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

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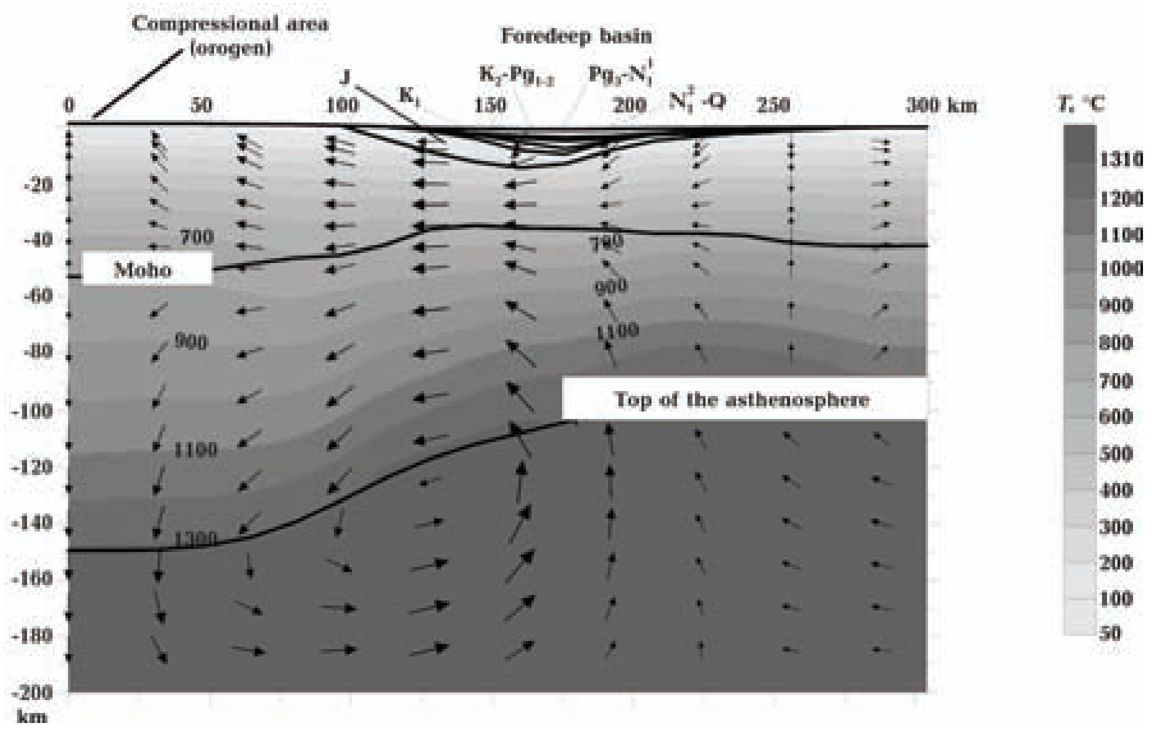
We investigated interaction of the lithosphere and the asthenosphere in continent-continent collision zone using a rheologically stratified model of the Earth outer shell including sedimentary layer, the lithosphere, the asthenosphere and uppermost part of the mantle. [Mikhailov et al., 1996]. The lithosphere — 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.

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Mantle seismic tomography beneath East-European Platform

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3D P-velocity model of the mantle under East-European platform was received as the solution of the seismic tomography problem by Taylor approximation method, which was supposed by V. S. Geyko [Geyko, 2004]. The solution don't depend from the referent model selection and can be imagine in Cartesian and spherical coordinate system. The used tomography method permits recovering the mantle model being optimal in the given metric in respect with the whole totality of P-wave first arrival traveltime data within the frame of selected basic model of interpretation. It includes the apriory assumptions? Theory and algorithms of numerical inversion, parameterization of velocity function, the smoothing method and other regularizing factors. The results are imagine in horizontal, longitude and latitude sections of the model. The generalized velocity-depth caracteristics $V_{\text{aver}}(z)$ were used in definitions high and low velocities and residual of velocities

$$V_{\max} = \sup_{\varphi,\lambda\in S} V(\varphi,\lambda,z), \tag{1}$$

$$V_{\min} = \inf_{\varphi,\lambda\in S} V(\varphi,\lambda,z), \tag{2}$$

$$V_{aver}(z) = z\left(\int_0^z \frac{d\zeta}{\sum(\zeta)} \iint_{S(\zeta)} \frac{d\varphi d\lambda}{V(\varphi,\lambda,\zeta)}\right)^{-1}, \tag{3}$$

where $S(\zeta)$ is the domain into horizontal section at the depth ζ, and $\Sigma(\zeta)$ is its space in the coordinates φ, λ.

The first time arrival from the ISC from 1964 to 2005 year were used as the input data.

The 3D P-velocity model analysis shows the next properties:

1) common velocities characteristic for received mantle model under EEP is layer velocities structure, which defined by inverse changing of phone velocity for each layer: high velocity tomographic lithosphere layer(upper mantle velocity characteristic), low velocity Golitsin — Geyko layer (transition zone velocity characteristic), high velocity zone of division-1? low velocity middle mantle, high velocities zone of division-2, low velocities low mantle, Mantle under EEP surrounding, except eastern part, characterized by common inverse relate to mantle velocities characteristics under EEP;

2) by velocities characteristics tomographic lithosphere under EEP can be devided on three layers: 50—100±25 km, 100±25—200±25 km, 200±25 km — tomographic lithosphere bottom;

3) mantle velocity boundary under EEP don't coincides with EEP tectonic boundary. Maximum agreement is on the depth 50 km, and maximum changing at the Golitsyn — Geyko depth;

4) as a whole by velocity characteristics mantle under EEP can be divided into three parts:

• boundary mantle velocity region of interaction with 1 type activation;

• main part with two type mantle velocity activations;

• east part of mantle under EEP, which has different velocity characteristics from another mantle part. The first type of velocity activations correspond to propagation of high velocity layers from the Golytsin — Geyko layer under surrounding regions to the low velocity Golytsin-Geyko layer under EEP and increase the part of high velocities in upper mantle layers under surrounding zone to EEP. Second type of velocity activation correspond to subvertical low velocities layers propagation from the middle mantle to the upper mantle. It is pick out inclined layers, which mainly corresponded boundary mantle velocity region of interaction (Figure);

5) mantle under Barents-Pechora Platforme units with mantle under EEP by velocity characteristics

So that by velocity characteristics we have both horizontal process and the vertical process in the mantle under East European Platform.