Geophysical Research Abstracts
Vol. 15, EGU2013-2583, 2013
EGU General Assembly 2013

Disequilibrium dihedral angles in layered intrusions: the microstructural record of fractionation

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The dihedral angle formed at junctions between two plagioclase grains and a grain of augite is only rarely in textural equilibrium in gabbros from km-scale crustal layered intrusions. The median of a population of these disequilibrium angles, Θcpp, varies systematically within individual layered intrusions, remaining constant over large stretches of stratigraphy with significant increases or decreases associated with the addition or reduction respectively of the number of phases on the liquidus of the bulk magma. The step-wise changes in Θcpp are present in Upper Zone of the Bushveld Complex, the Megacyclic Unit I of the Sept Iles Intrusion, and the Layered Series of the Skaergaard Intrusion. The plagioclase-bearing cumulates of Rum have a bimodal distribution of Θcpp, dependent on whether the cumulus assemblage includes clinopyroxene. The presence of the step-wise changes is independent of the order of arrival of cumulus phases and of the composition of either the cumulus phases or the interstitial liquid inferred to be present in the crystal mush. Step-wise changes in the rate of change in enthalpy with temperature (ΔH) of the cooling and crystallizing magma correspond to the observed variation of Θcpp, with increases of both ΔH and Θcpp associated with the addition of another liquidus phase, and decreases of both associated with the removal of a liquidus phase. The replacement of one phase by another (e.g. olivine ⇔ orthpyroxene) has little effect on ΔH and no discernible effect on Θcpp. An increase of ΔH is manifest by an increase in the fraction of the total enthalpy budget that is the latent heat of crystallization (the fractional latent heat). It also results in an increase in the amount crystallized in each incremental temperature drop (the crystal productivity). An increased fractional latent heat and crystal productivity result in an increased rate of plagioclase growth compared to that of augite during the final stages of solidification, causing a step-wise increase in Θcpp. Step-wise changes in the geometry of three-grain junctions in fully solidified gabbros thus provide a clear microstructural marker for the progress of fractionation.