マントル超塑性と異方性
Mantle superplasticity and anisotropy

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Recently, we have experimentally shown that a significant crystallographic preferred orientation (CPO) of forsterite develops during Newtonian flow of the forsterite aggregate (Miyazaki et al., 2013). The aggregate also exhibits (i) superplasticity (>>100 % tensile strain) (Hiraga et al. 2010), (ii) same phase aggregation at the direction of compression (Hiraga et al. 2013) and (iii) essentially, no change in grain shape before and after the deformation. Thus, we concluded that grain boundary sliding (GBS) should have accommodated a majority of the sample strain. We found that the preexisting grain shape, which is controlled by crystallography of forsterite, controls the CPO development and its pattern. Based on these results, we estimated that the preferential GBS at the boundary parallel to the specific crystallographic plane (i.e., low-index plane grain boundary) resulted in CPO. To examine this hypothesis, we imposed line markers to the lateral surface of samples which were subsequently deformed. Absence of intragranular deformation, significant GBS and grain rotation were identified after the sample deformation. We found that the grain rotation was well reproduced by resolved shear stress applied to the low-index plane grain boundary (GB). Based on analysis of rate of grain rotation, we estimated that the low-index GB is 3~4 times less viscous relative to general (normal) GB resulting in an alignment of low-index GB with respect to deformation geometry. Appearance and type of such boundaries change with temperature and presence of melt indicating that GBS-induced CPO change with geological conditions. We apply our prediction to the asthenosphere beneath the Pacific basin, where the horizontal flow of the mantle starting from beneath the East Pacific Rise is well resolved by seismic tomography. We show that strong radial anisotropy is anticipated at temperatures corresponding to depths where melting initiates to depths where strongly anisotropic and low seismic velocities are detected. Conversely, weak anisotropy is anticipated at temperatures corresponding to depths where almost isotropic mantle is found. We propose superplastic (diffusion) creep to be the primary means of mantle flow.

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