論文の内容の要旨

Polycrystal anelasticity at near-solidus temperatures: Experiments and seismological applications

（融点近傍における多結晶体の非弾性：実験と地震学的応用）

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Seismic low velocity and high attenuation observed in the upper mantle have been mostly attributed to the presence of melt. However, a recent experimental study on a polycrystalline aggregate showed that anelastic relaxation increases as temperature approaches the solidus temperature, indicating that seismic low velocity and high attenuation can occur without melt. In this previous study, because the experiment was performed only below the solidus temperature, the relationship between the increase of anelastic relaxation below the solidus temperature and partial melting was not clarified. The present study aimed to clarify the effects of temperature and partial melting on polycrystal anelasticity. For this purpose, the mechanical properties of a polycrystalline aggregate existing over a broad range of frequencies (elasticity, anelasticity, and viscosity) were measured at near-solidus temperatures ranging from below to above the solidus temperature (T_m).

The present experimental results show that the effects of partial melting on the mechanical properties of a polycrystalline material are twofold; changes just below the solidus temperature in the absence of melt and changes at the solidus temperature due to the onset of partial melting. Just below the solidus temperature ($0.92 \sim< T/T_m < 1$), anelastic relaxation significantly increases with increasing homologous temperature (T/T_m). Also, viscosity of the grain boundary diffusion creep is reduced significantly in this temperature range. At the solidus temperature

($T/T_m = 1$), further reduction of elasticity, further increase of anelastic relaxation strength, and further reduction of viscosity occur. The mechanical properties of a partially molten aggregate are determined by the total of these twofold changes.

The changes just below the solidus temperature are caused by a solid state mechanism, whereas the changes at the solidus temperature are caused by the direct effect of melt. I speculate that a structural transition at grain boundary occurs just before partial melting (premelting), which may change the dynamical properties of grain boundary and enhance grain boundary sliding (anelasticity) and grain boundary diffusion creep (viscosity). The present experimental result showed that the changes due to the premelting has a large amplitude even for a sample which generates a very small amount of melt (0.4–0.5%) at the solidus temperature, whereas the changes due to the direct effect of melt are very small for a sample with very small melt fraction. The present result predicts that in most part of the upper mantle, where the melt fraction is considered to be very small, the direct effect of melt is negligibly small and the premelting effect is dominant.

To assess the effect of premelting on the seismic waves, I performed the parameterization of the present experimental results and obtained a general empirical formula for polycrystal anelasticity and viscosity. It was fitted to the temperature dependence of seismic shear wave velocity (V_S) in the Pacific mantle. The present model explains well the steep reduction of V_S just below the solidus temperature by the premelting effect without invoking any direct effect of melt. In the fitting, the material parameters (elasticity and viscosity) of the mantle rock needed to calculate V_S were determined as the fitting parameters. The obtained parameters agree well with those experimentally measured for olivine aggregates. By using the empirical formula and the material parameters determined by the fitting, a new anelasticity model applicable to the mantle was established.

The new anelasticity model was further applied to the lithosphere-asthenosphere boundary (LAB) to examine whether the premelting effect can explain the seismic discontinuity. Vertical structure of V_S was calculated, by using the geotherm obtained from the cooling models of oceanic plate and the solidus temperature of peridotite obtained from the thermodynamic models. The result shows that if the solidus temperature is decreased by the existence of volatile, seismic discontinuity is reproduced as the steep reduction of V_S by the premelting effect. In addition, the premelting effect can explain high attenuation in the asthenosphere. The present study proposes a new insight that premelting is the origin of the asthenosphere.