Diffusion creep and grain growth in polymineralic rocks: Their common diffusional process

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The Earth's interior is considered to flow by diffusion or dislocation creep. Dislocation creep has been thought to be dominant in seismically anisotropic regions caused by crystallographic preferred orientation (CPO) of minerals, but recent experiments have shown CPO under diffusion creep and diffusion creep may dominate in the Earth's interior to a greater extent than previously thought [1][2][3]. During diffusion creep, creep rates change significantly with grain size even under constant differential stress and temperature, and grain size is considered to be determined by grain growth. Most rocks are polymineralic, and their grain growth rates proceeds via Ostwald ripening of the secondary phase which pins grain boundary of the primary phase. Such ripening may require the surrounding primary phase to deform, and the diffusion required for that deformation can rate-control the grain growth. This assumption could be tested by comparing diffusion creep and grain growth rates in the forsterite + periclase two-phase aggregates, in which the slowest diffusion, Si, is contained only in the primary phase, forsterite.
Highly dense, fine-grained (~1 μm) forsterite + 10 vol% periclase aggregates were prepared by vacuum sintering [4], and grain growth and uniaxial compressive deformation experiments were performed on these samples under atmospheric pressure and high temperature (1200°C-1450°C). The time dependence of the grain growth rate indicates that grain boundary diffusion is the rate-limiting process for the grain growth, and the stress and grain size dependence of the creep rate confirms grain-boundary diffusion creep. The grain-boundary diffusivities corresponding to the obtained creep and grain growth rates were determined, both of which correspond to grain-boundary diffusion of Si in forsterite, indicating that diffusion creep and grain growth are caused by the common diffusion mechanism [5].
Most rocks are polymineralic and usually contain a silicate mineral as their main phase, in which Si is the slowest diffusing species. This leads to the prediction that a single diffusivity, which is Si diffusivity in most cases, determines the rates of grain growth and diffusion creep in much of the Earth's interior. The grain size, which is the result of grain growth, and the time it takes to achieve that size, indicate the diffusivity. Therefore, viscosity during diffusion creep can be described in terms of grain size and time. We believe that the viscosity of the subduction zones can also be estimated using these findings.
References: [1] Miyazaki et al., Nature 2013; [2] Maruyama & Hiraga, JGR 2017a; [3] Maruyama & Hiraga, JGR 2017b; [4] Koizumi et al., PCM 2010; [5] Okamoto & Hiraga, JGR 2022.

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