EGU21-13799, updated on 04 Dec 2021
https://doi.org/10.5194/egusphere-egu21-13799
EGU General Assembly 2021

Origin and significance of seismic discontinuities in the continental upper mantle: An interdisciplinary study

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The mid-lithosphere discontinuity (MLD) and the lithosphere-asthenosphere-boundary (LAB) are two well-known seismic discontinuities in the continental upper mantle. Both MLD and LAB are present in most of the continents but at different depths and with different magnitude of velocity change and sharpness. Understanding the causes for these discontinuities including their regional variations is critical in inferring the evolution of the continents from geophysical observations on these discontinuities.

Among various models, we focus on the elastically-accommodated grain-boundary sliding (EAGBS) model that provides plausible and unified explanations for the MLD and the LAB (Karato and Park, 2019). This model has a few testable predictions, and the main purpose of this talk is to review the current status of these tests.

- (i) One assumption of the EAGBS model is that EAGBS is enhanced by water. A recent paper by Cline et al. (2018) challenges this hypothesis by showing that water has no effects on attenuation in Ti-doped hydrated olivine. However, the relevance of the results on highly Ti-doped olivine to Ti-poor real upper mantle is unclear.
- (ii) A clear and unique prediction of the EAGBS is the presence of a peak in seismic attenuation at/near the MLD. However, inferring an attenuation peak in a narrow depth range is challenging and this hypothesis has not been tested.
- (iii) Another prediction of the “dry” version of the EAGBS model for the MLD is that although seismic wave velocity drops and there is a peak in attenuation, electrical conductivity does not change.
- (iv) If the MLD is caused by EAGBS, then materials below are in the “relaxed” state. This would explain the lack of large velocity drop at the LAB. However, the validity of this explanation depends on the pressure dependence of grain-boundary sliding. If pressure dependence of EAGBS is large, then the un-relaxed state will re-establish itself at a relatively shallow depth within the lithosphere. In this case, a deeper thermal transition to the relaxed state should

produce stronger LAB than reported.

We have conducted an interdisciplinary study to address these issues including mineral physics and seismology. We found that the addition of Ti modifies the defect-related properties of olivine and complicates the application of Cline et al. (2018) to actual upper-mantle conditions. We determined the pressure dependence of olivine grain-growth, from which we infer that the pressure dependence of grain-boundary sliding is small. Regarding the seismological test of attenuation peak, we forward-modeled surface-wave dispersion in a dispersive medium. Calculations show that the over-tones of Love waves are a key to detecting an attenuation peak near the GBS transition. Combined with a comparison of seismological studies (on velocity and attenuation) and MT estimates of electrical conductivity, we will have better constraints on the validity of the EAGBS model for the origin of the MLD.