What controls the explosivity of subglacial rhyolite in Iceland?

Jacqueline Owen*[1], Hugh Tuffen**[1], Dave McGarvie[2]

[1] LEC, Lancaster University, Lancaster LA1 4YQ, UK (* j.owen2@lancaster.ac.uk, ** presenting author)
[2] Department of Earth and Environmental Sciences, The Open University, Milton Keynes MK7 6AA, UK

XL264: **EGU2012-10295**
EGU General Assembly 2012
Vienna, 22 – 27 April

Introduction

Subglacial rhyolitic edifices have a wide spectrum of sizes, morphologies and lithofacies (Figs 1-3), reflecting various eruptive styles and degrees of explosivity[1]. However, a subglacial rhyolitic eruption has never been observed and so the controlling factors on eruptive behaviour are poorly understood[2].

During subaerial eruptions, volatiles are thought to be a key factor in determining eruptive style with (1) a high pre-eruptive H_2O and CO_2 content and (2) closed system degassing, leading to more explosive volcanism[3].

During subglacial eruptions, explosivity is at least partly determined by the degree of magma-water interaction[4,5]. Lab based studies[6,7] suggest that the presence of bubbles may hinder phreatomagmatic explosions. This would imply that, contrary to subaerial eruptions, subglacial eruptions favour volatile-poor magma for explosive activity.

Dalakvísl (mixed behaviour)

Figure 2: (a) effusive and (b) explosive, lithofacies from Dalakvísl

Geological background

All of our samples were collected from the Torfajökull central volcano in South Iceland (Fig. 4). We sampled from three edifices: Bláhnúkur (Fig. 1), Dalakvísl (Fig. 2) and SE Rauðfossafjöll (Fig. 3) that erupted with effusive[4], mixed[2] and explosive[8] behaviour respectively. They all have similar major element chemistry and erupted under similar thicknesses of ice [9,10]. See poster on reconstructing palaeo-ice thicknesses (XL265: EGU2012-10295). Do volatiles provide an explanation for their contrasting styles?

