The Skaergaard Intrusion and its Liquid Line of Descent

A new reference profile through the Layered Series of the Skaergaard intrusion has been established using GPR positioned surface samples collected during fieldwork in 2003 and mineral exploration core drilled in 1990 essentially in the same profiles as used by Wager and Deer (1939). The profile offers a detailed picture of the Skærgaard layered series. Cryptic variation was determined by electron microprobe analyses of the main minerals. Bulk cumulus compositions were analyzed by XRF and ICPMS. Modal variation was determined by least-squares approximations of bulk gabbro compositions to the constituent minerals.

Mineral Modal Variation. Cryptic variations reveal a systematic near linear decrease in plagoclase composition from An$_{90}$ at the base of the LZa and An$_{50}$ at the top of the UZc. In contrast, the mafic minerals (olivine and augite) show systematic upward increases in iron content that progressively become more marked in UZ. The compositions of olivine are affected by the appearance of Fe-Ti oxides in the Lz and shift towards more magmas compositions. The minor element Mn increases systematically in olivine and augite until UZc and the appearance of forsterite. The Al content in augite shows a systematic decrease while the Ti content remain constant until UZ where it systematically increases.

Mineral Modal Variation. Modal modes were calculated on a weight basis by least squares linear approximation of mineral compositions to bulk rock major element compositions. There is a systematic but irregular decrease in the proportion of plagoclase upsection from Lz to Uz. The boundary between Lz and Lz is marked by an abrupt increase in the clinopyroxene mode into Lz. The olivine mode is low throughout Lz while olivine is rare or absent in Mz. In Uz, olivine re-appears and increases sharply into Uz and UZc. The average gabbros of the LZa and LZb contain systematic low amounts of Fe-Ti oxides. The transition to the UZc appears to be gradual, with higher Mi of >16% ilmenite, and >8% magnetite reaching >25% ilmenite and <1% magnetite in the UZc. The magnetite/ilmene ratio in the gabbros is constant throughout the series (~0.5).

Liquid Line of Descent. The lack of knowledge of oxide modes in low temperature experimental investigations of the Skaergaard liquid line of descent has been a main hindrance for accurate predictions (Thy et al., 2006). The actual modes of oxides in the Skaergaard gabbros can instead be used to extrapolate to the low melt fractions of the UZ for which the phase relations and the $T-O_2$ variation remain uncertain. The forward modeling results revealed a fundamental conflict between the suggestion that the iron content of Skærgaard liquids increases during Fe-Ti oxide fractionation and the previous observation that at the same oxygen fugacity ($f_{O2}$) close to the FMQ buffer (Toplis and Carroll, 1996). Such a drop would require an unexpectedly high proportion of Fe-Ti oxides and high magnetite content in the fractionating assemblage that is not supported by the gabbros. It is suggested that the strong reduction in the UZc may be related to open system crystallization and exchange of oxygen between the crystalizing magmas and the host basalt.

Future Studies. The new petrographic understanding of the Skaergaard layered series allows accurate modeling of the liquid line of descent, crystallization, and solidification processes that have not been possible based on the existing information.