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Experimental constraints on the origin of aphyric phonolitic magmas

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Large explosive phonolitic eruptions are commonly characterized by aphyric juvenile eruptive products. Processes leading to the origin of such large volumes of crystal-poor differentiated magmas are still uncertain. A large number of processes, indeed, may be invoked to explain crystal-melt separation (i.e. crystal settling, compaction, filter-press), but the efficacy of each process in generating significant volumes of aphyric eruptible magmas is questionable. Seeking for an answer, we have experimentally investigated crystallization in presence of a thermal gradient as a possible mechanism for the origin of large volume of differentiated aphyric melts. Our case study is the phonolitic volcanism of Sabatini Volcanic District (SVD), Central Italy. We used a natural tephri-phonolitic composition as starting material and performed thermal gradient-driven crystallization experiments in order to simulate the crystallization process in a thermally zoned magma chamber.

In the experimental products, crystallization degree and melt composition vary as a function of the thermal gradient. In particular, melt composition ranges from tephri-phonolitic (starting material) at the bottom of the charge (hottest and aphyric zone) to phonolitic at the top (cooler and heterogeneously-crystallized zone), reproducing the liquid line of descent observed in equilibrium experiments. Backscattered images of experimental products clearly evidence: i) the aphyric tephri-phonolitic melt region at the bottom of the charge; ii) a drop-shaped crystal clustering in the middle zone; and iii) large aphyric belts and pockets (up to 100 μm wide) of phonolitic melt, with large deformed-shaped sanidine occurring at their margin, at the charge top region. Intriguingly, these batches of aphyric phonolitic melt are separated from the highly crystallized zone by a thick mush of crystals (clinopyroxene+plagioclase).

According to our experimental data a mere crystal settling process cannot explain the upward accumulation of the aphyric phonolitic melt whereas the high viscosity of the crystalline region would limit the efficacy of compaction and filter-press mechanisms. Alternatively, the brittle behavior of the crystal framework (glass<10% vol.) could have lead to the instability of the crystal mush and to the abrupt extrusion of the interstitial glass forming the phonolitic belts and pockets. The occurrence of a fast and intense segregation of the interstitial melt is supported by abundance of deformed crystals of sanidine.

Textural features and phase relations observed in the experimentally-reproduced crystal mush are in good agreement with observations from crystalline ejecta emplaced in large phonolitic eruptions of SVD, representative of the crystallizing boundary layer of a phonolitic magma chamber.