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Zoned clinopyroxenes reflect magmatic processes and eruption triggers: constraints on the crustal architecture of an off-ridge ocean island (Terceira, Azores)

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Constraining the plumbing system and crustal architecture of volcanic systems is integral in understanding pre-eruptive processes. Early-forming minerals record changes in the magmatic environment in their crystal chemistry and clinopyroxene is a particularly good candidate as its composition is highly sensitive to crystallisation conditions, and its low chemical diffusivity preserves changes in the magmatic environment (e.g. magma recharge and mixing, ascent and decompression) over time. Here we show that clinopyroxene crystals from basaltic to mugearitic lavas track eruption triggers and pre-eruptive processes in the volcanic system of Terceira (Azores). By applying a range of techniques including SEM, in-situ analysis (EPMA and LA-ICP-Q-MS) and multi-element mapping (EPMA, LA-ICP-TOF-MS), we can interrogate clinopyroxene crystals to uncover the magmatic processes recorded within. Clinopyroxenes from Terceira show diverse textures including oscillatory, hourglass and abrupt zoning, any combination of the three (complex zoning), and both mottled and resorbed cores. Multi-element mapping illustrates that sector zoning is reflected in highly charged elements e.g. Al, Ti, Zr, Hf, and REE, while Cr and low charged cations e.g. Mn and Ni record multiple oscillatory zones. Chromium is highly compatible in clinopyroxene and its distribution reveals a complex history including multiple episodes of primitive magma intrusion at depth and mixing events in a more mature mush. Chromium rich rims reflect eruption-triggering mafic recharge events into a more evolved, mature mush, while crystals with relatively homogenous Cr-rich cores were entrained in a primitive magma travelling through the lower crust. Crystals with multiple Cr-rich zones may record periodic recharge. Chromium-rich zones can therefore be used as a means of reconstructing pre-eruptive history, which has important implications for volcanic hazard monitoring, and can help us to understand crust formation in ocean islands similar to Terceira. Thermobarometric results indicate a crustal architecture comprising a lower crustal storage zone (~15 km depth) from which primitive basalts rise and interact with mixed magmas in an increasingly mature crystal mush, and a shallower storage zone (mid to upper crust) where further differentiation occurs.