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A new perspective on cumulate formation and melt extraction from mushy reservoirs: the "melt flush" model

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Volcanism is the surface expression of extensive magmatic systems, with their intrusive counterpart representing ~80% of the total magma budget. Our knowledge of igneous processes therefore largely relies on our understanding of deep plutonic processes. In continental or oceanic environments, most of the intrusive igneous rocks bear geochemical cumulate signatures (e.g., depletion in incompatible elements, enrichment in compatible ones) that are commonly explained by minerals-melt segregation during differentiation. Nevertheless, in many cases the processes aiding melt segregation still need to be further constrained.

In oceanic environments, deformation-assisted compaction aided by melt buoyancy is the main process involved in melt extraction. However, a number of cumulative rocks are lacking any clear compaction evidence, opening the potential for the involvement of other processes. Here, relying on current descriptions of melt dynamics within oceanic magma reservoirs, i.e. the mushy nature of the reservoirs and inferred cyclic replenishment by primitive melts, we propose the involvement of a new igneous process. In the "melt flush" model, repeatedly injected fresh melts hybridize within the injected mush triggering mineral dissolution and crystallization, and concurrent partial extraction of the former interstitial melt forced out of the system by the incoming melts aided by buoyancy.

This model is consistent with the widespread occurrence of reactive porous flow (RPF) identified in oceanic igneous systems, and matches the petrographical (e.g., olivine and plagioclase dissolution) and geochemical constraints (trace element signatures) brought by natural oceanic samples. More specifically, it has been shown that RPF proceeds following melt consuming reactions that ultimately result in a progressive closure of the mush porosity. The extraction of the evolved interstitial melts replaced by more primitive ones, and the porosity closure are here proposed to account for some of the cumulative signatures observed in igneous rocks. The "melt flush" model we describe eventually adds to the other processes involved in cumulates formation from various settings like magma compaction or crystal settling.