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Problems and advances in the use of magmatic degassing during subglacial eruptions to reconstruct palaeo-ice thicknesses

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The degassing of magmatic volatiles during eruptions beneath ice sheets and glaciers, as recorded by the dissolved volatile content quenched in volcanic rocks, could provide powerful new constraints on former ice thicknesses in volcanic areas. As volcanic rocks are readily dateable using radiometric methods, subglacial volcanoes may therefore provide crucial information on Quaternary palaeo-environmental fluctuations. The use of a degassing-based reconstruction technique would be particularly valuable when studying deposits that were erupted entirely subglacially and therefore lack other diagnostic indicators of ice thickness such as subglacial-subaerial transitions.

In order for magma degassing to potentially record palaeo-ice thicknesses a number of factors need to be considered[1,2], which include whether non-equilibrium degassing may have occurred, whether samples have undergone post-eruption hydration, are strongly compositionally heterogeneous, or have moved post-quenching, whether the quenching pressure reflected loading by rock, ice or meltwater, and whether pressure may have deviated significantly from glaciostatic due to meltwater drainage. Degassing during individual eruptions may be considerably more complex than anticipated[2], making interpretation of results challenging. Examples from both rhyolitic and basaltic eruptions in Iceland and elsewhere will be used to illustrate these important factors.

The analytical techniques used to measure volatile concentrations need to improve on the common practise of using infra-red spectroscopy alone to determine H2O contents in one part of a sample. Multiple analyses are required to quantify the degree of heterogeneity within samples and techniques such as manometry, ion microprobe or electron microprobe are required to analyse other species (CO2, S, F, Cl). CO2 is particularly important as only trace amounts, beneath the detection limits of commonly-used analytical techniques (30 ppm), strongly affect the solubility-pressure relationships of water in silicate melts[1]. Measurement of the initial volatile contents of magmas, as recorded in melt inclusions, is also needed to provide full insight into the degassing path from the chamber to the surface.

More evidence for non-glaciostatic pressures and abrupt changes in pressure during subglacial eruptions needs to be gathered from detailed measurements of volatile concentrations and combined with geological evidence for changes in subglacial meltwater drainage. Studies of deposits with good secondary constraints on ice thickness (from direct observations of recent eruptions or other geological evidence for ancient eruptions) are also required in order to assess the reliability of using volatile degassing to reconstruct palaeo-ice thicknesses. We are beginning to gain limited understanding of the behaviour of magmatic volatiles during subglacial eruptions, and to realise their potential for palaeo-environmental reconstructions. However, there remain many substantial and fundamental gaps in our knowledge that must be addressed in future research.

[1] Tuffen, H., Owen, J., Denton, J. S. (2010) Magma degassing during subglacial eruptions and its use to reconstruct palaeo-ice thicknesses. Earth Science Reviews, in press.

[2] Owen, J., Tuffen, H., McGarvie, D. W., Pinkerton, H., Wilson, L. The use of magmatic water to reconstruct palaeo-ice thicknesses during subglacial rhyolitic eruptions. Poster presentation, this session.