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含水かんらん石多結晶体の変形における鉄の効果
Effect of iron content on the creep behavior of olivine under hydrous conditions

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Since iron and hydrogen play important roles in dynamic processes not only in Earth's mantle but also in Mars's mantle, we conducted triaxial compressive creep experiments on polycrystalline samples of olivine, $(Fe_{1-x},Mg_x)_2SiO_4$, with x = 0, 0.53, 0.77, 0.90, and 1.0 under hydrous condition. A Paterson-type gas-medium apparatus was used for these experiments. The water contents, determined from Fourier transform infrared (FTIR) spectroscopy analyses of larger Fo_{90} crystals embedded in the olivine aggregates, demonstrate that the samples are water-saturated both before and after deformation. The grain sizes of initial and deformed samples were determined using electron backscatter diffraction (EBSD).

Creep tests at 300 MPa confining pressure were conducted at temperatures from 1050 to 1200C at constant stresses in the range 25 to 315 MPa. The values of the pre-exponential term, stress and grain size exponents, and activation energy in the constitutive equation were determined for a wide range of iron concentrations. Samples with high Mg contents are finer grained (1-2 μm) than those with low Mg contents (10-20 μm). Furthermore, samples with high Mg contents ($x \geq 0.90$) exhibit a stress exponent of n = 2, whereas samples with low Mg contents (x <0.90) deform with n = 3. This result is consistent with the dislocation-accommodated grain boundary sliding model of Langdon (1994), which predicts that fine-grained samples that do not contain sub-grains should exhibit n = 2 while coarser-grained samples that do contain sub-grains should exhibit n =3. The flow stress decreases with increasing iron content of the olivine samples at constant temperature, strain rate, and grain size. Following the analysis of previous studies (Mackwell *et al*., 2005; Zhao *et al*., 2009), we fit our creep data to the following flow law: strain rate = $A\sigma^n$ d^{-p} $(1\text{-}x)^m$ $f_{H2O}{}^r$ $\exp\{-[Q_0 + \alpha(1\text{-}x)] / \mathrm{R}T\}$, where A is a material-dependent parameter, σ is stress, d is grain size, p grain size exponent, m iron content exponent, f_{H2O} water fugacity, r water fugacity exponent, Q_0 activation energy at $(1\text{-}x)$ = 0, and α a constant. The dependence of strain rate on iron concentration is characterized by two parameters - directly, through the iron content exponent m and, indirectly, through the term $\alpha(1\text{-}x)$ in the activation energy. The values of m and α are determined by the rate-controlling mechanism of deformation and the charge neutrality condition for Fe-bearing olivine.

Keywords: olivine, iron content, creep, rheology, experiments, deformation