Grain growth in dunite, crynopyroxene, and wehrlites

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The grain size of rocks is one of the most important microstructural parameters that control their rheological properties. The mean grains size is determined by the two counteracting processes in the interior of the Earth; grain growth and dynamic recrystallization. Although many experimental studies on grain growth have been carried out on monomineralic rocks (e.g., Tullis and Yund, 1982), experiments on bi- and polymineralic rocks are rare. Ceramists and metallurgists have long recognized that grain growth can be inhibited by the second phases. This phenomenon, Zener pinning, was found in the systems with rock-forming minerals such as calcite-mica (Olgaad and Evans, 1988) and $CaTiO_3$-FeO wustite (Wang et al., 1999). In the $MgSiO_3$ perovskite-MgO periclase system, in which grain growth of the first phase was drastically inhibited by the second phase (Yamazaki et al, 1996), however, the experimental data was not explained by the Zenner pinning. The inhibitation mechanism in the two-phase systems is thus controversial. Moreover, the previous experiments were performed in the bimineralic systems of which volume fraction of the second phase is lower than 10 percent. Little is known about the grain growth in the systems of volume fraction of the second phase is larger than 10 percent. In this study we have conducted a series of grain growth experiments on the synthesized wehrlites in which volume fraction of the second phase ranges from 0 to 90 percent in order to understand the grain growth in natural silicate rocks.

The wehrlites with various forsterite (Fo)/ diopside (Di) ratios were synthesized at 1.2GPa, 1200 degC for 2 – 700 h, and increase of the mean grain size was examined in the time-series experiments. The run products were quenched, cut and polished for SEM observation. The mean grain size of the run products was measured on the back-scattered electron images.

The grain growth processes of Fo100-Fo80Di20 and Fo70Di30-Di100 wehrlites (numbers represent the volume fraction of each phase) were quite different with each other. Abnormal grain growth proceeded in former: small number of abnormal grains whose grain sizes are 10 times larger than the mean grain size were formed and grown by consumption of the smaller grains. In contrast to this, normal grain growth proceeded in the latter wehrlites. This difference in the growth mechanism produced the clear difference of the mean grain size (grain growth rate) between Fo100-Fo80Di20 (smaller than 30 micrometer) and Fo70Di30-Di100 wehrlites (larger than 10 micrometer). This indicates that mean grain size of the Fo-rich wehrlites (Fo100-Fo80Di20) is 3-15 times larger than that of the Di-rich ones (Fo70Di30-Di100). If this result is applicable to the uppermantle, it is estimated that strain rate of the Di-rich wehrlites is more than 9 times faster than that of the Fo-rich ones in diffusion creep region. In other words, creep strength and rate strongly depend on the modal composition of Di. Similar to the case of grain growth of dunite (Karato, 1989), grain growth rate of wehrlites was accelerated by addition of water.