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The role of H_2O in controlling the eruptive behavior observed during 2008 Chaitén eruption

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Although highly explosive and with the capacity of producing impacts in a world-wide scale, the underlying mechanisms driving rhyolitic eruptions are not yet fully understood. The lower frequency of these events in comparison to intermediate composition and mafic magmatic eruptions has hampered observation-based studies of rhyolite activity in last century. But in 2008, the eruption of Chaitén volcano (Southern Chile), gave us the first view of a rhyolitic eruptive cycle, start to finish. After an initial explosive phase that lasted for 10 days, the vigour of the eruption decreased and gave way to an effusive phase that was characterized by the emplacement of a dome complex. Surprisingly, a transitional phase between them was identified, with the simultaneous occurrence of explosive and effusive activity (Pallister et al. 2013). During the eruption, vast amounts of glassy rhyolite bombs with H_2O contents ranging from 0.1 to 1.58 wt. % H_2O were produced (Castro et al. 2012).
It is already well known that H_2O is one of the main players involved in the evolution of rhyolitic systems and in the occurrence of explosive volcanic eruptions (eg. Zhang et al. 2007). In this study, we conducted 90 high-temperature, 1 atm experiments in order to constrain degassing systematics and resultant foaming/fragmentation behavior of magma residing in the last hundred meters of Chaitén's volcanic conduit.
By using cylindrical cores (4 x 10 mm) drilled from obsidian bombs and lava dome samples, isothermal experiments were performed at temperatures between 740° and 1030°C among the whole range of H_2O contents measured in the deposits. Due to the experimental design developed, the complete evolution of the experiments was possible to monitor through a sapphire window with high-speed and conventional video cameras.
Post-experiment video analysis has revealed 3 types of behaviors of the samples: a) expansion followed by equilibrium (constant volume), b) expansion followed by shrinking and c) expansion followed by explosive fragmentation. This last behavior was identified exclusively in samples with $H_2O \geq 1.2$ wt.%, and at temperatures higher than 880°C. For samples with $H_2O < 1.2$ wt.%, no fragmentation was observed, even at higher temperatures (up to 1030°C), well above the estimated pre-eruptive temperature ($\sim$825°C) of the 2008 Chaitén rhyolite (see Castro and Dingwell, 2009). In samples that did not experience fragmentation, porosities of up to 85% were measured. Experimental results show that foaming and fragmentation behaviors reflect the efficiency of degassing of the system and this in turn depends on H_2O content and temperature. We show that diverse vesiculation and fragmentation behaviors are the result of a complex interplay between H_2O exsolution, diffusion rates and consequent changes in viscosity. Ultimately foaming versus fragmentation behavior depends on variations in the Peclet number, which balances viscous and diffusion-controlled bubble-growth regimes.