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Solidification fronts in thermally zoned magma chambers: the case of Sabatini Volcanic District (central Italy)

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The thermal evolution of magma chambers and its effect on magmatic processes is of major interest for igneous petrology. Theoretical and experimental studies have demonstrated that magma crystallization occurs mostly at the peripheral, cooler regions of magma chambers, where the development of solidification fronts determine the physical evolution of the magmatic system and magma differentiation as well. Solidification fronts, indeed, represent the connection between subvolcanic and volcanic realms, linking the ipoabyssal crystallization of the magma body with the formation of shallow reservoirs, responsible for the eruption of large volumes of crystal-poor, silicic magmas. To explain the formation of these magmas, a mere process of crystal fractionation (thought as a settling of crystals) may result inadequate. Conversely, the extensive crystallization in the solidification front and consequent extraction of differentiated interstitial melt is more likely. When erupted, crystal-poor silicic magmas carry with them fragments of the solidification fronts where they originated, in the form of crystal-rich lithic enclaves. The textural and chemical variability of these rocks provide useful information on the crystallizing conditions in the solidification front, which can be used to constrain the mechanisms of differentiation and pre-eruptive conditions.
In this work, the phonolitic volcanism of Sabatini Volcanic District (central Italy) is considered as study case to investigate the formation and evolution of a solidification front. Lithic enclaves emplaced in the course of major explosive eruptions have been analyzed, and natural evidences have been combined with numerical models of the cooling process and experimental simulations of crystallization along temperature gradients. The textural heterogeneity of lithic enclaves reveals the variable crystallization conditions in the solidification front and indicates the coexistence of two magmas at different degree of evolution, produced during the in situ differentiation of the solidification front. This heterogeneity also accounts for efficient crystal-melt separation processes, responsible of the extraction and accumulation of crystal-poor, silicic melt either into isolated batches (i.e. silicic lenses) or voluminous reservoirs (i.e. silicic cap at the roof of the magma chamber).