2D Thermo-mechanical modelling of Cenozoic lithospheric deformation in the Himalaya and Pamir-Tien Shan orogen

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Earth's most impressive and frequently studied orogeny, which was induced by the ongoing continent-continent collision of India and Eurasia, is the Himalayan orogeny. The collision, starting at around 55 Ma (*Burtman and Molnar*, 1993, *Ali and Aitchison*, 2005), gave rise to the Tibetan plateau, the largest highest and flattest plateau of the world, with an average elevation exceeding 5000 m and an area of around 2.5 million km^2. Ten out of fourteen of the highest mountains of the world are located in these active orogenic belt and the development of the Tibetan Plateau is assumed to have had an significant impact on the development of the Asian monsoon (*Zhisheng et al.*, 2001). Still the development of the mountain range is enigmatic and therefore remains a subject for ongoing research (*Molnar and Stock*, 2009), especially in the field of geodynamic numeric modelling.

One of the adjacent mountain ranges of the Himalayan orogenic belt is the *Tien Shan*, named after the Chinese term of "sky-high mountains", which hosts one of the Earth's most spectacular active intra-continental subduction zones.
The Tien Shan and Pamir collision zones are studied by a series of geophysical experiments within the framework of the multi-disciplinary Tien Shan - Pamir Geodynamic Program (TIPAGE)[1].
As participants of the program, our aim is to find controlling factors for continent-continent collisions with the help of 2D (and later on 3D) thermo-mechanical modells. The modelling is based on existing finite-element codes. Furthermore results of the TIPAGE program are implemented, i.e. the results of the magnetotelluric survey.

For this approach the finite-element code SLIM3D (*Popov and Sobolev*, 2008) is used, which allows coupled thermo-mechanical treatment of deformation processes and is capable of elasto-visco-plastic rheology with diffusion, dislocation and Peierls creep mechanisms and Mohr–Coulomb plasticity. It also features an arbitrary Lagrangian Eulerian formulation with free surface and Winkler boundary conditions.
Additionally, special routines for the 410 km and 660 km phase transition zones [olivine-spinel: 6% density increase, spinel-perovskite: 8% density increase] had been included and gabbro-eclogite, coesite-stishovite phase transitions had been taken into account as well (*Quinteros et al.*, 2010). The coesite-stishovite phase transitions is shown in Fig. 1 just above 410 km in the slab.

[1] in cooperation with

- Russian Academy of Sciences, Bishkek (Kyrgyz Republic)
- Timur Frunze, Central Asian Institute for Applied Geosciences (Bishkek)
- Institute of Geology, Academy of Sciences of the Republic of Tajikistan
- PMP International, Republic of Tajikistan
- GFZ German Research Centre for Geosciences
- TU Freiberg, Institute for Geology
- UNI Potsdam, Institute for Geosciences
- Friedrich-Schiller-University Jena, Institute for Geosciences

