Geophysical Research Abstracts
Vol. 16, EGU2014-14133, 2014
EGU General Assembly 2014

Numerical models on thermal and rheological sensitivity of deformation pattern at the lithosphere-asthenosphere boundary

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Understanding the interaction between the oceanic lithosphere and the upper mantle is a crucial part in understanding plate tectonics/kinematic, especially along the lithosphere-asthenosphere boundary (LAB).

In this study, we analyzed finite deformation ($f = log(\frac{a}{b})$, where a and b are the major and minor axis of the strain ellipse, respectively) integrated over time, within the upper 400 km of the mantle. The velocity field was numerically calculated within a two-dimensional channel of certain depth and length with a constant plate velocity on top (Couette flow), with no slip bottom boundary and open side boundaries. The viscosity is described by a composite rheology (dislocation and diffusion creep) which is given by a temperature field based on a half-space cooling model for an oceanic lithospheric plate using variable thermal parameters. A constant pressure was applied at the left boundary of the channel to obtain a faster flowing asthenosphere (additional Poiseuille flow). The depth of the LAB is assumed to be mechanically defined and corresponds to the depth at which no additional strain is accumulated on the downstream side, separating the high-viscous non-deforming lithosphere from the low-viscous asthenosphere. Model results show that the lower part of the lithosphere defined in this way is characterized by large inherited strains (f ~ 2).

Due to the applied kinematic boundary conditions for a Couette-flow model and the lateral viscosity variations within the channel a minor induced Poiseuille-flow component is obtained within the model. Thus, the stresses vary significantly in comparison to the 1D solution of a Couette-flow.

Preliminary results show that deformation along the LAB is strongly governed by the temperature and the plate velocity. The maximum depth of the lithosphere defined in the above way is 120 km, and correlates with the 1230 °C temperature contour line. Moreover, assuming steady state, the finite deformation will always increase with depth due to the slower moving material at the lower part of in the channel. Thus, the maximum deformation does not correlate with the base of the lithosphere. Besides, an additional pressure leads to a faster flowing asthenospheric material and thus to a shift in polarization of the deformation. The numerical simulations show that finite strains above and below the LAB are predicted to be large and subhorizontal, but may shift in shear sense within the asthenosphere.