

鉄なしかんらん石+輝石の2相系変形メカニズムの応力と温度に対する依存性

Dependency of creep mechanism on stress and temperature for two phase system of forsterite + enstatite

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Flow mechanism of the earth's upper mantle is estimated based on observation of microstructure of natural rocks, geophysical observation and experimental results obtained in laboratory. The experimental results are extrapolated to the mantle condition by using flow law. Therefore, obtaining precise flow-law parameters are key to understand the mechanism. However it is difficult to determine their values with small error range because of their strong dependency on stress, grain size and temperature. Tasaka et al. (2013) developed a viscosity model which includes a fraction of second phase for forsterite + enstatite system. They showed that a combination of flow laws for each mineral phase is applicable to polymineralic system with incorporating the fraction of mineral phases. However, their proposed activation energy of creep have a large error of ± 50 kJ/mol, and obtained stress exponent, n , varies from 1.0 to 1.5 so that application of their results to nature is not precise yet.

We conducted two different types of creep experiments with synthetic sample of forsterite + 10vol% enstatite under high temperature ranging from 1150°C to 1370°C with application of various constant loads of 3 to 320 MPa. One was aimed for evaluating activation energy of creep and the other was for obtaining a precise stress exponent. We obtained stress-dependent activation energy and temperature-dependent stress exponent. At lower stress condition, apparent activation energy is ~ 600 kJ/mol. In contrast, at stress range of 60~120 MPa, the lower energy of ~ 370 kJ/mol was obtained. At 1370°C, the apparent stress exponent of ~ 1.2 was obtained whereas a larger value of ~ 1.5 was obtained at 1150°C. These results indicate that two types of deformation mechanisms were operated during our experiments.

In two-phase system, Burton (1973) proposed that the second phase particle on grain boundaries of the primary phase inhibits diffusion creep, because the second phase limits grain boundary to act as a perfect sink or source of vacancy. When density or mobility of defects at grain boundary is small, deformation will be rate-controlled by defect formation at interfaces. In this case, strain rate is proportional to $\sim s^2/d$ (Ashby and Verrall 1973) where s is applied stress and d is grain size. Since such interface reaction-control creep and diffusion creep both are rate-limiting processes for bulk deformation, reciprocal bulk strain rate can be expressed by a sum of reciprocal strain rate of interface-controlled diffusion and normal diffusion creep. Based on our obtained flow-law parameters, interface-reaction controlled diffusion creep dominated at lower temperature and lower stress conditions, and Coble-type diffusion creep dominated at higher temperature and higher stress conditions.

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