Grain boundary migration rate of plagioclase aggregates:preliminary estimation from texturally equilibrated gabbros

Kentaro Hasebe[1], Michihiko Nakamura[2]

[1] Inst.Earth Material Sciences,Graduate School of Science,Tohoku University, [2] Inst. Mineral. Petrol. Econ. Geol., Tohoku Univ.

http://www.ganko.tohoku.ac.jp/

Grain size of rocks is a fundamental parameter to determine rheological properties and rate of chemical reaction. Only little data have been reported for silicate grain growth rates. Mainly due to the limitation of run duration, experimental data are restricted to some fast-growing, fine-grained minerals such as calcite and quartz. In this paper, we present a preliminary estimation of plagioclase grain boundary migration rate by texture analysis of natural hornblende gabbros of Miyamoto Plutonic Complex (MPC), Abukuma, Japan. Results of `natural experiments` might allow us to obtain the slower rates for coarser rocks in longer time scale than those of laboratory experiments.

Hornblende gabbros of MPC composed mainly of (ferropargasitic,ferro-edenitic) hornblende and plagioclase showing cumulate texture. Monomineralic domains of plagioclase aggregate occur in some MgO- and SiO2-rich gabbros (MgO=8.93wt%, SiO2=52.63wt%). Plagioclase grains often have smooth grain boundaries that meet at triple junctions having 120 angles, in which potassium feldspar can be sometimes observed. These observations show that plagioclase aggregates were textually equilibrated to reduce interfacial energy and gain boundary migration occurred by subsolidus annealing. Petrologic estimation of chemical compositions of the melts coexisted with plagioclase in igneous stage revealed that melt density was very close to that of plagioclase, which suggests that plagioclase crystals of ca. 200 micrometer swimming together in magma chambers formed aggregates of ca. 1.2mm in diameter and settles to have formed so-called `Synneusis` texture (Vogt,1964). Each plagioclase grain has concentric compositional zoning, characteristic of cumulate. It should be emphasized here that present grain boundaries often deviate from the original grain boundaries supposed from the concentric compositional zoning. Cathodoluminescence observation supports the idea that some plagioclase grains have coalesced to form single grain.

In order to evaluate the rate of plagioclase grain boundary migration, we took back-scattered electron images and X-ray compositional maps of Al using electron microprobe. Initial grain boundaries just after solidification (at solidus temperature) were estimated supposing that grains have equal rim widths, then distance from the present grain boundaries were measured as migration distance. Migration direction was examined in relation to the size contrast of grains on either side, that is, the cases consistent with theoretical migration direction from larger to smaller grains were taken as valid data. The maximum migration distance was 20 micrometer. To evaluate the migration rate from the measured distance, two methods are available; 1) Comparison with volume diffusivities in plagioclase crystals, assuming original compositional zoning profiles, and 2) Estimation of cooling history (T-t path) based on geological and petrologic background of MPC. (1) Based on the compositional zoning of An content with calcic core (An 80-90 mol%, tens of micrometers width) and sodic rim (An-50-60), typical diffusion distance is a few micrometers, which is similar to, or an order of magnitude larger than, the grain boundary migration distance. (2) Assuming the diameter and thickness of the MPC as 5 and 6km, respectively, cooling interval of the gabbro from 1000 to 700o was calculated to be 85000 years using the Tomiya (2000)'s conduction model and parameters on cooling.

The initial grain boundaries might have small curvature due to faceting of the plagioclase crystals. In addition, migration distance data are not abundant enough for statistical analysis of usual grain growth analysis. Further studies including estimation of the activation energy of the grain growth rate are necessary to deduce good grain growth rate from the natural texture-equilibrated samples.