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Magmatic architecture and mush disintegration prior to the 2020-21 eruption of La Soufrière (St Vincent, Lesser Antilles)

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After more than 40 years of dormancy, La Soufrière (St. Vincent, Lesser Antilles) began extruding a highly viscous lava dome in late December 2020, which was destroyed upon transition to a major explosive eruption starting in April 2021. We present petrological data to characterise the eruptive products and reconstruct the initiation processes leading up to these events.

Bulk-rock SiO_2 contents range from 52.8 to 55.4 wt.%, classifying the lava dome and explosive products as basaltic andesite, the latter being slightly more mafic. Surprisingly, modal mineralogy (plag, cpx, opx, tmt, ol), crystallinity (45-50 vol. %), and mineral chemistry are identical for both phases of the eruption, indicating that the transition in eruptive style reflects outgassing efficiency during ascent. Pyroxene compositions are relatively homogeneous with interquartile Mg# between 71 and 74 for cpx and 67 to 69 for opx. On the contrary, plagioclase shows strong zonation with cores of An70-96 and overgrowth rims between An60-64, resulting from magma ascent and stalling at multiple crustal levels. Machine learning thermobarometry on cpx crystals shows that crystallisation predominantly took place between 10 and 13 km depth at 1020-1060°C, but also extended to deeper crustal levels of up to 20 km.

While pyroxenes are euhedral in crystal shape, calculation of Fe-Mg exchange coefficients reveals widespread disequilibrium between the groundmass and the crystal cargo. Using trends in melt compositions for historic eruptions from La Soufrière, we show that the crystals have most likely precipitated from basaltic andesite liquids that are distinct from the whole-rock composition. Disequilibrium between crystals and carrier melt, as well as the ubiquity of crystal mush fragments in the eruptive products, suggests that the eruption was heralded by the segregation of an andesitic melt that disrupted and entrained antecedent magma batches. Olivine diffusion timescales indicate that melt-mush interaction preceded the eruption by no more than a few years at maximum. Based on these findings, we propose a new conceptual model of the magma feeding system and melt mobilisation processes at La Soufrière with implications for the interpretation of monitoring signals.