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Physical constraints for effective magma-water interaction along volcanic conduits during silicic explosive eruptions

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Aravena et al. (2018) breathed fresh air into understanding the role of external water in silicic phreatomagmatic eruptions with their hypothesis that significant involvement of external water is only feasible *above* the level of primary fragmentation of the magma. We discuss here strong supporting evidence that primary fragmentation does not involve external water from the microtextures of the pyroclasts erupted from the two 'type' examples of large-scale interaction of silicic magma with external water.

In both the Askja (Iceland, A.D. 1875) and Taupo (New Zealand, A.D. 181) eruptions, 'wet' phreatomagmatic (phreatoplinian) phases involving interaction with external water are enclosed by pyroclastic units of 'dry' or magmatic origin (Fig. 1). Askja phreatoplinian unit C lies between subplinian unit B and Plinian unit D; i.e., in a succession of increasing eruptive intensity. Taupo phreatoplinian unit 3 lies within a similar escalating sequence between moderate Plinian unit 2 and powerful Plinian unit 5. All of these phases erupted rapidly vesiculating viscous magma (a second phreatomagmatic unit at Taupo unit 4 is from a different vent erupting largely outgassed magma). These phases were used to frame the definition of a new eruption style called 'phreatoplinian' by Self and Sparks (1978).

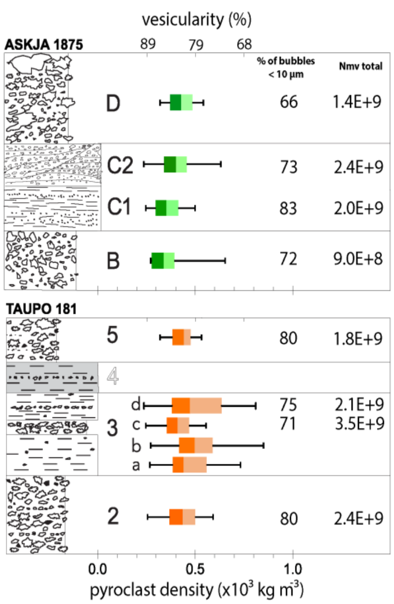

Figure 1. Left: Proximal stratigraphy of the Askja A.D. 1875 and Taupo 181 eruptions, after Carey et al. (2009) and Houghton et al. (2010). Center: Density data for the principal pyroclastic fall products of the Taupo and the Askja eruptions. Box-and-whisker plots for the density/vesicularity analysis of all diameters. Boxes and whiskers represent the 25th–75th and 5th–95th percentile intervals, respectively. The color change within the boxes represents the mean density. Corresponding vesicularities are plotted on the upper axes, calculated with the method of Houghton and Wilson (1989) using a dense rock equivalent (DRE) of 2350 kg/m^3. Right: Percentage of vesicles in each clast <10 µm in diameter, and vesicle number densities expressed as vesicles per cm^3.

Aravena et al. remark that "phreatomagmatic eruptions have been traditionally related to low vesicularity indices (<40%) and broad vesicularity ranges in the pyroclastic products...". This is *not* the case for unit C at Askja and unit 3 at Taupo. There are no differences statistically between the microtextures of the phreatoplinian pyroclasts and those of the enclosing dry magmatic units, in terms of vesicle size or number density. Perhaps the most telling similarity lies in the very high abundance in every sample of very small vesicles, which realistically represent a subpopulation that formed only immediately prior to primary fragmentation. For example, for Askja, vesicles with equivalent radii <10 µm form 73% and 83% of the vesicle populations in the phreatomagmatic pyroclasts, and 66% and 72% in the subplinian/Plinian pyroclasts. For Taupo, vesicles with equivalent radii <10 µm form 71% and 75% of the populations in the phreatomagmatic pyroclasts, and 80% in the subplinian/Plinian pyroclasts. Vesicles with equivalent radii <100 µm form 99% of the populations in all clasts. By analogy to Gonnermann and Houghton (2012), it seems this subpopulation of small vesicles probably nucleated and grew to their final size within a few hundred milliseconds of quenching and fragmentation.

Thus, in all episodes, the magma fragmented during the peak of an episode of rapid ascent and vesiculation. We have previously interpreted the vesicularity data (Carey et al., 2009; Houghton et al., 2010) as powerful indirect evidence of a similarity of fragmentation mechanisms in the wet and dry phases of these two eruptions.

In both sets of the phreatoplinian deposits, there *is* evidence of ample involvement of external water in transport (near-vent abundance of fine–very fine ash, abundant aggregates of fine ash particles) but *not at* primary fragmentation. This initiated 'flushing' and premature deposition of fine ash, and the formation of accretionary ash aggregates. There is clear evidence at Taupo for a source of abundant *surface* external water during the eruption (Walker, 1981), in the form of the ancestral Lake Taupo whose dimensions rivaled those of the 200-m-deep modern lake. The situation is more equivocal at Askja, as only a shallow water-filled depression was present in the caldera region prior to the eruption.

A key issue for more investigation is whether flashing of the external water to steam also fundamentally changed the grain size of the erupted pumice, by promoting a secondary fragmentation in the conduit and/or plume, as opposed to whether its role was limited to influencing processes of transport and deposition of unmodified preexisting clast populations fragmented by vesiculation.

In summary, an intriguing consequence from Aravena et al.'s study is that neither of these 'type' phreatoplinian eruptions can be termed phreatomagmatic in the true sense of the word because the contact of external water was not with magma but rather with a two-phase gas/pyroclast mixture. Perhaps the alternative name 'hydrovolcanic' is the only acceptable alternative?

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