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Lithosphere-asthenosphere boundary: Where and why?

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A necessary condition of the lithosphere steady state is that the convective boundary layer (CBL) accommodating a transition from the lithosphere to the convecting mantle is on the verge of instability. The common practice of solving the stationary heat equation with boundary conditions (temperature and heat flow) imposed on the surface provides a solution which does not necessarily satisfy the marginal stability condition (MSC) of the CBL and therefore does not necessarily describe a valid steady state. We suggest the approach to the thermal modeling that uses the MSC instead of the heat flow boundary condition, which guarantees that the solution describes the steady-state lithosphere. In addition, in contrast to the commonly used approach, the MSC-based solution only weakly depends on the uncertainty of the crustal heat production in the sense that any two steady-state geotherms corresponding to different crustal heat production, but the same potential temperature and lithosphere structure, converge at depth.

We demonstrate that if there is no obstacle to the mantle convection like chemical boundary layer (ChBL) comprising the crust and the layer of depleted rock then the lithosphere base occurs at the rheological depth, H_{rh}, which is of 70 to 50 km under the potential temperature of 1300 to 1350^{o}C. This situation is characteristic of the mantle beneath the old oceanic crust areas far from disturbed regions, with the heat flow and the seafloor depth depending only on the potential temperature,T_p. An absence of noticeable distinctions between the heat flows in different oceanic basins suggests a global constancy of the potential temperature T_p at least in suboceanic mantle.

Beneath continents, the ChBL thickness, H_{depl}, exceeds H_{rh} even in Phanerozoic regions and, all the more so, in Precambrian ones. Therefore, in the subcontinental mantle the lithosphere is the same as the chemical boundary layer and the CBL is immediately adjacent to the lithosphere base. We suggest the quantitative relations between the surface heat flow, q, the lithosphere thickness, H_{depl}, and the potential temperature, T_p. These relations correlate well with the lithospheric geotherms documented based on the kimberlite xenolith/xenocrystthermobarometry.

Across the CBL the basal shear traction dragging the lithosphere plates acts, and one may expect that in the bottommost lithosphere and/or the topmost CBL a fracture zone develops. This zone is a good candidate for the region from where the kimberlites entrain strongly deformed xenoliths. Also, shear deformation associated with this zone makes it a good candidate for the role of the Lehmann discontinuity observed globally beneath continents at a depth of about 200 km and presumably having anisotropic character.