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Role for syn-eruptive plagioclase disequilibrium crystallisation in basaltic magma ascent dynamics

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Magma ascent dynamics in volcanic conduits play a key role in determining the eruptive style of a volcano. The lack of direct observations inside the conduit means that numerical conduit models, constrained with observational data, provide invaluable tools for quantitative insights into complex magma ascent dynamics. The highly nonlinear, interdependent processes involved in magma ascent dynamics require several simplifications when modelling their ascent. For example, timescales of magma ascent in conduit models are typically assumed to be much longer than crystallisation and gas exsolution for basaltic eruptions. However, it is now recognized that basaltic magmas may rise fast enough for disequilibrium processes to play a key role on the ascent dynamics. The quantification of the characteristic times for crystallisation and exsolution processes are fundamental to our understanding of such disequilibria and ascent dynamics. Using observations from Mount Etna's 2001 eruption and a magma ascent model we are able to constrain timescales for crystallisation and exsolution processes. Our results show that plagioclase reaches equilibrium in 1-2 h, whereas ascent times were $\sim$1 h. Furthermore, we have related the amount of plagioclase in erupted products with the ascent dynamics of basaltic eruptions. We find that relatively high plagioclase content requires crystallisation in a shallow reservoir, whilst a low plagioclase content reflects a disequilibrium crystallisation occurring during a fast ascent from depth to the surface. Using these new constraints on disequilibrium plagioclase crystallisation we also reproduce observed crystal abundances for different basaltic eruptions: Etna 2002/2003, Stromboli 2007 (effusive eruption) and 1930 (paroxysm) and different Pu'u' O'o eruptions at Kilauea (episodes 49–53). Therefore, our results show that disequilibrium processes play a key role on the ascent dynamics of basaltic magmas and cannot be neglected when describing basaltic eruptions. Quantifying the characteristic times for crystallisation and exsolution represents a major step towards a more complete, realistic and general model of basaltic volcanism