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Crystallization, re-melting and interstitial melt segregation in a mafic igneous complex (Unit 9, Rum layered intrusion, Scotland)

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In mafic magma chambers, olivine, plagioclase and clinopyroxene fractionate along the basaltic liquid line of descent. Olivine-rich, troctolite and gabbro cumulates crystallize. Hot primitive magma sills are regularly injected into igneous complexes where they heat and partially melt surrounding hot rocks, percolate, hybridize and crystallize new and secondary phases. Here, I quantify the effect of gabbro cumulate partial melting and hybridization with invading primitive basalt using field observations, clinopyroxene microtexture and core-rim geochemical profiles from the Rum sill complex (Scotland). In the Eastern Layered Series, the Unit 9 comprises an underlying lens-like body of peridotite overlain by a sequence of troctolite and gabbro (termed allivalite), with some local and minor anorthosite. Towards the extremity of the peridotite lens, the troctolite grades into a poikilitic gabbro, with clinopyroxene oikocrysts, forming an oblique channel into the overlying gabbro.

The poikilitic gabbros contain multiple generations of clinopyroxene, with Cr-rich (1.1 wt.% $Cr2O_3$), anhedral cores with moderate REE concentrations (core1) overgrown by an anhedral Cr- (0.7 wt.% $Cr2O_3$), Al-, Zr- and REE-depleted second generation (core2) with high Mg#, Eu* and Sr*. Plagioclase and olivine inclusions are small and randomly oriented. These composite cores are overgrown by a Cr- (0.2 wt% $Cr2O_3$), Al-, Zr- and REE-depleted rim with high Mg#, Eu* and Sr* (rim). Plagioclase and olivine inclusions are large and preferentially oriented parallel to the foliated troctolilitic groundmass. The groundmass plagioclase is reversely zoned. Fractional crystallization fails to explain the combined dissolution texture and incoherent compatible and incompatible elements zoning. We interpret these microstructures as a consequence of two separate episodes of partial melting triggered by the intrusion of hot olivine-phyric picrite sill to form the discontinuous lenses that comprise the Unit 9 peridotite. Gabbro cumulate partial melting experiments produces a clinopyroxene-depleted residue (i.e. clinopyroxene-poor gabbro, troctolite) and a melt that is saturated in clinopyroxene, depleted in Cr, Al, Zr and REE and with high SiO_2 and Mg# contents. REE-poor clinopyroxene rim crystallized from a hybrid basalt-gabbro magma, which has a lower REE and DREE. The poikilitic gabbro formed from clinopyroxene-saturated melt moving upwards and laterally through the cumulate pile, after efficient extraction from the compacted reacted crystal mush.

Gabbro partial melting products can be very difficult to distinguish from cumulates crystallized along the basalt liquid line of descent, because of the limited mineralogical and chemical contrast between gabbro and co-genetic basalt. Combining microtextural and geochemical studies is necessary. Relics of partially molten gabbro cumulate occur in hot spot, ridge and arc settings, showing it is certainly a widespread and important process.