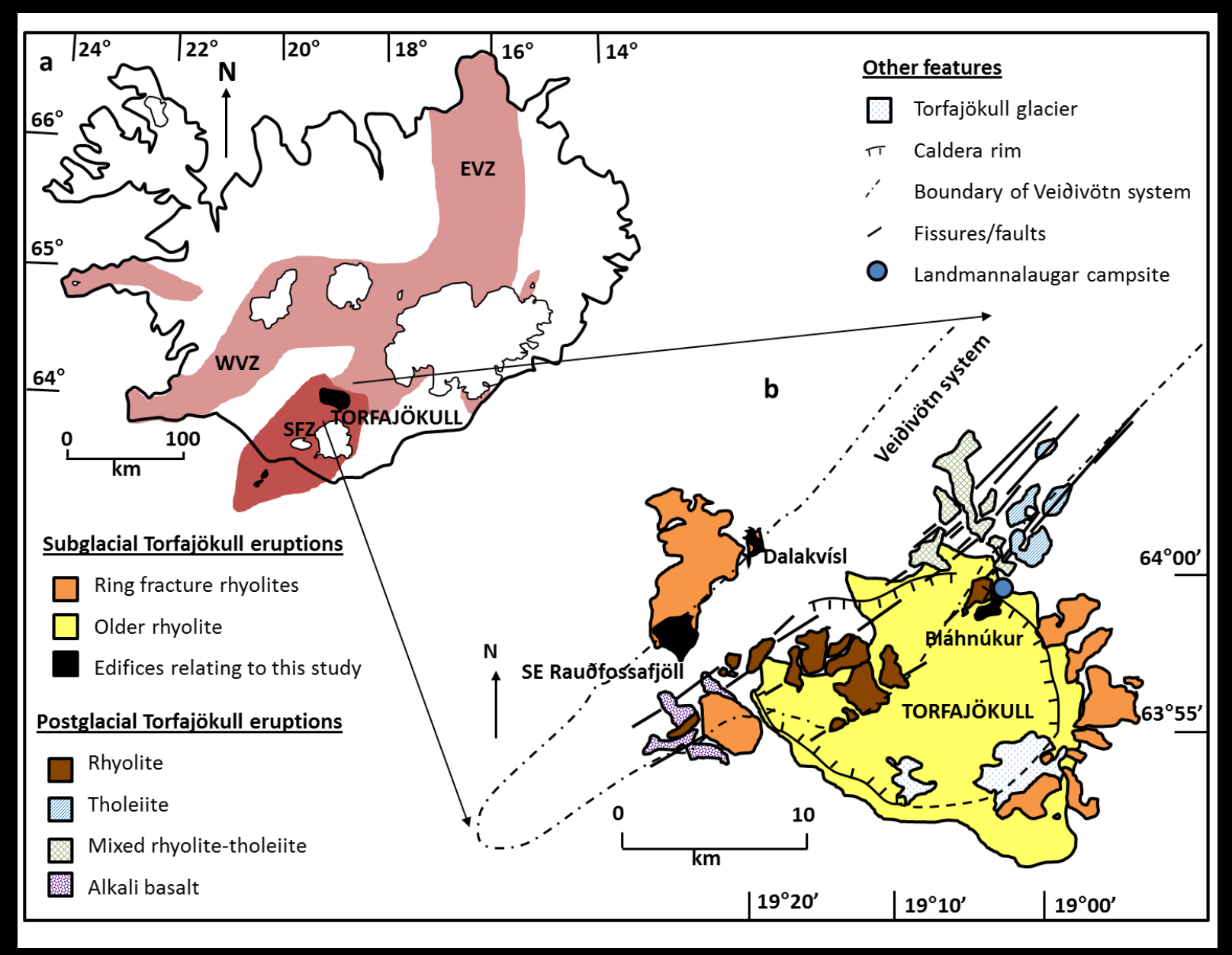

Figure 4: Geological maps of (a) Iceland and (b) Torfajökull[9]

Bláhnúkur (effusive)

Figure 1: Bláhnúkur

Project aim

We investigate the role of volatiles in determining the explosivity of subglacial rhyolitic eruptions by comparing pre- and post- eruptive volatile contents from samples collected from a range of Icelandic edifices erupted through contrasting eruptive styles.

In doing so, we will provide the first direct measurements of pre-eruptive volatile contents for Icelandic rhyolite.

SE Rauðfossafjöll (explosive)

Figure 3: SE Rauðfossafjöll

Method

Volatile concentrations were measured using the Ion Microprobe Facility at the University of Edinburgh.

We probed matrix glass as well as melt inclusions to determine the post- and pre- eruptive volatile contents respectively.

We applied formulas[11] to model open and closed system degassing and also looked at vesicle and microlite textures as these also shed light on degassing paths[3,12].

Results: Pre-eruptive volatile content

Ion-probe data indicates that explosively produced samples have a higher pre-eruptive water content (Fig 5c, 5d) than effusively produced samples (Fig. 5a, 5b). These values (up to 5.1 wt%) are significantly higher than the expected values for Icelandic rhyolite, which is described in the literature as being 'dry'[13,14].

Water-poor matrix glass (Fig. 5) suggests that the water-richness of melt inclusions is not due to hydration.

Our results show that as well as being water-rich, explosive samples are also Cl-poor. Whereas the opposite is true for effusive samples (Fig. 6). This could reflect differences in degassing paths.

