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Solidification of interstitial melt in a gabbroic crystal mush: the Skaergaard intrusion, Greenland

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The Eocene Skaergaard intrusion of East Greenland occupies a box-shaped, fault-bounded chamber, approximately 8km × 11km × 4km, at the contact between Precambrian gneisses and a thick overlying sequence of Eocene plateau lavas. The intrusion is divided into three main units: the Layered Series (LS) which crystallized on the floor, the Upper Border Series (UBS) which crystallized from the roof, and the Marginal Border Series (MBS) which grew inwards from the vertical walls. The order of appearance of cumulus phases in the LS is considered to be: plagioclase + olivine (HZ, LZa) + augite (LZb) + Fe-Ti oxides (LZc) – olivine (MZ) + olivine (UZa) + apatite (UZb) + ferro-hedenbergite (UZc). The Marginal Border Series (MBS) is subdivided in an analogous manner to the LS into HZ*, LZa*, LZb*, LZc*, MZ*, UZa* and UZb*.

We measured plagioclase compositional profiles in the LS and MBS for major (EPMA) and trace (ion probe and LA-ICP-MS) elements. Plagioclase profiles in the MBS show a relatively simple pattern of continuously decreasing An-content from core to rim. Compatible trace elements evolve similarly to An, while incompatible trace elements continuously increase. In contrast, compositional profiles in the LS are highly complex. In the lowest stratrigraphic unit (LZa), the core of the plagioclase grains has a mantle of decreasing An-content with an external rim of constant composition at An55-58. Compatible and incompatible elements decrease and increase respectively from core to rim, signifying decoupling of major and trace elements in the external rim. In LZb, similar profiles are observed except that the external rim has a composition of An50-51. From LZc to UZa, plagioclase grains are mostly unzoned. However, where zoned they also show an external rim of constant composition, but this time at An40. From UZb to UZc, plagioclase grains are unzoned or show normal zoning without external constant composition rims.

We suggest that the external rims at An58, An50 and An40 in the LS reflect thermochemical changes within the crystal mush. An58, An51 and An40 correspond to the three plagioclase compositions at the successive appearance of cumulus clinopyroxene, Fe-Ti oxides and apatite along the Skaergaard liquid line of descent. Saturation of these phases in the intercumulus melt is thought to result in significant chemical disequilibrium between the intercumulus melt and the liquid in the main magma body. Chemical diffusion of some components, especially sodium, might result in rapid plagioclase growth, resulting in the constant composition rims. Thermal buffering due to the release of significant latent heat might also help in the diffusional process. Diffusion of trace elements probably did not occur or was very slow, explaining the absence of chemical buffering for trace elements in plagioclase rims. The absence of external rims of constant composition in the MBS, as opposed to what is observed in the LS, is perhaps related to the relatively high liquid/crystal ratio in the MBS compared to the LS.