Geophysical Research Abstracts
Vol. 14, EGU2012-3612, 2012
EGU General Assembly 2012
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Links between the mechanical, seismic and thermal thickness, rheological structure and mechanical stability of the continental lithosphere.

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To fulfill its plate-tectonics functions, the lithosphere has to remain mechanically strong over geological time spans and be capable to support important geological loads while transferring horizontal tectonic stresses at global scales. We use thermo-mechanically and thermo-dynamically coupled numerical models accounting for brittle-elastic-plastic rheology and petrologically and seismologically consistent pressure-temperature dependent density and elastic structure to obtain more robust insights on thickness of the mechanical lithosphere (Hm) and its links to the LAB depth and its seismic (Hs) and thermal thickness (Ht). Testing the mechanical stability of lithospheres with different thermo-rheological structures allows us to constrain rheological parameters needed for long-term survival of lithospheric plates and establish links between LAB,Hm,Hs and Ht. Mechanical lithosphere appears to be 1.5-2 times thinner than Hs and Ht and its mechanical thickness, Hm, is strongly dependent on thermal and rheological structure. The important contribution of inelastic components (brittle and ductile behavior) to the mechanical strength of the lithosphere suggests that Hm is also stress and strain dependent: within the same plate, it might drop by 30-50% in the areas of high strain or stress, and remain much higher in the areas where tectonic deformation is moderate. In some cases it is possible to establish direct links between the laterally variable mechanical, seismic and thermal lithosphere thickness. This is of special importance since tracking the mechanical thickness of the lithosphere allows us to put better constraints on its stress/strain dependent rheological properties. We explored relationships between Hs,Ht and Hm of the lithosphere in oceans and in more complex continental lithospheres. In oceanic plates, Hm corresponds to the observed equivalent elastic thickness (EET) multiplied by a factor of 1.2-1.5, and correlates well with Ht and Hs. In continents, the rules are similar for young hot plates (thermo-tectonic age < 150 Myr) but different for older plates. In old plates, the mechanical thickness appears to be roughly equal to crustal thickness Hc + EET multiplied by a factor of 1.2-1.5. It thus varies from about 80-100 km to 200 km. Comparing Hm and EET in oceans and continents with seismic thickness Hs indicates stable correlations between these quantities. However, no correlation exists between Hm-EET and seismogenic layer thickness Ts. In turn, the latter parameter seem to anti-correlate with Hm-EET in cases of strong local deformation while in cases of small strain/stress states there is no any depictable link. We show that stabilization of the surface, LAB and Moho topography generally requires strong mantle lithosphere with Ht > 150 km and rheology close to that of "typical" dry olivine flow law. Independently of their crustal properties, lithosphere with weaker mantle rheology and thermo-mechanical ages from 100 to 300Ma is unstable so that RT instabilities at the LAB boundary, and small-scale convection below it, result in rapid destruction (typically less than in 60 Myr) of the lithosphere. At same time surface dynamic topography shows unrealistic undulations on the order of 2000m in amplitude. Assumption of strong mantle lithosphere reduces surface undulations to the acceptable 200m while the lithosphere survives over time spans exceeding 200Myr. For older plates (> 1000 Myr) surface topography, Moho and LAB are still unstable for rheological models based on the assumption of weak wet olivine rheology.