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Verification of ultra-low strain rate effect from microstructural observation on naturally deformed olivine

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Kitamura et al. (1986) and Ando et al. (2001) reported Fe concentration on dislocation core in naturally deformed olivine. They suggested that compositional heterogeneity is formed by Cottrell atmosphere of solute atoms. This phenomenon is well known in the realm of metallurgical science, and only occurs during dislocation creep at very low strain rate condition. The presence of Cottrell atmosphere has a pinning effect on dislocations and prohibits their movements. As a consequence, plastic behavior of materials is drastically changed in the presence of Cottrell atmosphere. On the basis of this compositional heterogeneity, they demonstrate that the study of ultra-low strain rate effect on olivine plasticity is very important to understand the dynamics of the upper mantle.

With this background, the purposes of the present research are: (1) to confirm whether the Fe concentration on dislocation core is a common phenomenon in deformed olivine grains of mantle-derived peridotite, (2) to verify the deformation condition at which Fe concentration was occurred, from the microstructural observation of each studied peridotite samples, (3) to clarify the exact mechanism of Fe concentration, namely Cottrell atmosphere or pipe diffusion. The studied peridotite samples are xenoliths from basalt (Takashima, Megata, Kurose and Salt Lake), and alpine rocks (Uenzaru and Horoman). The techniques employed for the present study include optical microscopy, EPMA, SEM-EBSD, TEM and ATEM.

The main results are as follows:

1) Fe concentration on dislocation core in all olivine samples is detected, which suggests that it is common phenomenon in mantle peridotite.

2) The mechanism of Fe concentration on dislocation core in olivine grains is preferably Cottrell atmosphere than other phenomena such as pipe diffusion. However we need to carry out more careful and detailed observations to confirm it.

3) The microstructural observations indicate that the all peridotites preserve the deformation characteristics developed at the upper mantle. This fact suggests strongly that the Fe concentration on dislocation core in olivine grains occurred in the upper mantle condition.

Ando et al. (2001) Nature, 414, 893; Kitamura et al. (1986) Proc.Japan Acad., 62, 149.

Keywords: Olivine, Cottrell atmosphere, Dislocation creep