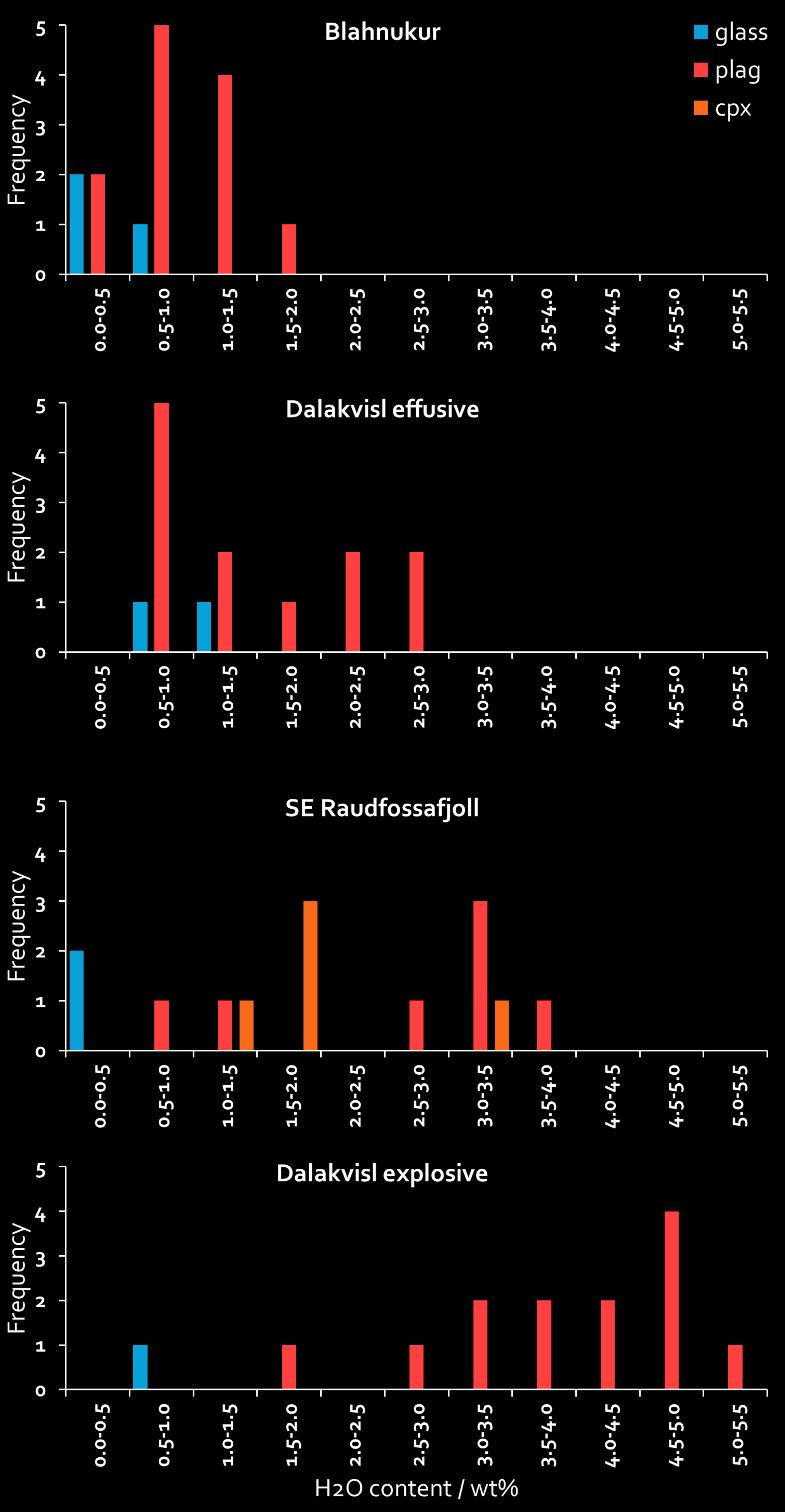

Figure 5: Water contents of melt inclusions in feldspar (pink) and pyroxenes (orange) and of matrix glass (blue) from (a) Bláhnúkur, (b) effusive parts of Dalakvísl, (c) SE Rauðfossafjöll and (d) explosive parts of Dalakvísl.

Discussion: Degassing paths

Modelled open and closed system degassing paths[11] have been compared with H_2O-Cl relationships but no significant distinction was found (Fig. 6). However, effusive samples require a much higher (>50) Cl distribution coefficient (D_{Cl}) than explosive samples (<30).

Increases in D_{Cl} can occur due to microlite growth[12]. Geochemical data shows that for the effusively erupted Bláhnúkur, there is a significant difference between melt inclusion and matrix glass data (Fig. 7) which could be attributed to microlite growth, but for the more explosively erupted Dalakvísl, there has been little change in chemistry.

