Diffusion creep in the oceanic lithosphere and asthenosphere

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Two important experimental results on grain-boundary-diffusion creep of olivine aggregates are applied to the oceanic lithosphere and asthenosphere.

We conducted grain growth and high-temperature creep experiments on forsterite + 20vol% enstatite aggregate, finding that the common diffusion mechanism controls both grain growth and creep. As a consequence of their common diffusional process, effective activation energy of the creep, which is accompanied by grain growth, equals one-fourth of activation energy of the grain boundary diffusion. The change of the viscosity with temperature from 700 to 1350C is followed by the change in grain size from 10 micron to 2 mm during diffusion creep accompanied with grain growth mechanism. Such process is identified in peridotite mylonite and likely to be responsible for the long-term deformation of the oceanic lithosphere where the low effective activation energy (100-150 kJ/mol) is estimated from the geophysical modelling. .

The Ca (+Al)-doped and non-doped olivine aggregates exhibited the same strength at low temperature (=1100C), while we observed significant weakening of the doped sample with increasing temperature at >1100C. Such chemical weakening explains the difference of the strength of olivine aggregates synthesized from natural olivine crystals (Hirth and Kohlstedt 1995, Hansen et al. 2011) and from chemical agents using sol-gel method (Faul and Jackson 2007). We apply our obtained flow law of the doped aggregates to the upper mantle, finding that the presence of the weak mantle asthenosphere can be explained by the chemical weakening appeared at the high temperature conditions.

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