



Paleo-stress modelling of Africa from plate kinematic reconstructions

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Towards the end of the Cretaceous, the African plate was bounded by mid-ocean ridges, the Owen transform fault in the NE, and the Neotethys convergent boundary in the north. Convergence in the north was accommodated by subduction under the Eurasian plate and collision of tectonic blocks separated by shifting plate boundaries. The major plate tectonic event influencing the plate's geometry at the time was the neighbouring Indian plate's unusually rapid northward movement. This motion was approximately parallel to the absolute motion of Africa and to the Owen transform, while it caused sea floor spreading along the Mascarene ridge east of Madagascar. Accompanying intraplate events include the evolution of passive continental margins between Madagascar and Africa and multiple rifting episodes in northern Africa, notably along NW-SE trending rifts through what is now Kenya, South Sudan and eastern Niger. Using new constraints on the oceanic age east of Africa, our aim is to investigate the relationships between lithospheric forces and these geological events.

The intraplate stress field of the African plate at 75 Ma, and the tectonic forces that drove these geological events are constrained using torque balance and plane stress finite element models. Forces along subduction boundaries include slab pull, friction with the overriding plate, and viscous resistance between the slab and surrounding asthenosphere. Shear resistance acts along transform faults. Collisional forces act perpendicular to convergent plate boundary segments, following the perpendicular relative motions between the plates. Mid-oceanic ridges are considered to be traction free. Body forces within the African lithosphere are estimated from simple reconstructions of topography and crustal thickness. Horizontal gradients in gravitational potential energy (GPE) encompass both gravitational collapse of high continental topography and ridge push in oceanic parts of the plate. Pilot experiments showed that mantle convective tractions along the base of the African plate were not needed to achieve mechanical balance. As results from previous studies demonstrated that such tractions can be significant, but relatively complicated and mutually cancelling, we opted to omit mantle convective tractions from our calculations.

We find that African plate motion at 75 Ma was mostly driven by slab pull in combination with GPE. Since relative motion of India with respect to Africa is roughly in the same direction as the absolute motion of Africa at the Owen transform, we consider India to be driving there. However, the traction on this transform fault was relatively low (<4 MPa). This is in accordance with other studies that suggest oceanic transform strength is low and only weakly velocity dependent. The driving forces were counterbalanced by viscous resistance on the slab, plate contact resistance and, in a small part, by the continental collision. The traction of the net slab pull (slab pull minus viscous resistance) at the trench is 15-20 MPa.

The modelled stress field directions are highly variable and dominated by GPE variations. We discuss the relation between observed geological deformation and our modelled stress field. We find that the directions of maximum compressive horizontal stresses mostly do not align with the direction of absolute plate motion of Africa.