

## Differentiation mechanisms in a sheet-like intrusion: Constraints from composition and microstructure in the Aosawa dolerite

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Homogeneous differentiation involving separation of crystals nucleated and grown in the main magma body of a crustal magma chamber and boundary layer fractionation involving compositional convection induced by crystal growth in the cooler marginal zone are thought to be the major differentiation mechanisms (e.g., Jaupart and Tait, 1995; Marsh, 1996). These contrasting differentiation mechanisms are linked to mechanisms of heat transfer: thermal convection and heat conduction, respectively, showing strong coupling between material and thermal transfer in a magma chamber. There is, however, no consensus about which mechanism is actually operated and its controlling factors determining the fate of magma chamber. This issue can be addressed by combining theoretical modeling and observation on a geometrically simple sheet-like intrusion, which records temporal change of the physical and chemical conditions of the magma system as sequential changes of composition and microstructure from the chilled margins to the last frozen zone. The aim of this study is to examine if magma in a sheet-like intrusion without bottom cumulate pile can be differentiated over the length scale of intrusion and which mechanism was operated if the magma was actually differentiated, which may serve as firm basis for theoretical treatment.

We examined one of dolerite sills in Aosawa area (Fujii, 1974), Yamagata prefecture, which is approximately 100m in thickness and is more than 5km in lateral extension. This intrusion is concordantly intruded into the late Miocene mudstone. The Aosawa dolerite is composed of plagioclase, clinopyroxene, olivine, and magnetite. The chilled margins contain olivine (5.3wt %) and plagioclase (1.9wt %) phenocrysts, but no clinopyroxene phenocryst is present. The mode and size of clinopyroxene increase from the upper contact toward the lower part, and rapidly decrease near the lower contact. Two types of clinopyroxene with different Cr<sub>2</sub>O<sub>3</sub> content coexist in the intrusion. The mode of olivine increases downward and reaches a maximum near the bottom as in the case of clinopyroxene. The size of plagioclase shows bimodal distribution: coarse ones range 1.0-2.2mm and fine ones 0.6-0.8mm in size. The coarse plagioclase is concentrated in the upper 20m showing downward increase in its size and mode, and is also slightly concentrated in the lower part.

Rocks near the chilled margin have essentially the same composition, and their average can be regarded as chemical composition of the intruded magma. The whole-rock elemental concentrations show systematic sill-scale vertical changes, and the average values are approximately the same as the estimated composition of the intruded magma. On the basis of these evidence, it is concluded that the intrusion was formed by one injection of a homogeneous magma including a few olivine and plagioclase phenocrysts. There are systematic correlations among concentrations of major and trace elements, although the maximum variation in SiO<sub>2</sub> is less than 3wt%. The TiO<sub>2</sub> contents show positive correlations with other incompatible element and negative correlations with compatible elements. The compositional vectors require addition or subtraction of clinopyroxene in addition to olivine and plagioclase present in the initial magma. The correlations are reflected in the systematic spatial variations over the sill thickness.

These petrologic and geochemical features of the Aosawa dolerite requires settling of augite crystals grown in situ in addition to olivine from the upper part to the lower part with suppressed settling of plagioclase crystals only in the upper part, and transportation of fractionated melt from the bottom boundary layer. It is concluded that, sill-scale magmatic differentiation in Aosawa dolerite is very limited, but was actually took place by combination of homogeneous fractionation and boundary layer fractionation.