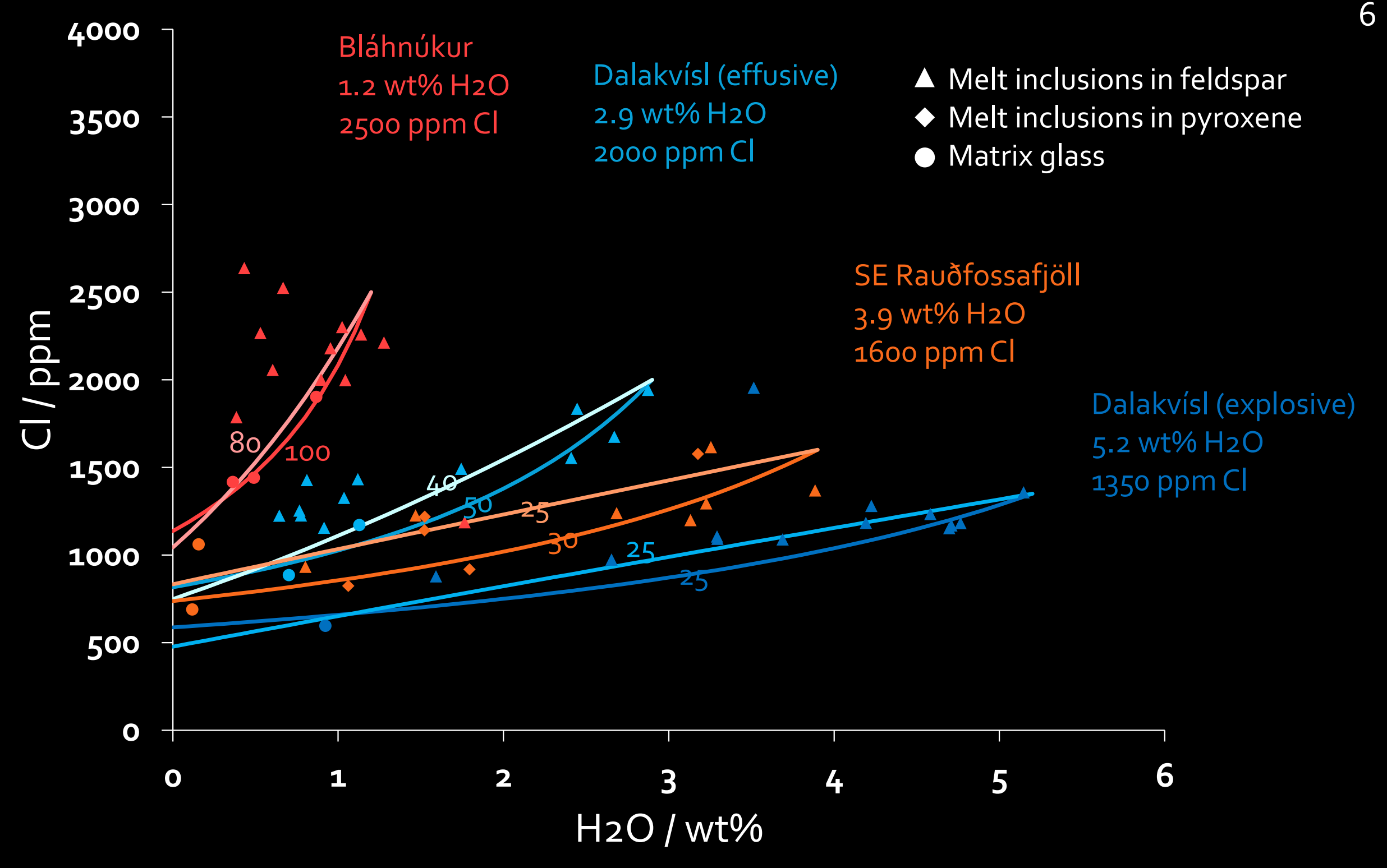

Figure 6: H_2O content plotted against Cl content. Different symbols represent host material, different colours represent sampling location. For each location, we assigned an initial H_2O and Cl content (as labelled) and used this to model open (pale line) and closed (dark line) system degassing. The numbers overlying each degassing path show the D_{Cl} used to create the best fit to our data.

