Induced small-scale convection in the asthenosphere in continent-continent collision zones

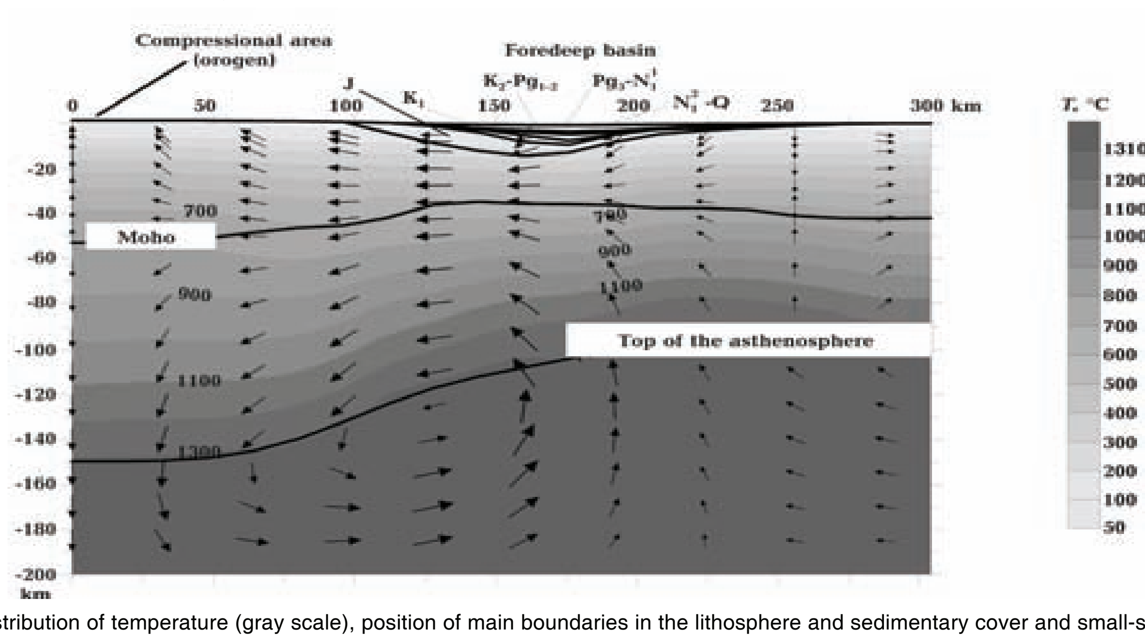
© E. Timoshkina, V. Mikhailov, 2010

Institute of Physics of the Earth, RAS, Moscow, Russia
tim@ifz.ru
mikh@ifz.ru

We investigated interaction of the lithosphere and the asthenosphere in continent-continent collision zone using a rheologically stratified model of the Earth outer shell including sedimentary layer, the lithosphere, the asthenosphere and uppermost part of the mantle. [Mikhailov et al., 1996]. The lithosphere — asthenosphere boundary is a rheological one and determined by position of specified isotherm. Equation for the top of the model includes detailed description of sedimentation and erosion. The model is asymptotically matched to the model of mantle convection what solves the problem of boundary conditions at its lower boundary. The model permits modelling of active extension and compression by mantle-induced or intraplate forces as well as relaxation of mechanical and thermal disequilibrium arose at active tectonic stages.

Active tectonic deformations of the Earth's outer shell by external mantle-induced or intraplate forces disturb thermal and mechanical equilibrium within this shell. Our model demonstrates that these disturbances lead to formation of small-scale convection within low-viscosity asthenosphere. This convection plays important role in restoration of thermal and mechanical equilibrium in the Earth outer shell and it style depends also on the surface (sedimentation and erosion) processes. Small-scale convection lasts over a long period of time after cessation of external tectonic forces, causing deformations in overlying lithosphere. In a continent-continent collision environment the small scale convection amplifies uplift of orogenic belts and causes subsidence at their periphery. We consider the small scale convection to be the main driving mechanisms of foredeep basins formation [Mikhailov et al., 1999; Timoshkina et al., 2010].

To illustrate this model we perform results of detailed modelling of the Great Caucasus orogen formation. To assign correctly initial conditions to the beginning of compressional stage, we considered preceding stages including: 1) extension of continental lithosphere in the early Jurassic; 2) subsequent post-extensional subsidence; 3) compressional (collisional) stage, when the system orogen — foredeeps forms. Parameters of the lithosphere and the asthenosphere and parameters of exten-



Distribution of temperature (gray scale), position of main boundaries in the lithosphere and sedimentary cover and small-scale convection in the model of the Great Caucasus — North Caucasus foredeep formed in result of four compressional events before beginning of the present-day compressional one. The right side of the symmetric figure is shown. The centre of the orogen is at the left (x=0). The maximum length of arrows corresponds to 1.3 mm/year.

sional — compressional processes were selected to provide a result close to the Great Caucasus — North Caucasus foredeeps, including topography, deep structure, thermal regime, subsidence history, gravity anomalies and so on.

The suggested model shows a good agreement with the data on the foredeeps structure and evolution. In particular, it is able to explain thickness of sediments in foredeep basins and their shape, formation of foredeeps not only at the front but also at the back of compressional thrust belts, uplift of a foredeep during compression in the belt and rapid subsidence after cessation of external compression.

Comparison of the numerical results with the observed data on the North Caucasus foredeep permits new interpretation of existing geological data [Timoshkina et al., 2010]. In particular, it is possible to conclude, that the system orogen — foredeep resulted from at least five active compressional events separated by periods of relatively weak tectonic activity. The first compressional event took place before the formation of the Maykopian series, i. e. 39.5 Ma, and could be related to the closure of the Arabian Ocean and subsequent beginning of the continent-continent collision in the Lesser Caucasus. There is still no consensus on when compression and orogeny in the Caucasus region commenced, many researchers estimate beginning of the compression by considerably later date. The four further compressional events can also be recognised — one of them being between 16.6 and 15.8 Ma, the others — between 14.3 and 13.7 Ma and between 7.0 and 5.2 Ma. These stages coincide well with geological data. The present day stage is also an active compression one.

References

Mikhailov V. O., Myasnikov V. P., Timoshkina E. P. Dynamics of the Earth' outer shell evolution under extension and compression // Izvestiya. Physics of the Solid Earth. — 1996. — **32**, № 6. — P. 496—502.

Mikhailov V. O., Timoshkina E. P., Polino R. Foredeep basins: the main features and model of formation // Tectonophysics. — 1999. — **308**. — P. 345—360.

Timoshkina E. P., Leonov Yu. G., Mikhailov V. O. Formation of orogen — foredeep system: geodynamic model and its comparison to the North Caucasus data // Geotectonics. — 2010. — № 5. — P. 1—20.