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What is a plate ? Dynamical definition of the transition between lithosphere and asthenosphere

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While the lateral limits of tectonic plates are well mapped by seismicity, the bottom boundary of the lithosphere, the uppermost rigid layer of the Earth comprising both crust and shallow mantle, remains elusive. Lithospheric plates are usually viewed as cold, rigid, internally undeformed blocks that translate coherently. The base of the lithosphere, designated as the lithosphere-asthenosphere boundary (LAB), could thus theoretically be characterized from either temperature, viscosity, strain rate and horizontal velocity.

Several LABs as defined from these different fields are investigated here using thermo-mechanical models of plate and upper mantle dynamics, either in a transient subduction or in a steady-state plate-driven set-up. Mantle material is modelled as homogeneous in composition with a viscosity that depends on temperature, pressure and strain rate. In such systems, the thermo-mechanical transition between lithosphere and asthenosphere occurs over a finite depth interval in temperature, strain rate and velocity. We propose that the most useful dynamical LAB is defined as the base of a “constant-velocity” plate (i.e. the material translating at constant horizontal velocity). The bottom part of this plate deforms at strain rates comparable to those in the underlying asthenosphere mantle: the translating block is not fully rigid.

Thermal structure exerts a major control on this dynamical LAB, which deepens with increasing plate age. However, the surface plate velocity and more generally the asthenospheric flow geometry and magnitude also impact the depth of the dynamical LAB, as well as the thickness of the deformed region at the base of the constant-velocity plate. Moreover, the mechanical transitions from lithosphere to asthenosphere adjust when mantle dynamics evolves.

The dynamical and thermo-mechanical LABs occur within a thermal lithosphere-asthenophere gradual transition, in agreement with the results obtained from geophysical proxies. The concept of a constant-velocity plate can be extended to a constant-velocity subducting slab, which also deforms at its borders and drags the surrounding mantle. This dynamical definition of a lithospheric plate is relevant to interpret mantle seismic anisotropy in terms of (past) flow

direction, and to quantify mass transport within the Earth's mantle.