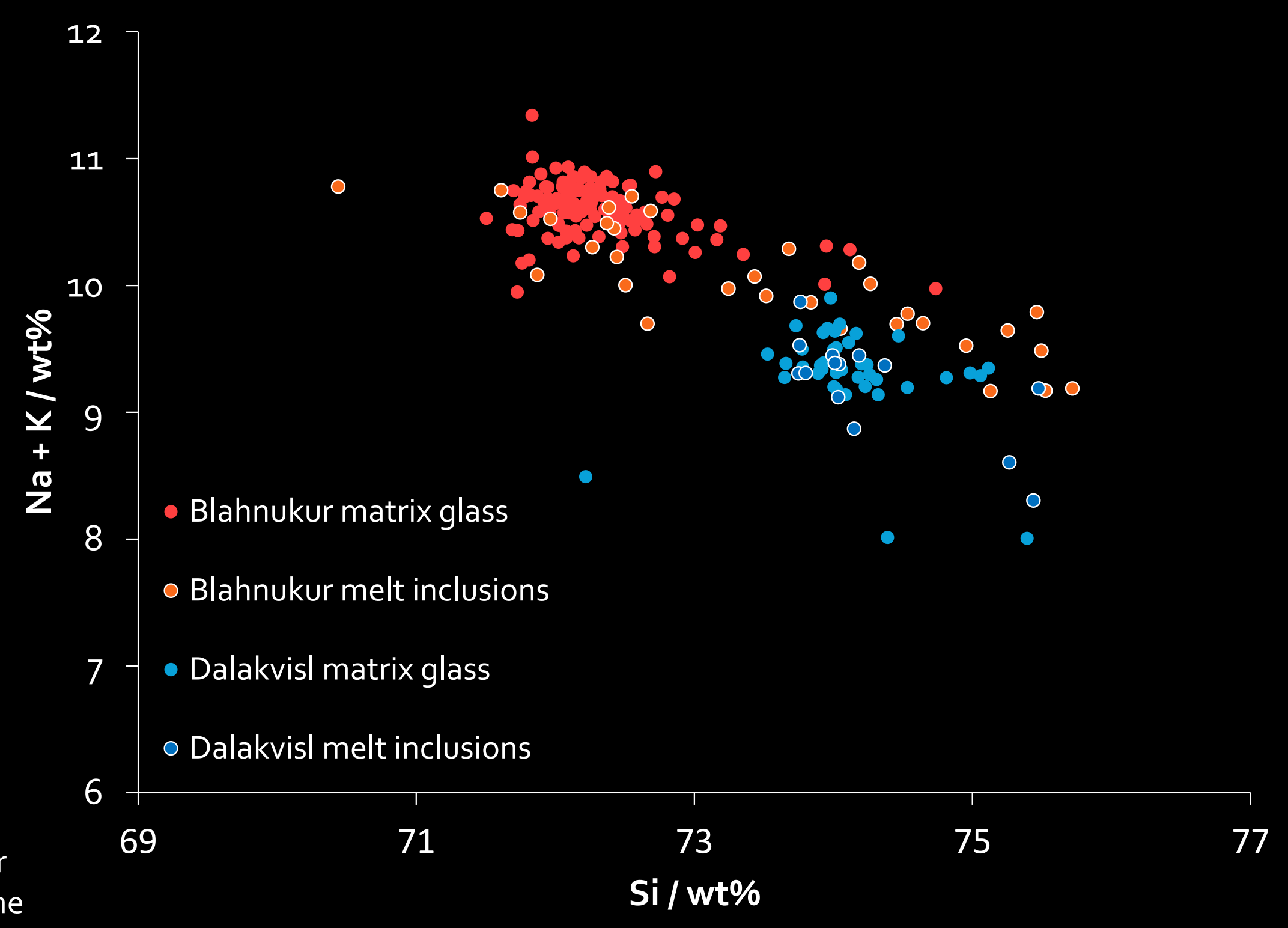

Figure 7: A total alkalis vs silica (TAS) plot, showing electron microprobe (EMPA) data, of samples from Bláhnúkur and Dalakvísl distinguishing between melt inclusion and matrix glass data.

Thin section images (Fig. 8) confirm that effusive samples are microlite-rich and explosive samples are microlite-poor.

Microlite growth is associated with slow rise speeds and open system degassing; a lack of microlites suggests fast ascent and closed system degassing[3,12].

We use the contrasting D_{Cl}s (Fig. 5), geochemcial changes, or lack there of (Fig. 6) and textural evidence (Fig. 7) to suggest that our effusive samples experienced slow ascent rates and open system degassing, whereas our explosive samples experienced fast ascent rates and closed system degassing.

