TWO- AND THREE-DIMENSIONAL THERMO-MECHANICAL MODELING OF CENOZOIC LITHOSPHERIC DEFORMATION IN THE HIMALAYA-TIBET-PAMIR-TIEN SHAN OROGEN

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Summary The Pamir-Hindu Kush region is the locus of a large number of intermediate-depth earthquakes and an almost vertical high velocity zone, seen in seismic tomography. Our hypothesis is: The high velocity zone below the Pamir - Hindu Kush is the last remaining and hanging undetached part of the semi continental - oceanic "outer India" shelf and has only survived due to mechanical locking with delaminated mantle lithosphere of the Tarim block. We use the finite-element codes SLIM2D/3D which are allowing coupled thermo-mechanical treatment of deformation processes. These codes are capable of highly nonlinear elasto-visco-plastic rheology and allow self-consistent generation of faults and free surface boundary conditions. Since the 2D cross-section models are ignoring strike-parallel relations they miss 3D effects e.g. stress concentration around the tip of the advancing Indian plate. Hence we run low resolution 3D models in order to incorporate these effects.

INTRODUCTION

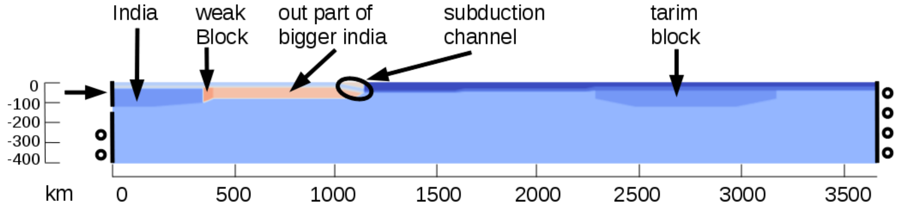
Earth's most impressive and frequently studied orogeny, which was induced by the ongoing continent-continent collision of India and Eurasia, is the Himalayan orogeny. The collision, starting at around 55 Ma (Ali and Aitchison, 2005), gave rise to the Tibetan plateau, the largest highest and flattest plateau of the world, with an average elevation exceeding 5000 m. 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) and remains a subject for ongoing research (Molnar and Stock, 2009), especially in the field of geodynamic numeric modeling.
The Pamir-Hindu Kush region located in the western syntaxis of the Himalaya is the locus of a large number of intermediate-depth earthquakes and an almost vertical high velocity zone, seen in seismic tomography (Negredo et al., 2007). The seismicity is not clearly related to oceanic subduction and forms an S-shaped zone between north-western Afghanistan and the eastern Pamir. In depth, the earthquake hypocenters are forming what some authors interpret as a V-shaped pattern which supports the model of two converging subduction zones. However, other models propose a single but highly contorted Indian slab or even a Rayleigh-Taylor instability due to a higher density in the lithosphere compared to the asthenosphere.

TIPAGE PROJECT (TIEN SHAN - PAMIR GEODYNAMIC PROGRAM)

TIPAGE is a collaborative multidisciplinary research program, aimed to exploit the western part of the Pamir-Tibet-Himalaya orogenic system. As part of the TIPAGE project our aim is to find lithospheric scale models constrained by all TIPAGE observations as well as to find controlling factors for the extreme Cenozoic shortening in the Pamir-Tien Shan orogen. In our current modeling approach, we use the finite-element codes SLIM2D and SLIM3D (Popov and Sobolev, 2008) which are allowing coupled thermo-mechanical treatment of deformation processes. These codes are capable of highly nonlinear elasto-visco-plastic rheology including diffusion, dislocation and Peierls creep mechanism and allowing self-consistent generation of faults. They incorporate free surface boundary conditions and are equipped with petrological routines for gabbro-eclogite, coesite-stishovite phase transitions (Quinteros et al., 2010).

MODEL SETUP

We run several 2D cross-section models in order to explain the high velocity zone below the Pamir-Hindu Kush and the seismicity which distinguishes the region from the rest of the Himalaya.



In a typical model setup India has two parts: the "inner part" which comprises 35-45 km thick continental crust and relatively thick cratonic mantle lithosphere; the "outer part" has 25-30 km thick crust and a less depleted, more ocean-like lithosphere. Inside of Asia we place an "inclusion" of thicker cratonic lithosphere, like that of the Tarim (Tadjik) block. The size of our basic model is 3700 km N-S and 400 km in depth with an equidistant resolution of 5 km.

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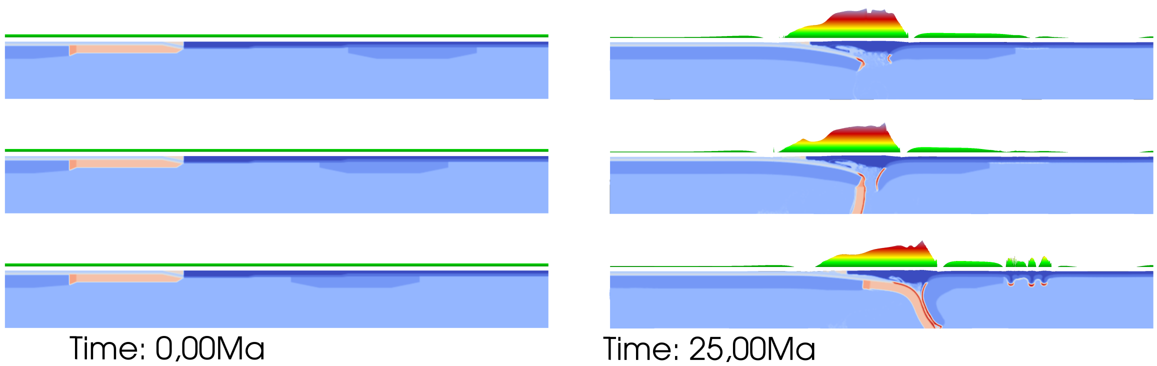

Given that our experiments are starting at 45 Ma and the postcollision shortening within Asia is well beyond 1000 km, we are using the ”moving window” technique (Sobolev, et al. (2006)). This allows us to improve computing time and to follow the center of collision, while the Indian plate is advancing.
Kinematical boundary condition for the lithosphere at the left side are dynamic-velocity values taken from paleoreconstructions in (Molnar and Stock, 2009) while the right side is closed and free slip condition is applied. The bottom of the model has been left open and true free surface is applied on top.
Varying only the initial distance between the outer part of India and the Tarim (Tajik) block has a profund influence on the behaviour of our model.

HYPOTHESIS

Our hypothesis is: The high velocity zone below the Pamir - Hindu Kush is the last remaining and hanging undetached part of the semi continental - oceanic ”outer India” shelf and has only survived due to mechanical locking with delaminated mantle lithosphere of the Tarim (Tadjik) block.

OUTLOOK AND CURRENT SETTING

Since the 2D cross-section models are ignoring strike-parallel relations they miss 3D effects e.g. stress concentration around the tip of the advancing Indian plate. Hence we run low resolution 3D models in order to incorporate these effects. Setup for these models are the 2D cross-sections. Calculations are conducted in a $\sim$ 3200km x 1400 km x 400 km (N-S, E-W, depth) domain with an assigned velocity at its southern boundary. Modeling in 3D is excessively time-expansive, limiting the amount of finite elements to $\sim$200.000 all together.

Results of the 3D models will help us to proof or disproof the hypothesis we stated above.

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