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Dynamics and stress field of the Eurasian plate

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We address the connection between forces on the Eurasian plate, the plate's motion and the intraplate stress field. Resistive forces along convergent plate boundaries have a major impact on surface deformation, most visibly at collisional plate boundaries. Although quantification of these forces is key to understanding the evolution and present state of mountain belts, they remain highly uncertain due to the complexity of plate boundary structures and rheologies. In this study we analyse the forces along the southern boundary of the Eurasian plate, presently the most prominent suture zone on Earth, resulting from the closure of the Neo-Tethys ocean.

We address the dynamics of the Eurasian plate as a whole. This enables us to base our analysis on mechanical equilibrium of a tectonic plate and to evaluate the force distribution along the Tethyan boundary as part of an internally consistent set of forces driving and deforming Eurasia. We evaluate force distributions obeying this mechanical law on the basis of their ability to reproduce observed stress orientations. We incorporate tractions from convective mantle flow modelling in a lithospheric model in which edge and lithospheric body forces are modelled explicitly and compute resulting stresses in a homogeneous elastic thin shell. Our investigation is structured according to two research objectives, pursued in a corresponding step-wise approach: (1) a detailed understanding of the sensitivity of Eurasia's stress field to the distribution of all acting forces; and (2) a quantification of collision-related forces along the southern boundary of Eurasia, including their relation to observed plate boundary structure, in particular plateau height. Intraplate stress observations as compiled in the World Stress Map project are used to constrain the distribution of forces acting on Eurasia.

Eurasia's stress field turns out to be sensitive to the distribution of collision forces on the plate's southern margin and, to a lesser extent, to lithospheric density structure and normal pressure from mantle flow. Stress observations require collision forces on the India-Eurasia boundary of 7.2 − 10.5 T N/m and on the Arabia-Eurasia boundary of 1.3 − 2.3 T N/m. Implication of mechanical equilibrium of the plate is that forces on the contacts with the African and Australian plates amount to 1.0 − 2.1 and 0 − 0.8 T N/m, respectively. The inferred collision forces are part of the best-fitting overall set of forces acting on the Eurasian plate, satisfying constraints from basic mechanics, absolute plate motion and stress field.

We use our results to assess the validity of the classical view that the mean elevation of an orogenic plateau can be taken as a measure of the magnitude of the compressive (in this case: collision-related) forces involved. We find that for both the Tibetan and the Iranian plateau, two plateaus with significantly different average elevations, the horizontal force derived from the excess gravitational potential energy (collapse force) is in balance with the collision force, thus confirming the hypothesis of balanced topography.