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Late-stage melt migration in the Skaergaard Intrusion

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Layered intrusions provide an insight into the geochemical evolution of magmas, increasing our understanding of processes operating in solidifying mushes in the shallow crust. The well-exposed Skaergaard Intrusion of East Greenland offers a perhaps unparalleled example of closed-system behaviour and uninterrupted fractionation. The intrusion preserves a variety of well-known structures interpreted to record the behaviour of late-stage evolved liquids, such as gabbroic pegmatites, dendritic anorthosites, and melanogranophyres. Striking associations of irregular Si-rich and Fe-rich patches are interpreted as the remains of unmixed immiscible liquids. Previous studies of these late-stage features have been localised, focused on particular localities in the intrusion, and omit a consideration of the role of silicate liquid immiscibility in controlling the migration rates and pathways of late-stage liquids in the crystal mush. In this study, we present a synthesis of late-stage liquid behaviour in the Skaergaard mush, using field observations, bulk rock geochemistry and mineral chemistry to establish relationships between the different structures and to link their morphological and compositional variation to the physical properties of the crystal mush and the progressive evolution of the bulk magma.

The morphology of gabbroic pegmatite bodies is known to vary with stratigraphy through the floor cumulates, being irregular and podiform in the lowest stretches of the stratigraphy (in Lower Zone, LZ), but forming sharply-defined sills and dykes in the upper parts (in Upper Zone, UZ): this evolution was linked to changes in mush rheology (Larsen and Brooks, 1994). Newly developed methods to constrain mush thickness (Holness et al., 2017) show that this evolution is controlled by mush thickness: pegmatites are podiform in thick mush and planar in thin mush. Gabbroic pegmatites are spatially associated with paired Si-rich and Fe-rich lenses, which occur 5-10 metres stratigraphically above pegmatites in LZ, but at the same stratigraphic horizon in UZ. The paired lenses form irregular, approximately layer-parallel clusters in thick mush, but thin concordant dendritic structures within strongly foliated modally graded layers. The modal mineralogy of the paired lenses evolves upwards, consistent with experimental evidence for compositional evolution down the silicate liquid immiscibility binodal: below LZc the mafic component comprises olivine pyroxenite, but is dominated by oxides above LZb. In UZb pegmatites are melanogranophyric, and paired Si-rich and Fe-rich lenses are confined to localised horizons recording significant syn-magmatic disruption, consistent with the inferred evolution of the bulk magma towards the Si-rich side of the binodal.

These observations demonstrate that the physical properties of the mush control the movement of late-stage interstitial liquids, with implications for our understanding of the rheology of sub-volcanic mush and the mechanisms of melt segregation.

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Larsen, R.B. and Brooks, C.K., 1994. Origin and Evolution of Gabbroic Pegmatites in the Skaergaard Intrusion, East Greenland. Journal of Petrology, 35(6): 1651-1679.