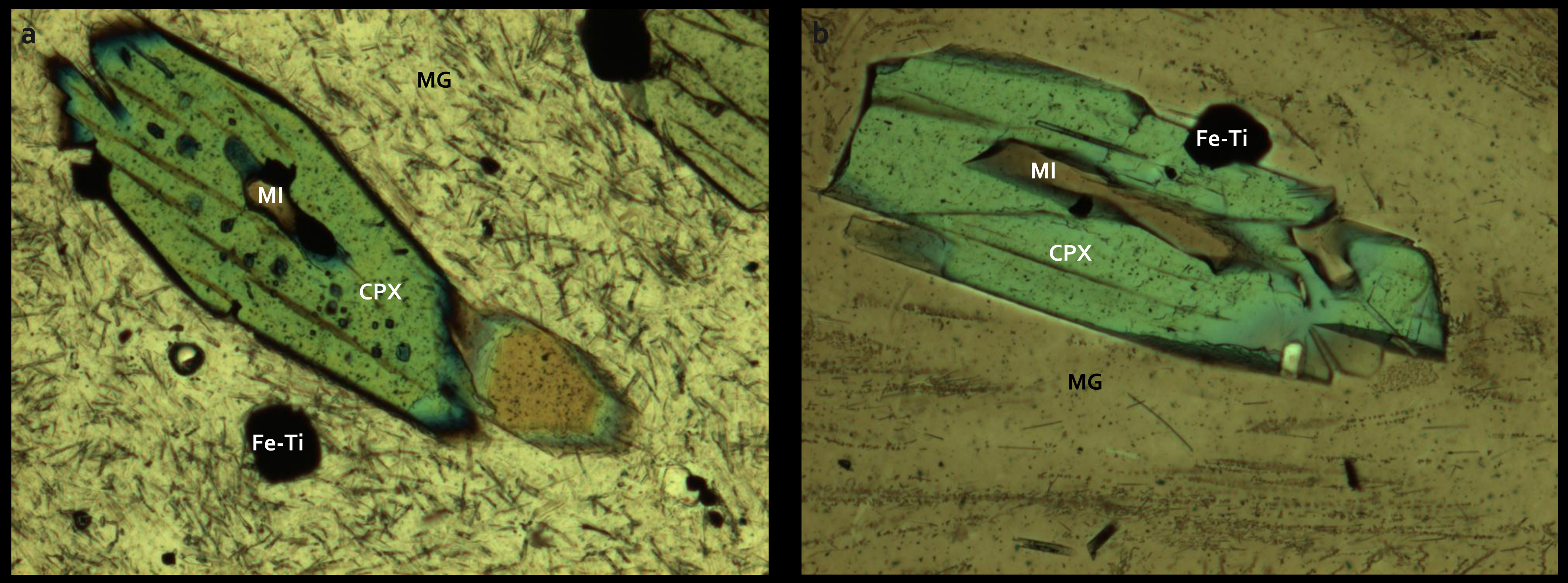

Figure 8: Typical thin section images (600 μm across) from (a) Bláhnúkur (b) SE Rauðfossafjöll. CPX: clino-pyroxe phenocryst, MI: melt inclusion, Fe-Ti: Fe-Ti oxides, MG: matrix glass which is microlite-rich in Fig. 8 (a) and microlite-poor in Fig. 8 (b).

Conclusion

Our data suggests that explosive subglacial rhyolitic eruptions are associated with high pre-eruptive water contents and closed system degassing whereas effusive eruptions have low pre-eruptive water contents and open system degassing.

Thus it seems that during subglacial rhyolitic eruptions, volatiles play a similar role as they do in subaerial eruptions i.e. the presence of ice has little effect on the role of volatiles.

Our data shows that Icelandic rhyolite may be significantly more water-rich than previously thought; and this provides a recipe for highly explosive activity.

This story will be coming soon to a journal near you…

References

1 D. W. McGarvie (2009) *J Volcanol Geotherm Res* **185**, 367-389
2 H. Tuffen *et al.* (2008) *Bull Volcanol* **70**, 841-860
3 C. Martel *et al.* (1998) *Earth Planet Sci Lett* **156**, 89-99
4 H. Tuffen *et al.* (2001) *Bull Volcanol* **63**, 179-190
5 M. T. Guðmundsson (2005) *Dev Quat Sci* Vol. 5: 127-151
6 B. Zimanowski *et al.* (1991) *J Volcanol Geotherm Res* **48**, 341-358
7 A. Austin-Erickson *et al.* (2008) *J geophys Res* **113**, B11201
8 H. Tuffen *et al.* (2002) *Geol Soc Spec Pub* No. 202: 213-236
9 J. Owen *et al.* (2012 (in press)) *Bull Volcanol*
10 J. Owen *et al.* (in review) *J Geophys Res*
11 M. C. S. Humphreys *et al.* (2009) *Geochim Cosmochim Acta* **73**, 5693-5708
12 B. Villemant *et al.* (2008) *Earth Planet Sci Lett* **269**, 212-229
13 H. Sigurdsson (1977) *Nature* **269**, 25-28
14 R. MacDonald *et al.* (1990) *J Petrol* **31**, 429-459