Seismic discontinuity at lithosphere-asthenosphere boundary predicted from laboratory-based anelasticity model

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Seismic discontinuity has been observed around the depth of lithosphere-asthenosphere boundary (LAB). Recent seismological studies using both P to S and S to P converted waves (e.g., Rychert et al., 2007; Kawakatsu et al., 2009) have revealed that more than 5% Vs reduction occurs sharply (within a depth range of ~15 km) at about 60-80 km depth. Because the change of geotherm with depth is gradual, it has been difficult to explain such a sharp velocity reduction by temperature alone, and a discontinuous distribution of melt or water has been considered as a cause of the sharp LAB. However, recent experimental studies by using organic polycrystals as a rock analogue have shown that a reduction of seismic wave velocity by temperature can be much steeper than that considered in previous studies, because grain boundary premelting occurs from just below the solidus temperature and significantly enhances the polycrystal anelasticity (Yamauchi and Takei, 2016). We applied the anelasticity model obtained by Yamauchi and Takei (2016) to the oceanic mantle and investigated whether sharp LAB captured in seismology can be explained by grain boundary premelting.

The anelasticity model by Yamauchi and Takei (2016) is given as a function of normalized frequency f/f_M and normalized temperature T/Tm, where f_M and T_m represent the Maxwell frequency and solidus temperature, respectively. The Maxwell frequency is calculated by G_U/h, where G_U and h represent the unrelaxed shear modulus and diffusion creep viscosity, respectively. Yamauchi and Takei (2016) also gave the model of diffusion creep viscosity based on the experimentally observed enhancement of diffusion creep by premelting. Oceanic mantle geotherm T(z) was calculated for various plate ages by plate cooling models. Solidus profiles $T_m(z)$ were calculated by assuming some plausible distributions of volatiles (H_2O and CO_2). Substituting these results to the laboratory-based viscosity and anelasticity models, velocity and attenuation profiles Vs(z) and $Q^{-1}(z)$ at seismic frequency f were calculated and compared to the seismological observations. The results show that the sharp reduction in Vs can be explained by premelting. However, the predicted discontinuity depth is slightly deeper, and the predicted magnitude of velocity reduction is smaller than the seismological observations. We discuss these discrepancies from possible uncertainties in geophysical conditions and rheological models. We further compare the present results with another LAB model based on the other laboratory-based anelasticity model (Jackson and Faul, 2010).

Keywords: LAB, anelasticity, premelting, grain boundary

