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Dynamics and evolution of the plumbing system source of three major pumiceous eruptions in Dominica (Lesser Antilles): crystal system analysis and diffusion modeling on orthopyroxenes.

Clara Solaro (1), Hélène Balcone-Boissard (2), Georges Boudon (1), Caroline Martel (3), and Daniel Morgan (4)
(1) IPGP, Paris, France (solaro@ipgp.fr), (2) ISTeP, UPMC, Paris, France (helene.balcone_boissard@upmc.fr), (3) ISTO, Orléans, France (caroline.martel@cnrs-orleans.fr), (4) School of Earth and Environment, University of Leeds, Leeds, UK (d.j.morgan@leeds.ac.uk)

Modern volcanology studies have demonstrated that the crystal "cargo" of magmas can be used to unravel the dynamics of magmatic plumbing systems and constrain timescales of magmatic processes. Specifically, several studies focusing on large silicic eruptions (10 to 100 km3 DRE/eruption) have shown that crystal populations may be rapidly re-mobilized over short timescales of decades to centuries prior to eruption, making these systems more dynamic than previously believed.
We present a petrological study of three, major, pumiceous, dacitic eruptions produced on Dominica (Lesser Antilles Arc) in the last 50ky: Layou (∼50ka), Roseau (∼30ka) and Rosalie (∼20ka). We combine crystal texture and chemical analyses with modeling of diffusional relaxation of chemical gradients in orthopyroxene crystals. A systems analysis approach is used to decipher remobilization processes of crystals before each eruption, and to map the plumbing system evolution over time. Timescales are calculated by Fe2+-Mg interdiffusion modeling on selected orthopyroxenes, by inter-calibration of high resolution BSE-images and EMPA analysis profiles.
Textural analyses show that for each of the three eruptions about 80-85% of orthopyroxenes are unzoned, while about 15-20% exhibit normal, reverse and multiple zoning. Systems analysis of the zoned crystals reveals the presence of four different magmatic environments (ME): En46-51(ME1), En52-53(ME2), En54-58(ME3) and En59-63(ME4). During the eruptive history, the main magmatic environment, represented by the 80% of unzoned orthopyroxenes, moves from ME2 (for Layou and Roseau) to ME3 (for Rosalie), indicating a shift of the system to less-evolved compositions. For all eruptions, a main crystal transfer pathway can be identified between ME2-ME3, describing a progressive sinking of crystals from the main environment En52-53(ME2) to the less-evolved En54-58 (ME3), which receives crystals, and, by the Rosalie eruption, becomes the volumetrically most significant magmatic environment. Occurrence of ME4 (En59-63) in the Roseau and Rosalie eruptions further suggests a progression toward a less-evolved composition.
To assess timescales of these remobilization events, intra-crystalline diffusion has been modeled along the a- and b-axes of 22 zoned orthopyroxenes per eruption at the magmatic temperature of 850°C. Independently of the orthopyroxene zoning patterns, timescales for Layou and Roseau are of the same order of magnitude, showing that the crystal mobilization event occurred tens of years before each eruption.
We propose that orthopyroxene crystals of ME2 (∼80%, En52-53) represent the main crystallized mush body. About ten years before the Layou and Roseau eruptions, the intrusion in the system of a less evolved magma re-heats the system, extracting eruptible melt plus crystals from the mush and producing the zoning patterns in pyroxenes (En54-56 and En58-63 rims).