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Deep and shallow mantle partial melting, water, grain-boundary sliding and the origin of the asthenosphere

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Abstract
The asthenosphere is a soft layer below the lithosphere. Its mechanical softness is essentially due to its high temperature. However, the exact cause for its seismological signature and geochemical characteristics has been controversial. A commonly believed model is that the sharp velocity drop at the lithosphere-asthenosphere boundary (LAB) is due to the incipient partial melting, and geochemical homogeneity is due to well mixing of highly depleted materials (formed after continental crust formation) and undepleted materials. I will show that these conventional models are inconsistent with the plausible thermal models and melting relations and rheological properties of materials. A new model is proposed in which the role of deep and shallow mantle partial melting and resultant redistribution of elements is emphasized. If a new result on anelastic properties showing the importance of grain-boundary relaxation (high-frequency relaxation) is included, most of mechanical and geochemical features of the asthenosphere are explained in a unified fashion. In this model, a small amount of partial melting at ~ 410-km produces modestly depleted and nearly homogeneous materials that form the asthenosphere. These materials still contain a substantial amount of water to reduce its mechanical strength including seismic wave velocities. Shallow mantle partial melting near ridges creates a sharp layering in water content at ~70 km that causes a sharp and large velocity drop involving high-frequency grain-boundary relaxation. This model also provides an explanation for the seismological observations on the continental upper mantle.