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Deformation experiment on synthetic polycrystalline anorthite: effect of water

FUKUDA, Jun-ichi[1*], MUTO, Jun[1], NAGAHAMA, Hiroyuki[1]

[1]Department of Earth Sciences, Graduate School of Science, Tohoku University

Feldspar is a major constituent of the crust as well as quartz. The rheology of the middle-lower crust is mainly governed by that of feldspar. Therefore, the deformation mechanisms of feldspar have been investigated from analyses of natural samples and by deformation experiments. Plastic deformation of materials including feldspar is broadly classified into two main mechanisms; grain-size-sensitive creep (dislocation creep) and grain-size-insensitive creep (diffusion creep and grain boundary sliding). The former mechanism exhibits lattice preferred orientation (LPO) and the latter does not.

It is well known that increasing water contents in polycrystalline feldspar promote plastic deformation, as reported in Dimanov et al. (1999, JGR) and Rybacki et al. (2006, JGR). However, capability of a pressure range by a gas a gas (Paterson-type) deformation apparatus used in their studies is limited up to 400 MPa. Therefore, a solid-medium deformation apparatus should be used to investigate the middle-lower crustal condition, where water circulation is important as suggested in recent tomographic studies. Also, H2O fluid easily diffuses into a polycrystal through grain boundaries as fast mass paths. Then, the subsequent solution-precipitation process may occur, as inferred from grain morphologies and development of LPO controlled by the solution-precipitation process (Vernooij et al., 2006 Tectonophysics for quartz; Heidelbach et al., 2000, JSG for feldspar). Therefore, the effects of water on e.g., transition from brittle deformation to plastic deformation, and relationship between stress/strain and deformation mechanisms should be quantitatively determined.

In this study, we focus on the middle-lower crustal conditions, external influx of water, and polycrystalline feldspar, and performed following deformation experiments. Shear and axial deformation experiments were conducted for initially dry feldspar samples with water added using a Griggs-type deformation apparatus. The temperature and confining pressure are up to 950 C and 1 GPa. As a starting material, fine-grained ($<$5 um) glass powders with the composition of anorthite 100 were sintered in vacuum at 1400 C during 4 hours. Then, polycrystalline anorthite with a grain size less than 5 um were prepared. Electron backscattered diffraction (EBSD) measurements revealed that crystallographic orientations of the synthesized polycrystalline anorthite were random, although elongated grains with the aspect ratio of up to 2 were observed in a band contrast image. Observation of sample morphology shows that pores up to 1 um are present at grain junctions. Infrared (IR) spectroscopy revealed that the sample is dry without water absorption bands. Using these samples, 0.1-0.5 wt % water was introduced into the sample by adding distilled water or by dehydration of pyrophyllite powders at high pressure and temperature. After the deformation experiments, concentration of interference color at 300 um from the sample edges were observed under a polarized optical microscope with a gypsum plate, indicating development of LPO. Pores were not recognized in these regions. These observations indicate that plastic deformation occurred due to introduction of water into the sample. In the IR spectra for this region, water absorption bands due to zoisite, which must be produced as a reaction product under differential stress, were recognized. The creep mechanisms of feldspar, which are dominated during deformation due to water distribution will be determined from electron backscattered diffraction (EBSD) analyses and observations of grain morphologies. We will discuss changes in stress/strain due to introduction of water into the sample, and relationship between water distribution and deformation mechanisms.

Keywords: anorthite, water introduction, Griggs deformation apparatus, EBSD analysis, infrared spectroscopy