I127-012 **Room: 301A** **Time: May 22 11:48-12:00**

Grain boundary migration in dunite

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Grain size of rocks is an important microstructural parameter for physical properties of rocks. Plastic flows of rocks by diffusion creep and superplasticity strongly depend on grain size. As well as dynamic recrystallization, grain growth kinetics is the most important mechanism in controlling grain size, which is crucial for understanding the rheological behavior of the interior of the Earth.

Several grain growth experiments have been conducted for mono- and bimineralic rocks (e.g., Tullis and Yund, 1982; Yamazaki et al., 1996). Although the mechanisms of grain growth can be roughly estimated using the value of the growth exponent (n) and the shape of grain size distribution (e.g., Faul and Scott, 2006), in-situ observation of grain boundary migration is required for understanding the details of grain growth mechanisms. Bestmann et al. (2005) performed in-situ observations of grain boundary migration in halite using a SEM equipped with a heating stage and an EBSD camera. However, this kind of experiments cannot deal high-pressure conditions. Nakamura et al. (2005) conducted experiments of oxygen-isotope exchange between aqueous fluid enriched by ^{18}O and quartzite in which grain growth had been proceeded, and showed that the area swept by grain boundaries were enriched by ^{18}O. This shows that we can deduce the migration of each grain boundary during the annealing experiments by measuring the distribution and concentration of specific elements in the recovered samples, if the area swept by grain boundaries is contaminated by specific elements.

We conducted grain growth experiments in dunite at 1200 degC and 1.2 GPa for 100-763 hours under water-saturated conditions using a piston-cylinder apparatus. The starting materials were prepared from gel powder (Mg-Si sys.). The starting materials were packed into Pt-lined Ni capsules, and then 1.0-1.5 wt. percent of distilled water was added with a microsyringe. Ni diffused from Ni-capsules to the samples via Pt wall during the experiments. The area swept by grain boundaries was expected to be contaminated by Ni, because diffusion of Ni via grain boundaries and fluid phase is faster than lattice diffusion of Ni (e.g., Watson, 1991). Back-scattered electron images of the run products were obtained with a scanning electron microscope for observation of microstructure. Ni concentration in the samples was determined using a WDS.

Normal grain growth of forsterite proceeded in dunite, as reported by Ohuchi and Nakamura (in revision). Grain boundaries showed high concentration of Ni. Ni-concentration profile across a grain boundary is expected to show a symmetrical shape if the grain boundary is immobile. Most of the Ni-concentration profiles across grain boundaries in dunite showed asymmetrical shapes, showing that migration of the grain boundaries had been proceeded. Average grain boundary velocity in dunite was estimated to be $2.3*10^{-6}$ (um/s) from the shape of the Ni-concentration profile across each grain boundary. This value is consistent with the value of average grain boundary velocity ($2.0*10^{-6}$ um/s) calculated using the values of growth exponent (n=7.2) and growth rate constant (k=$10^{8.48}$ um$^{7.2}$/h) reported by Ohuchi and Nakamura (in revision). This supports the consideration that the area swept by grain boundaries during an experiment coincides with the area contaminated by Ni in the recovered sample. The experimental method used in this study would be applicable to understanding the migration of interfaces by deformation of rocks as well as grain growth.