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Volatile concentrations in variably vesicular pyroclasts from the Rotongaio ash (181 AD Taupo eruption): did shallow magma degassing trigger exceptionally violent phreatomagmatic activity?

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Measurement of dissolved volatile concentrations in pyroclasts has formed the basis of our understanding of the links between magma degassing and the explosivity of silicic eruptions[1]. To date these studies have focussed exclusively on the densest pyroclastic obsidians, which comprise on a tiny proportion of the erupted products, in order to bypass the difficulty of analysing vesicular material. As a consequence, crucial information is missing about how degassing in the densest clasts relates to the behaviour of the bulk of the magma volume.

To overcome this shortcoming, the volatile content of variably vesicular pyroclasts from the Rotongaio ash has been analysed using both micro-analytical (SIMS, synchrotron FTIR) and bulk techniques (TGA-MS). The Rotongaio ash was an exceptionally violent phase of phreatomagmatic activity during the 181 AD rhyolitic eruption of Taupo (New Zealand), the most powerful worldwide in the last 5000 years. The Rotongaio phase involved opening of new vents beneath Lake Taupo and the ash is characterised by a wide range of clast vesicularities (<10 to ∼80 % by volume).

Volatile measurement was challenging due to the high bubble number densities and small clast sizes. The mismatch between the water content of matrix glasses measured using bulk and micro-analytical techniques reflects pervasive post-eruption hydration of vesicle walls, which is most problematic at high vesicularities. Micron-scale maps of water concentration variations around vesicles in 30–50 vol % vesicular samples were acquired using SIMS. They indicate strong hydration within ∼5 microns of vesicle walls, with pockets of unhydrated glass remaining in the thickest septa. Analysis of these unhydrated domains allowed robust measurement of water contents in pyroclasts ranging from ∼1 to >50 vol % vesicles. Matrix glasses had largely degassed (0.19–0.49 wt % H2O, compared with an initial concentration in melt inclusions of ∼3.6 wt %). The water contents measured using SIMS decreased systematically with increasing magma vesicularity.

These results are fit well by a simple magma degassing model, in which a batch of magma first undergoes partial open-system degassing to a uniform water concentration of ∼0.4 wt % H2O. Vesiculation then occurs with closed-system degassing, creating a negative relationship between vesicle content and the water content remaining in the melt. This model is consistent with the intrusion of a shallow cryptodome beneath Lake Taupo (depth ∼100–200 metres) and prolonged stalling of magma at this shallow level. This was then followed by abrupt magma ascent and vesiculation, accompanied by interaction with the overlying lake water.

Recent experiments have shown that the most violent interactions between rhyolitic magma and water may occur when the magma is highly viscous and prone to shear failure, as this creates the initial surface area for magma-water contact that results in explosive fuel-coolant interaction. The accumulation of a large volume (∼1 km3) of degassed, highly-viscous rhyolitic magma directly beneath Lake Taupo may have therefore caused the exceptionally violent magma-water interaction that occurred during the Rotongaio phase. This reveals new links between magma degassing and the explosivity of eruptions when external water is involved, and illustrates the value of analysing pyroclastic material spanning a wide range of vesicularity in order to better reconstruct

degassing systematics.

References

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