Bubble morphologies, gas escape and fragmentation of crystal-rich magma

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Hydrous intermediate and mafic magmas commonly erupt with abundant microlites that crystallized as volatiles exsolved during ascent. Both natural and experimental samples show that crystal-rich groundmasses are associated with substantially thicker bubble walls and more complex bubble morphologies than crystal-poor melts. The physical and chemical relationships between co-evolving bubbles and crystals are complicated. Here we combine observations from three-phase (gas, viscous liquid, solid particle) analogue experiments and textures of scoria from Fuego Volcano (Guatemala; October 14 and 17, 1974) to examine the effects of crystals on bubble morphologies, and their role in gas escape and fragmentation of crystal-rich magma.

The Fuego samples are extremely crystal-rich: in a typical basaltic scoria erupted Oct.14 1974, we find a matrix of 61 vol% microlites, which together with the phenocrysts gives a total crystallinity of 70 vol% on a vesicle-free basis. As is common for crystal-rich scoria, the bubbles are non-spherical and often polylobate. Similar bubble morphologies have been ascribed to extensive bubble coalescence, with implications for interpretations of bubble number densities and ascent conditions. However, our analogue experiments and analysis of bubble textures in rims and cores of lapilli, indicate that bubble expansion is sufficient to generate polylobate bubbles in crystal-rich suspensions (which can be further modified by bubble coalescence).

High crystal contents and thick bubble walls resist bubble expansion, promoting bubble overpressure. Analogue experiments indicate that if there is sufficient gas pressure, there is a transition from lobate bubbles to fracturing as the crystal content approaches maximum packing, and if crystal distribution is inhomogeneous, the fractures tend to propagate through regions of relatively high crystallinity. Such inter-crystal fracture networks would aid degassing as magma ascends and could play a role in the fragmentation of magma to ash and lapilli.

Fragmentation of crystal-poor silicic magma occurs if gas is unable to escape sufficiently quickly to prevent overpressured bubbles breaking the magma apart. For this reason, deposits from silicic Plinian eruptions contain abundant fine ash composed of bubble wall remnants, and the total deposit ash size distribution is closely related to the bubble-size distribution determined from co-erupting pumice. In contrast, the size distribution of fine ash from the well-characterized Oct. 14 1974 subplinian/vulcanian Fuego fallout deposit correlates with the crystal- rather than bubble-size distribution measured in scoria, suggesting a strong control of crystals on the production of the fine ash. The groundmass crystals are both smaller and much more abundant (by number) than the bubbles. There is a substantially larger median grain size (mm-scale) on a volume (mass) basis, which may be related to phenocrysts as well as bubble textures.