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The use of magmatic water to reconstruct palaeo-ice thicknesses during subglacial rhyolitic eruptions

Jacqueline Owen (1), Hugh Tuffen (1), Dave McGarvie (2), Harry Pinkerton (1), and Lionel 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

Magma degassing patterns can potentially be used to reconstruct ice thicknesses during subglacial eruptions, as the pressure dependence of water solubility in silicate melts is reasonably well constrained. The amount of water remaining in the quenched bulk glasses should record the quenching pressure, which, in a subglacial setting, will be dependent on the pressure of overlying ice and/or meltwater that was present. This reconstruction technique has been applied to several basaltic volcanoes[1]. In one study the dissolved water contents was seen to vary as a function of altitude, consistent with the presence of an ice sheet[2]. Similar techniques have been applied to a rhyolitic volcano, as described below.

Bláhnúkur is a small-volume rhyolitic, subglacial volcano at Torfajökull volcano, southern Iceland[3] that erupted at ~95 ka[4]. 45 glassy lava samples were collected from a variety of elevations and lithofacies types. These samples were analysed for water content using infra-red spectroscopy (FTIR), and pressure-solubility relationships were calculated using VolatileCalc[5].

The results reveal a general decrease in water concentration with elevation, consistent with the presence of an ice sheet with a surface elevation of ~1,050 m a.s.l.. This corresponds with an ice thickness of ~450 m, consistent with the field evidence from tuyas of a similar age within the same region[6]. Furthermore, the results suggest an eruptive temperature of 850°C and 0 ppm CO2. However, not all samples agree with this overall trend. We suggest that samples with anomalously low water contents could have formed in regions where there was meltwater drainage which lowered the quenching pressure[7]. By contrast, water-rich samples could reflect intrusive formation resulting in loading by rock as well as ice[8]. Crucially though, the anomalous values are all from the same locations, suggesting that there are processes that are specifically affecting certain localities.

In order to use palaeo reconstruction methods, certain conditions need to be met. Whilst no hydration or devitrification has occurred in any of the analysed samples, some are vesicle-free and therefore show no evidence of the degassing that is needed for volatile concentrations to reach equilibrium with the ambient pressure[1]. Interestingly, the samples that are vesicle-free are those with lower than expected water contents. Perhaps, these samples have not degassed because they had negligible pre-eruptive water contents. This provides a further explanation for the anomalously low values.

The results confirm that volatile degassing can be used to reconstruct palaeo-ice thicknesses in subglacial rhyolitic volcanoes and that they have the potential to reveal processes involved in the formation and subsequent modification of the edifice. Although there clearly are some limitations to the use of degassing to reconstruct palaeo-ice thicknesses (for example knowing the influence of other volatile species on the solubility of water[1]), the results to date are promising. Measurements are currently being carried out on other subglacial rhyolite edifices in Iceland. In the long term it is hoped that this may lead to advances in our knowledge of the role of degassing in controlling the explosivity of subglacial rhyolitic eruptions.

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