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Evolution of asthenospheric layers as a result of changing stress field

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The lithosphere is underlain by the asthenosphere. Traditionally, the boundary between the lithosphere and the asthenosphere (LAB) is defined by a difference in response to stress: the lithosphere remains elastic or brittle, while the asthenosphere deforms viscously and accommodates strain through plastic deformation.
The reology of rocks depends on many factors: temperature, pressure, chemical composition, size of grains, etc. However, the basic differences of lithosphere and asthenosphere properties could be explained as a result of the temperature and pressure. The effective viscosity of mantle is proportional to C exp(A q), where q is the ratio (melting temperature/temperature), C and A are positive constants. The mantle is not molten, so q>1. If the temperature is close to the melting temperature then q is close to 1 and effective viscosity is low (e.g. 1018 Pa s). This situation is observed in asthenosphere.
The lithosphere is a thermal boundary layer for the convection in the mantle. The temperature of the upper part is low (q is high) but the temperature gradient in the lithosphere is high and temperature is increasing fast. In the mantle below the lithosphere, the temperature gradient is low (could be close to the adiabatic one). The melting temperature is increasing with depth faster than true temperature. Hence, q and the viscosity reach minimum value just below LAB and are increasing with depth in the mantle below. It is a typical situation.
The tectonic processes in subduction zones could change this picture. The one lithospheric plate could be placed in the mantle below another plate. Distribution q in such a case could have two minima, so two asthenospheric layers could be formed.
Another important factor determining rheological properties is a stress tensor T. Generally viscosity is proportional to the power of the invariant of the stress tensor: I(T)ˆ(1-n). For n=1 the viscosity does not depend on stress (i.e. Newtonian rheology), for true mantle n is probably in the range from 3 to 5.
We investigate the processes of formation and evolution of low viscosity layers ("asthenospheric layers") in the upper mantle. The time scale of the temperature changes is of the order of 10 Myr. The characteristic time of stress changes could be much shorter depending on tectonic processes. Eventually processes of formation and vanishing of low viscosity layers is very dynamical. In a relatively short time (below 1 Myr) the pattern the viscosity distribution and velocity gradient could change substantially.
Using results from deep seismic sounding and surface wave tomography we have found that below some regions there are structures in the mantle that could be a forming/vanishing low viscosity layers. Reflectors in the lower lithosphere are observed beneath Trans-European suture zone between Precambrian and Palaeozoic platforms. In a thick Baltic shield lithosphere (200 km or more) low velocity zones and seismic reflectors are observed in the depth range 60-100 km, which could be interpreted as mechanical low Vp velocity zones, in contrast to thermal velocity zone in deeper asthenosphere.
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