are generally void of vesicles (Fig. 7), suggesting that degassing from here has been neglible. However, it is these samples that are also water-poor.

This supports the hypothesis that the initial water content for 'A ridge' was minimal (e.g. If it erupted from a different part of the magma chamber or had a different residence time). Preliminary melt inclusion work is in agreement with this hypothesis but further work is required for confirmation.

3.5: Future work

As well as determining the initial H_2O and CO_2 content (see section 3.4), I will better quantify the post-eruptive CO_2 content and determine whether crystallinity has any effect on the volatile content.

I will examine other subglacial, rhyolitic volcanoes in Iceland and use this insight into volcanic degassing to address the question of why they have different eruptive styles.

References

1: Dixon, J.E., Filberto, J.R., Moore, J.G. & Hickson, C.J., (2002) Volatiles in basaltic glasses from a subglacial volcano in northern British Columbia (Canada): implications for ice sheet thickness and mantle volatiles, In: Smellie, J.L., & Chapman, M.G. (eds) *Volcano-ice interaction on Earth and Mars*. Geological Society London Special;

2: Tuffen, H., Gilbert, J.S. & McGarvie, D.W. (2001) Products of an effusive subglacial rhyolite eruption: Bláhnúkur, Torfajökull, Iceland, Bulletin of Volcanology, 63: 179-190;

3: Gunnarsson, B., Marsh, B.D. & Taylor Jr., H.P. (1998) Generation of Icelandic rhyolites: silicic lavas from the Torfajökull central volcano, *Journal of Volcanology and Geothermal Research*, 83: 1-45;

4: Tuffen, H., McGarvie, D.W. & Gilbert, J.S. (2007) Will subglacial rhyolite eruptions be explosive or intrusive? Some insights from analytical models, Annals of *Glaciology*, 45: 87-94

5: Newman, S. & Lowenstern, J.B., (2002) VolatileCalc: a silicate melt–H_2O–CO_2 solution model written in Visual Basic for excel, *Computers and Geosciences*, 28: 597-604;

6: Landmælingar Íslands, National Land Survey of Iceland;

7: Tuffen, H., Owen, J. & Denton, J., (2010) Magma degassing during subglacial eruptions, in preparation for *Earth Science Reviews*; 99: 1-18;

8: Denton JS, Tuffen H, Gilbert JS, Odling N. (2009) The hydration and alteration of perlite and rhyolite from Iceland, *Journal of the Geological Society of London*, in press;

9: Forbes, A. (2008) Lipari Island Obsidian: formation mechanisms and insights into the volcanic system, unpublished dissertation;