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Factors controlling the thickness of stable continental lithosphere and its changes over time

Z. Garfunkel
Hebrew University, Jerusalem, Israel 91904 (zvi.garfunkel@huji.ac.il)

During plate motions the lithosphere of stable continental areas is subjected to a viscous basal drag that arises as it slides over the asthenosphere. The experimentally determined rheology of mantle rocks allows calculating the downward variation of the resulting shearing and its dependence on the geotherms, the magnitude of the basal drag, and the presence of fluids. It is found that though the shearing increases downward as the rocks become hotter, it remains negligible in a large depth interval, but then it increases rapidly to 1.5-2 cm/y (=1500-2000 km/100 Ma) over a depth interval of ca. 20 km. Over geologic time deeper levels are dragged sideways so much that they become effectively decoupled from the lithosphere. This decoupling zone marks the base of the lithosphere, separating it from the convecting mantle. Its depth depends primarily on the geotherm, and varies from some 200-220 km where the thermal gradient in the lithospheric mantle is ca. 4-5˚C/km (like xenolith geotherms under Archean cratons) to 120-100 km where the thermal gradient is 8-10˚C/km. For the lithosphere not to be hotter than the mantle adiabat with a potential temperature of ca. 1300˚C the basal drag should be $>$0.5 MPa in dry lithosphere. A stronger drag (1-1.5 MPa) will cause the decoupling zone to be 20-40 km shallower and colder than the adiabat, other factors being equal. The presence of fluids can have a similar effect, other factors being equal. Thus the thickness of the lithosphere depends on a combination of factors rather than on a single parameter.

The factors that control the depth of the decoupling zone are expected to vary from place to place and in time. The geotherm depends on the heat delivery by the convecting mantle and on the blanketing effect of heat generation in the crust. The latter tends to be considerably higher in Proterozoic and younger crust than in Archean crust, which will cause the lithosphere mantle to be hotter under the former, causing the decoupling zone to be significantly shallower by that under the latter, other things being

equal. The basal drag will depend on the vigor of convection under any place and on plate velocity, which can change with time. Such changes can change the thickness of the lithosphere, e.g. development of a new subduction system along the margin of a continent will induce a flow in the mantle wedge which can erode the continental lithosphere. Metasomatism of the deep lithosphere can change its rheology such as to reduce its thickness. Thus, in order to survive the lithosphere of any old region must escape being dragged sideways, regardless of the its buoyancy.