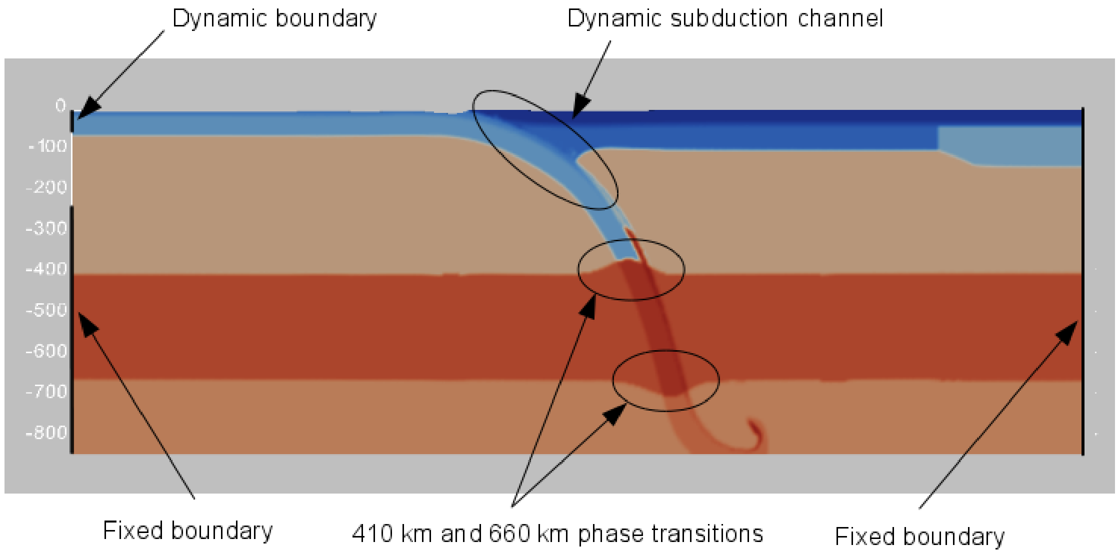


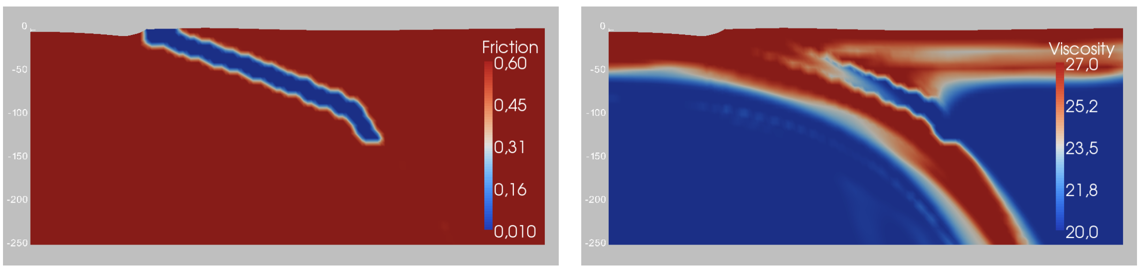
Figure 1: Model set-up and boundary conditions. Neotehthys (left side) subducting under stable Eurasia (right side).

For the initial phase of the India-Asia collision, when neotethys is subducting under stable Eurasia (*Replumaz and Tapponnier*, 2003), a dynamic subduction channel routine is implemented (*Sobolev and Babeyko*, 2005) to generate a three element wide subduction channel at the India-Asia plate boundary, with a slab velocity dependent friction [friction coefficient varies between $0.01 - 0.05$] and low viscosity (Fig. 2).

As our set of experiments is inherently 2D, the setup contains only one element on one of the coordinates. Realistic rheology has been applied and is constantly adjusted to recent research results. In the modell the slab velocity is fixed to 15 cm/yr for 4 Ma to start the subduction (*Molnar and Stock*, 2009, *Copley et al.*, 2009). After that, the slab is allowed to develop dynamically until a steady state is reached and bigger India (or some island arcs) are being introduced.

The study of first order effects concerning slab velocity development and mantle delemination has just begun. Experiments with (thermal) weakend zones in oceanic and continental plates to generate and control slab rollback, backarc spreading and slab breakoffs are beeing performed at the moment (Fig. 3).

In future another aim is to include erosion routines in the modell, since the effects of erosion seem to be generally underestimated (*Liu-Zeng et al.*, 2008).



(a) Friction coefficient

(b) Order of magnitude in Viscosity

Figure 2: Subduction channel

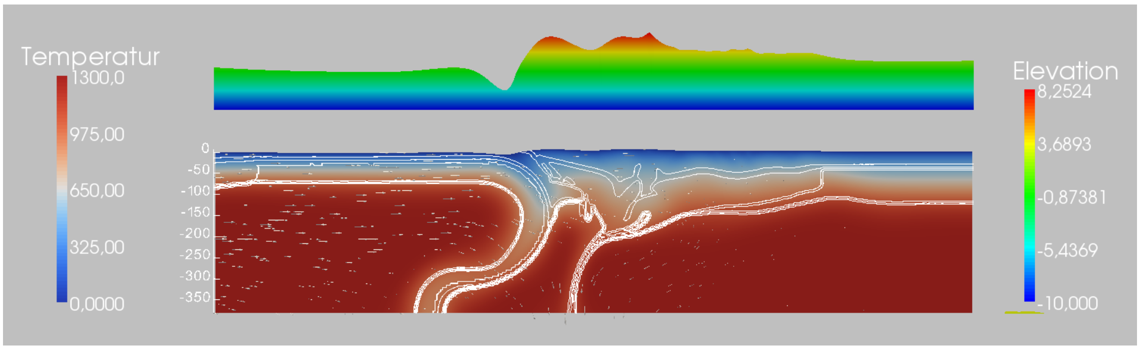


Figure 3: Model with 10x scaled elevation

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