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Diffusion to dislocation creep transition in the upper mantle inferred from silicon grain boundary diffusion rates

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The majority of the dynamical processes in the upper mantle are controlled by creep of minerals. Dislocation creep causes non-Newtonian viscosity and seismic anisotropy whereas diffusion creep causes Newtonian viscosity and no seismic anisotropy. Determination of deformation mechanism in the upper interior is thus essential to understand mantle dynamics. Previous deformation studies on olivine suggested that the shallow regions of the upper mantle should be dominated by dislocation creep and the deeper regions dominated by diffusion creep [Karato, 1992; Karato and Wu, 1993; Hirth and Kohlstedt, 2003]. However, recent study [Fei et al., 2013] demonstrated that those deformation experiments largely misunderstood the creep rate due to the experimental difficulties. Since the creep of olivine is controlled by silicon diffusion, we measured silicon grain-boundary diffusion coefficient in Mg-olivine aggregates as a function of pressure, temperature, and water content. The activation energy, activation volume, and water content exponent are found to be 240-260 kJ/mol, 1.8 ± 0.2 cm^3/mol, and 0.22 ± 0.05, respectively. Together with the silicon lattice diffusion data [Fei et al., 2012; 2013], our results predict the diffusion to dislocation creep transition in the upper mantle, which is in contrast with the previously considered model. In the asthenosphere, dislocation creep should dominate because of the high temperature. In the lithosphere, diffusion creep dominates in shallow regions and dislocation creep dominates in deeper parts. The seismic anisotropy jumps at mid-lithosphere discontinuity beneath continents and at Gutenberg discontinuity beneath oceans are caused by the transition from diffusion to dislocation creep. The weak anisotropy in cold lithospheres could be attributed to the fossil anisotropy formed at the spreading ridges. Dominance of diffusion creep in upper lithosphere accounts for the Newtonian rheology suggested by postglacial rebound.

Fei et al., *EPSL* **345**, 95-103 (2012).
Fei et al., *Nature* **498**, 213-215 (2013).
Hirth and Kohlstedt, *Geophys. Monogr.* **138**, 83-105 (2003).
Karato, *JGR* **19**, 2255-2258 (1992).
Karato and Wu, *Science* **260**, 771-778 (1993).

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