

GEODYNAMIC INVERSION TO CONSTRAIN THE RHEOLOGY OF THE LITHOSPHERE

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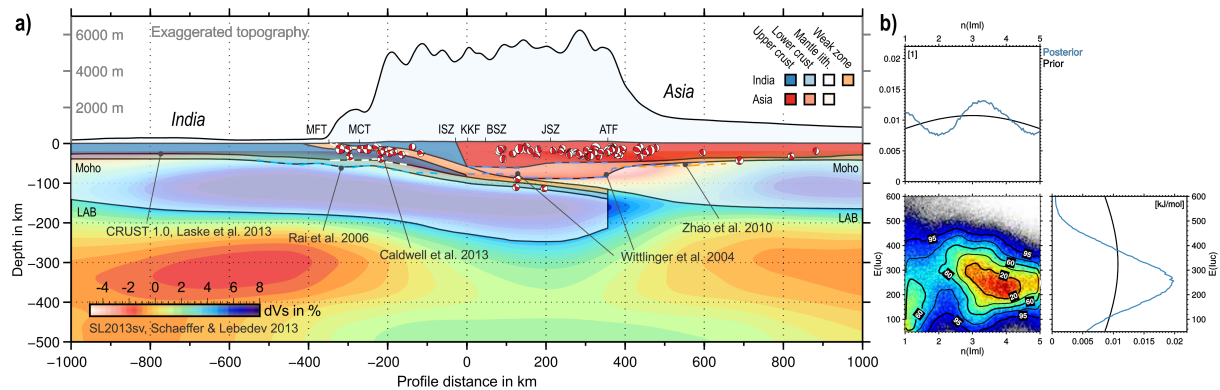


Figure 1. Geodynamic inversion applied to a SW-NE transect of the India-Asia collision [1]. **a)** 2D model geometry, constructed from multiple geophysical data. **b)** Example of the inversion results: marginal posterior distribution of two rheological parameters. Here, power-law exponent of the Indian mantle lithosphere and activation energy of the Indian upper crust.

A common method to determine the strength of the lithosphere is to estimate its effective elastic thickness (EET) from the coherence between gravity and topography. This method assumes a priori that the lithosphere is a thin elastic plate floating on a viscous mantle. Whereas this works well with oceanic plates, it has given controversial results in continental collision zones. Usually, continental collision zones are well-studied areas for which additional geophysical datasets such as receiver functions and seismic tomography exist that constrain the geometry of the lithosphere and often show that it is rather complex. Yet, lithospheric geometry by itself is insufficient to understand the dynamics of the lithosphere, as this also requires knowledge of the rheology of the lithosphere. Experimental results show significant variability between various rock types and there are large uncertainties in extrapolating laboratory values to nature.

An independent approach is thus required to better understand the rheology and dynamics of the lithosphere in collision zones. Our method combines numerical thermo-mechanical forward models of the present-day lithosphere with a Bayesian inversion approach [1]. The geometry of the forward models is part of the a priori knowledge and is constructed from seismological data. We jointly invert topography, gravity, horizontal and vertical surface velocities to constrain the unknown rheological material parameters of the forward models in a probabilistic sense. The model rheology is described with experimentally determined viscous creep laws and other parameters describing the plastic behaviour. As viscosity is temperature dependent, the temperature structure of the forward models is parameterised as well.

We apply the method to a cross-section of the India-Asia collision system (Fig. 1a). In this case, we deal with 17 to 20 model parameters, which requires solving around 2×10^6 forward models (Fig. 1b). The resulting models fit the data within their respective uncertainty bounds, and show that the Indian mantle lithosphere must have a high viscosity. Results for the Asian part of the model are less clear, but a detailed appraisal of the model ensemble using a neural network technique enables us to identify four end-member models that fit the data nearly equally well. The striking differences between the end-member models can be reduced to the existence of three model characteristics: a weak lower Tibetan crust, a weak Asian lithospheric mantle and a strong dislocation creep character of the Indian mantle lithosphere. The classification results also suggest that reducing observational uncertainties of vertical velocities is crucial to reduce the model ambiguities.

References

- [1] T.S. Baumann, B.J.P. Kaus (2015), *Geodynamic inversion to constrain the non-linear rheology of the lithosphere*, *Geophys. J. Int.* **202**(2), p. 1253–1270.