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Chemical evolution of a sheet-like magma body induced by compositional convection: constrains from the Nosappumisaki intrusion

Rayko Simura[1]

[1] Univ. of Tokyo

Detailed investigation of a thin sheet-like intrusion with wide compositional diversity provides precise information of magmatic processes in a solidifying magma chamber with high resolutions in both the space and time. The Nosappumisaki intrusion in Nemuro, Hokkaido, is a suitabletarget for such study. It is a Cretaceous shoshonite sill intruded into Cretaceous sedimentary rocks. 'Phenocrysts' already present at the time of intrusion are concentrated in the bottom accumulation (cumulate) zone and are almost absent in the overlying middle zone. The intrusion is consists mainly of these two zones, which are sandwiched between the marginal zones and the chilled zones in this order.

The interstitial melt composition as well as the whole-rock composition shows a S- or flipped S-shaped vertical variation. The whole-rock variation is primarily explained by the distribution of phenocrysts, as shown from the S-shaped vertical variation of modal abundance. For interstitial melt composition, mafic components and compatible trace elements are rich in the lower part, and felsic components and incompatible trace elements are rich in the upper part. The average interstitial melt composition in the sill is statistically the same as the melt composition at the time of intrusion estimated from the groundmass composition of the chilled zones. These facts suggest transfer of a fractionated melt from the cumulate zone to the overlying middle zone. This is also suggested by the presence of phenocryst-poor leucocratic pipe-like structures and the variation of extent of partial dissolution of augite 'phenocrysts' in the cumulate zone. There is systematic downward increase in the content of felsic component and incompatible trace elements in the middle zone, where 'phenocrysts' are absent except for near the bottom of the zone. Because of the lowest liquidus temperature for the major minerals, the horizon corresponds to the final solidification point.

A mass balance model that can treat the formation of fractionated melt and its migration in the sill was constructed being in consistent with the aforementioned observations and applied to the sill. The relevant parameters are solidification rates from the top and bottom of the sill, exchange rate of melt between the mush (the cumulate zone) and the crystal-free melt layer (the middle zone), and degree of fractionation at the freezing horizon in the cumulate zone. The comparison of the modeling results with the observed variation of the interstitial composition shows that the velocity of the downward growth of the upper solidification front must have been very slow in the early stage relative to the upward advance rate of the bottom solidification front. Noticeable drop in the liquidus and solidus temperatures may have suppressed the rate of downward growth of the upper solidification front due to the extensive injection of fractionated liquid from the cumulate zone to the middle zone in the early stage. In the later stage, the growth rate must have been very large, which is suggested by the nearly constant liquidus temperature and skeltal morphology in the lower one third of the middle zone.