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Origin of the lithosphere-asthenosphere boundary (LAB) and the mid-lithosphere discontinuity (MLD)

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Sub-solidus origin of the lithosphere-asthenosphere boundary (LAB) has been discussed based on recent laboratory data (e.g., Karato, 2012). The principal message in such a model is that in these sub-solidus models, the observed geophysical anomalies (low seismic wave velocities and high electrical conductivity) can be explained without ad hoc assumptions. In contrast, if one were to explain these anomalies by partial melting, a number of parameters such as melt fraction and melt geometry must be chosen, making it less attractive model because the choice of these parameters is not easy to justify. In this presentation, I will discuss two issues related to the origin of LAB and MLD.

(1) One of the strongest arguments for the partial melt origin of the LAB was the geophysically observed high and highly anisotropic electrical conductivity. Previous lab studies on olivine conductivity showed small anisotropy, and explaining high conductivity ($\sim$0.1 S/m) was also difficult. We have recently measured the electrical conductivity of hydrated olivine single crystals to high temperature (to 1373 K). The results show that the degree of anisotropy becomes large at temperature above $\sim$1000 K, and both the average values and the anisotropy of conductivity of the asthenosphere are consistent with the lab data on hydrogen-assisted conductivity if the water content of $\sim$0.01 wt % that is consistent with geochemical inferences is assumed.

(2) One of the challenges in sub-solidus models for the LAB is to explain geophysically observed sharp and large velocity drop at the LAB. Through the analysis of lab data on anelasticity obtained in Jackson's lab at ANU, I showed that a large and sharp velocity drop at the LAB can be explained by a subsolidus model assuming a sharp increase in water (hydrogen) content at $\sim$70 km depth that enhances elastically accommodated grain-boundary sliding (EAGBS) (Karato, 2012). I will present a compilation of geophysical observations to show that the same process (EAGBS) also explains the MLD, although for the MLD, enhanced EAGBS is likely not caused by the change in the water content but by temperature. Possible geophysical implications of this model will be discussed.