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Chlorine as a tracer of aqueous fluid in a crystallizing magma reservoir: a geochemical study of the Murotomisaki Gabbro

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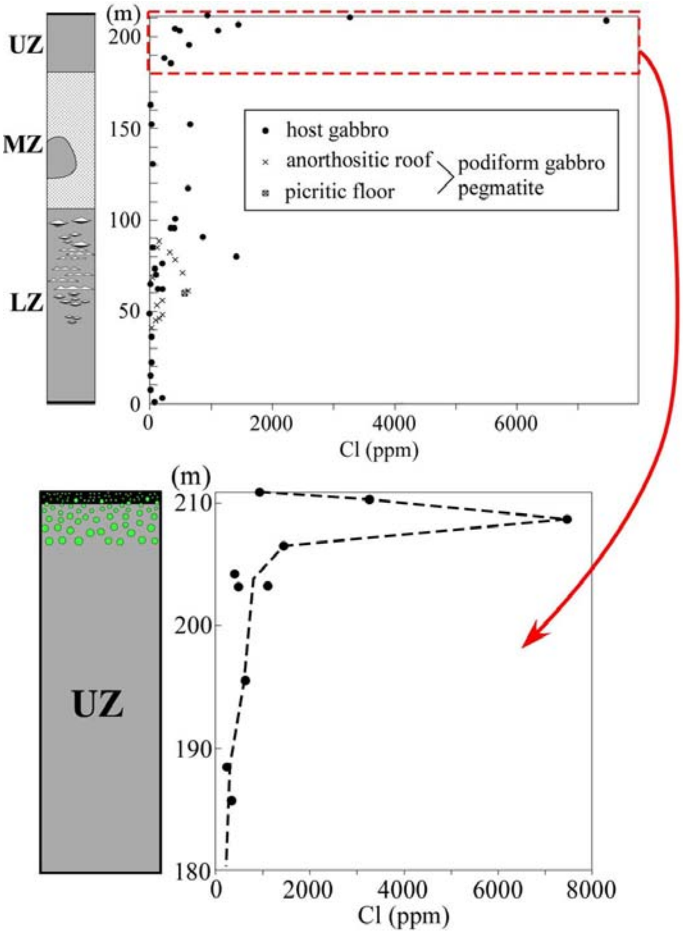

In a solidifying magma chamber, the role of generation and migration of magmatic fluids on the magma processes is important. We found a significant variation in bulk Cl contents in the Murotomisaki Gabbroic Intrusion (MGI; 220m thick) and on the basis of geochemical and petrological analyses that Cl is a useful tracer of magmatic fluids.

The MGI is a sill-like layered intrusion emplaced in a Tertiary sediment near the Cape Muroto, Shikoku, Japan. The intrusion is divided into three major stratigraphic zones: the Lower Zone (LZ; Ol-rich gabbro), the Middle Zone (MZ; coarse gabbro, Ol-free) and the Upper Zone (UZ; Ol-poor gabbro). The LZ can further be subdivided into lower, crystal-accumulation zone (AC) and upper, crystal-growth zone (GR). The AC zone was formed by Ol-phenocryst accumutation and the GR zone resulted from the overgrowth of olivine. While the AC zone is rather massive, the GR zone has various inhomogeneous structures, like pegmatites and fine-scale modal layering. The detailed analysis of plagioclase zoning shows that the plagioclase from the host gabbro of the GR zone has euhedral calcic cores, while those from the pegmatites have significantly resorbed calcic cores. In both types, the calcic cores are surrounded by a sodic mantle. On the basis of observations of resorbed and zonal structures of the plagioclase, we discussed that the formation of pegmatites in the GR zone had occurred by dissolution of plagioclase as a result of an increase of water pressure brought by migration and dissolution of aqueous fluids (Hoshide and Obata, Proceedings of Hutton symposium VI, in press).

In this presentation, the bulk composition was analyzed by XRF for major elements and halogens and by LA-ICP-MS (at ANU) for trace elements including REE. We found that olivine gabbros from the LZ are depleted in Cl, while rocks from the MZ and UZ were more enriched in Cl than the LZ gabbros. Especially, the uppermost part of the UZ, less than 5 m from the roof, shows significant enrichment of Cl (7500 ppm, Fig.1). Another important finding is that pegmatitic and anorthositic parts in the GR zone are significantly higher in Cl content than the surrounding host gabbros. The REE contents in pegmatites are also higher than those in the host gabbros, but they do not show good correlations with the Cl content. Because both Cl and REE are expected to behave as incompatible elements in the early stages of crystallization, the observed decoupling between Cl and REE suggests that aqueous fluid that strongly partition Cl played an important role in the formation of pegmatites.

The observed Cl variation in the intrusion can be explained as follows: First, an aqueous fluid phase is generated from the interstitial melt in the lower horizon of the boundary layer with the advance of crystallization. The Cl enriched in the interstitial melt is strongly partitioned into the fluid. As the fluid rises up by buoyancy and reaches a H_2O-undersaturated zone in the upper horizon of the floor boundary layer, it is dissolved forming a hydrous and Cl-rich layer. In the hydrous melt layer, crystallized plagioclase is dissolved into the melt again due to the increase of water pressure, and segregation between liquid and solid occurs by local increase of the melt fraction to form water- and Cl- rich pegmatites. As the fluid phase (bubble) transported from the lower horizon disappears here, the Cl enrichment in the MZ and UZ cannot be ascribed to the migration of the fluid. We propose that the Cl enrichment in the MZ and UZ was caused by the diapiric ascent of anorthositic crystal mushes generated from the top of the Cl-enriched pegmatites. The extreme enrichment of Cl in the uppermost part of the UZ cannot be explained by this model, however, but must be ascribed to a migration of fluid phases (bubbles). These fluid phase, however, are not those generated in the lower boundary layer, but instead those that had existed in the intrusive magma.

Keywords: chlorine, fluid phase, crystallization boundary layer, pegmatite, crystal mush,
Layered Intrusion