高温高圧下における斜長石のレオロジーと水の効果

Effect of water on rheology of plagioclase under high temperature and high pressure

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1. Introduction
Rheological behaviors of rocks depend on pressures, temperatures and chemical environment. Particularly, water is known to play an important role in rheology of rocks in terms of physical and chemical aspects by previous experiments. Here, two ways of water effects are considered. Pore fluid pressure reduces the effective stress of rocks supported by mineral frame. Water also reduces the strength of plastic deformation of minerals by increasing concentration of lattice defects. Moreover, tomographic observations have shown that there are fluid-rich zones beneath active fault zones and strain concentration zones in the middle-lower crust (e.g., Nakajima et al., 2010). It is proposed that water affects crustal deformation and earthquake occurrence (e.g., Iio et al., 2009). However, the effect of water on rheology has not yet been revealed quantitatively for lower crustal materials under pressure conditions equivalent to the lower crust. Moreover, in most of previous studies, experiments were performed under two end-member cases: water saturated or anhydrous conditions. Thus, it has not been understood in the environment that water is gradually introduced into samples similar to natural lower crustal condition.
2. Deformation experiment
In this study, we performed deformation experiments on synthetic anorthite (An) aggregates using the Griggs-type solid medium deformation apparatus. We added 0.5 wt% water to samples and infiltrated under high temperature and high pressure. Times for infiltration of water into samples were changed to investigate the variation of deformation behaviors associated with diffusion of water. Strain rate stepping test was performed at a temperature of 900 °C and a confining pressure of 1.0 GPa. Strain rates were 1st: 10^{-5}, 2nd: $10^{-4.5}$ and 3rd: 10^{-5} s^{-1}. Constant strain rate tests were also performed at a strain rate of 10^{-5} /s, temperature of 900 °C and confining pressures of 0.8 and 1.1 GPa. The experimental conditions in the present study were roughly equivalent to the environment of the middle-lower crustal fluid-rich zones. Thus, the present study is suitable for investigating the effect of water on plastic deformation in such zones.
3. Results
In all experiments, wet samples were weaker than an anhydrous sample. Strain weakening was observed in experiments at a strain rate of 10^{-5}/s at all confining pressure conditions. Strengths tended to decrease with infiltration time or strain magnitude. Photomicrographs after the experiments of wet An deformed under confining pressure of 1.0 GPa were taken. Almost no deformation was observed in the upper part of the sample, and deformation was concentrated in the lower part.
4. Discussion and implication
We compared the measured differential stresses with predicted values by the flow law for wet An obtained by low pressure experiments (~0.4 GPa, Rybacki et al., 2006). The estimated stress values were higher than the measured values in our experiments under similar conditions. Moreover, because recovered samples were deformed in their lower part intensively, actual strain rates might be higher and estimated stress values became higher for that part than those estimates. This implies that the chemical effect of water, such as fugacity, in higher pressure condition might be larger

than those predicted by lower pressure experiments. Present study shows that measured differential stresses of hydrous samples tended to decrease with infiltration time or strain magnitude. It is assumed that plastic deformation is promoted by increase of water-related defects by water diffusion into samples. The results of present study indicate that the strength of lower crust become lower than previous studies.

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