

Melt alignment in the largely deformed partially molten media

Yasuko Takei[1]

[1] ERI, Univ. Tokyo

Mechanical properties of the partially molten rocks depend on the geometry of the melt pores. Under the hydrostatic stress, the pore geometry is determined to minimize the total interfacial energy of the system. At this equilibrium state macroscopic elasticity and deformability of the media can be predicted quantitatively from the contiguity of the grain-to-grain contacts which is determined by the dihedral angle of each system. Comparing these results to the seismological observations, we can see that the partially molten rocks in the Earth are not always at the equilibrium state. Seismic tomographic images obtained beneath the northeastern Japan subduction zone [Nakagima et al, 2001] show the low velocity zones having a large $d\ln V_s/d\ln V_p$ ratio (larger than 1.5) which cannot be explained by the elasticities of the texturally equilibrated partially molten rocks. Seismic anisotropy observed in these zones cannot be explained by the equilibrium texture. Also, low-frequency earthquakes observed in these low velocity zones suggest the occurrence of a mechanical instability. One important key to understand these phenomena is considered to be a melt alignment which is expected in the deformed partially molten rocks. Evolution of the pore geometry under deviatoric stresses is still unknown. We cannot clearly answer the questions whether the melt alignment actually occurs, under what conditions it occurs, and what the mechanism is. This study made an experimental approach to this subject.

Deformation experiments were performed using analogue partially molten media (a binary eutectic system of organic compounds). The dihedral angle of this system is similar to that of the olivine-basalt system in the mantle. A large sample (70mm-cube) was deformed under a nearly pure shear stress ($2-4 \times 10^4$ Pa) with a strain rate of 10^{-8} - 10^{-6} s $^{-1}$. Melt fractions of the samples were 0.089, 0.167, and 0.22. During the deformation, evolution of the microstructure was observed in situ by using the ultrasonic shear waves. One deformation run consists of a creep stage under a constant shear stress and a relaxation stage under the hydrostatic stress. In the present apparatus, the maximum shear strain applicable at each run is not large (less than a few percent), because the uniformity of the stress field becomes poor. However, repeated deformations by changing the directions of maximum and minimum compressive stresses can cause a large total shear strain to each sample, especially when the sample has a relatively large melt fraction and hence has a relatively large strain rate. The total shear strains of the samples were 0.02, 0.4, and 0.7 for the samples of 0.089, 0.167, and 0.22 melt fractions, respectively.

Two types of melt alignment were observed in these samples. One is the melt alignment formed perpendicular to the direction of minimum compressive stress, which was observed by the shear wave splitting. This type of melt alignment was dominant in a small strain range and was observed (by the shear waves) in all samples. This alignment is not stable in that when the stress was removed (=in the relaxation stage) the initial isotropic structure almost recovers. The other type is the melt alignment formed parallel to the direction of maximum shear stress, which was observed in the cross-section of the core. This type of melt alignment was dominant in the large strain range and were observed in the samples of 0.167 and 0.22 melt fractions. Probably due to the formation of this melt alignment, shear wave velocities were reduced significantly after a series of deformation runs. Hence, this structure is stable in that it survives the relaxation stages. If the latter type of melt alignment, which is expected to reduce the strength of the media, occurs in the Earth, it will affect the dynamics of the partially molten regions.