***Superplastic Earth Hypothesis***

Takehiko Hiraga
Earthquake Research Institute, University of Tokyo

The unusual capability of solid crystalline materials to deform plastically, known as superplasticity, has been found in metals and even in ceramics. Such superplastic behavior had been speculated for decades to take place in geological materials, ranging from surface ice sheets to the Earth's lower mantle. We could demonstrate that polycrystalline forsterite + periclase and forsterite + enstatite + diopside, which are good analogues for Earth's mantle, undergo homogeneous elongation of up to 500 per cent under subsolidus conditions. Grain- to multiple-grain-scale deformation processes during superplastic deformation (diffusion creep) of the fine-grained synthetic mineral aggregates are examined in detail. Grain-switching events allow dispersed phases to contact grains of the same phase and orient in the direction of compression. We identify similar aggregated microstructures in natural deformed rocks. The serial operations of grain boundary sliding, rigid body grain rotation, and grain neighbor switching are observed. Grain rotation occurs due to grain boundary sliding that occurs preferentially along low-index (crystallographic) plane grain boundaries (i.e., low-index GB). We estimate that low-index plane boundaries have a lower viscosity relative to general grain boundaries, which results in the development of crystallographic preferred orientation (CPO) during superplastic deformation. Such CPO can be found in microstructures of rocks derived from the earth's crust and upper mantle.

Mineral aggregates sintered at high pressure and temperature tell that crystallographically controlled grain shape (= low-index GB) appears only shallower regions of the upper mantle and the lowermost lower mantle. Our model of CPO during superplastic deformation predicts that CPO develops only at such regions in the earth's mantle. Major mantle minerals are elastically anisotropic such that the development of CPO yields elastically anisotropic rock, the presence of which can be detected by directional seismic wave velocity (i.e., seismic anisotropy). Recent study on depth profile of the seismic anisotropy supports our prediction.

Viscosity of the mantle should be highly dependent on its grain-size in case of

*Superplastic Earth*. We compare grain growth rates and creep rates of the polymineralic mantle mineral aggregates, finding that both processes are rate-controlled by the same diffusional mechanism. Such common diffusional process provides a unique constraint on the mantle viscosity which changes by depth and age of the mantle. We calculate grain size during one cycle of the mantle convection, which gives us the viscosity at each depth of the mantle. The obtained viscosity is well compared to the values from geophysical observations.

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