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Magma differentiation in volcanic conduits – the clinopyroxenite body of Fuerteventura (Canary Islands)

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Fractionation processes and magma differentiation/mixing occur at various levels during magma transportation through the crust. These processes are usually thought to occur in magmatic chambers or reservoirs into which magma stagnates before continuing to ascent and/or erupt. Here we discuss dynamic fractionation and magma differentiation processes in the plumbing system of an ocean island volcano.

Fuerteventura, Canary Island, allows insight into the root-zone of an alkaline ocean island volcano. The PX1 pluton is a 22 Ma-old vertically layered mafic intrusion emplaced at ca. 0.1 GPa. This body shows large- and small-scale alternations of cumulate assemblages evolving from ol-rich wehrlite to clinopyroxenite to gabbro. These cumulates are intruded by numerous dykes of various compositions and veins of more evolved melt. Dykes, veins, and the large scale lithological variations define a general NNE-SSW vertical layering within the pluton. In some areas free of layering, numerous wehrlitic and clinopyroxenitic enclaves appear in a slightly more evolved matrix revealing clear mixing features of crystal mushes. Neither horizontal layering nor marginal facies are observed within PX1. Thus, clinopyroxenites do not represent accumulation of crystals through gravitational settling in a magma chamber.

Compositions of cpx define a clear differentiation trend among all lithologies, from sp-bearing dunite (average cpx mg#: 85.99) to plg-ol- or kst-clinopyroxenites (mg#: 75.4). Chemically zoned cpx are present in all coarse-grained lithologies. They are characterised by a rather primitive resorbed core (higher Cr and Mg content), surrounded by a more evolved rim (higher Ti, Al and REE contents, similar to cpx in the matrix). Rims sometimes preserve clear oscillatory zoning and resorbtion features.

Cores are interpreted as inherited crystals from deeper levels, whereas rims are considered to have crystallized at the final emplacement level in the root zone of the volcano. We consider clinopyroxenites to represent phenocryst concentrations left behind porphyritic basaltic magmas rising through the volcano plumbing system. Variations in the degree of differentiation and temperature of the rising magma pulses would determine which mineral phases are crystallizing at a given time during magma migration; the latter would accumulate as phenocrysts or overgrow pre-existing grains of the surrounding crystallizing mush. As long as temperature is high, only cpx will crystallize. With decreasing T, plg and kst will co-crystallize. Voluminous cpx accumulations are thus expected to develop progressively. Successive magma pulses will percolate through a porous, although increasingly crystallized mush. This would lead to overgrowth and coarsening of early-accumulated cpx phenocrysts, as well as interstitial crystallization of plg and kst when stable. Rim oscillatory zoning of cpx would record successive high-temperature magma pulses injecting and percolating though the crystal mush structure. Relatively large volumes of porphyritic basalts are requested to transit through the plumbing system of the volcano to account for the large size and coarse-grained texture of the cpx cumulates. This process is expected to generate a high-heat flow, which is consistent with the spectacular contact aureole developed around PX1, in which gabbros remelted above 1000°C (Hobson et al. J. Pet 39, 1998).