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

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Reconstructing palaeo-ice thicknesses during ancient volcanic eruptions is useful for understanding the link between ice thickness and eruptive behaviour and, if ages are known, for reconstructing palaeo-environments. In the past, palaeo-ice thicknesses have been determined from the subglacial to subaerial transition of tuyas, which has limited ice thickness reconstructions to emergent volcanoes. However, the new millennium saw the birth of the magma-degassing technique, where in theory, palaeo-ice reconstructions could be determined from any type of subglacial eruption, based on water content measurements on glassy samples[1].

This presentation tests the fidelity of this statement by applying the magma degassing technique to three contrasting rhyolitic edifices from Torfajökull, Iceland[2] thought to have been emplaced in the same eruption under very similar ice thicknesses. The eruption also produced numerous tuyas, so lithofacies transitions provide independent palaeo-ice thickness estimates. The eruption products at SE Rauðfossafjöll, Dalakvísl & Kakafjall are very different, suggesting three contrasting eruptive behaviours: explosive, transitional and effusive respectively. The application of the magma degassing technique only resulted in a successful reconstruction of the palaeo-ice thickness for Kakafjall.

SE Rauðfossafjöll is a tuya and seems to have fully degassed to atmospheric conditions, even for the samples erupted subglacially, suggesting that rhyolitic tuyas may not be suitable for the magma degassing technique. Dalakvísl was a mixed eruption, but the transition in style seems to have complicated issues as the magma degassing technique produces two palaeo-ice thicknesses; one associated with the effusive phase and the other with the explosive. Quantitative estimates are also impossible at Dalakvísl, due to an apparent loading by hyaloclastite as well as ice.

For Kakafjall, however, and for the first time in the history of the magma degassing technique, a single, quantifiable palaeo-ice thickness can be produced using the magma degassing technique. This value is in close agreement with estimates from lithofacies transitions at nearby tuyas formed in the same eruption. This suggests that in the interests of obtaining a quantifiable palaeo-ice thickness, the magma degassing technique can only be applied to small volume, effusive edifices that have had little/no erosion such as Kakafjall. This is not to say, however, that the magma degassing technique should not be used on other types of edifices as it has many secondary uses[3] such as identifying alternative loading conditions, degassing scenarios and potential triggers for changes in eruptional behaviour such as the depressurisation that seems to be associated with the transition in style at Dalakvísl.

[1] Tuffen et al. (2010) Earth-Sci Rev, 99: 1-18
[2] McGarvie (2009) JVGR, 185(4): 357–389
[3] Owen et al. (in review) Bull Vol.