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Rifting in a continental collision setting: The separation of Arabia from Africa

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In a recent analogue modelling study Bellahsen et al.(EPSL, v. 216, p. 365-381, 2003; hereafter B2003) drew attention to an intriguing paradox in lithosphere dynamics: Arabia separating from Africa, or rifting and initiation of spreading in a setting of convergence and continental collision. The authors proposed the major change in plate boundary forces associated with the Late Eocene collision of Africa and Eurasia to have caused the subsequent extension in the Gulf of Aden and Red Sea. Whereas they presented results from analogue experiments we investigated the problem by finite element modelling of the Africa(-Arabia) plate as a whole, focussing on the stress field in the northeastern corner.

We model the evolution of the stress field during ongoing collision. The collisional segment of the Africa/Arabia–Eurasia plate boundary gradually increases in length in E-SE direction. The stress field results show overall SW-NE tension in Arabia just prior to collision, followed by a drastic reduction in tensional stress upon collision. In the vicinity of the Owen Fracture Zone, however, tensional stresses remain high. At the same time the Red Sea region the stress level is very moderate, thus not indicating simultaneous rifting. Since the initiation of rifting postdates the rifting, we consider the high tensional stresses (after collision) at the eastern boundary to have started rift formation towards the Afar region (Gulf of Aden). Upon incorporation of a propagating rift the model results show two important changes: (1) near the tip of the propagating rift, stress concentration leads to high tensional stresses, and the rifting process becomes self-sustaining; (2) the orientation of the tensional stress axis rotates clockwise with the changing boundary conditions along the plate contact during ongoing collision and rift propagation. When the rift arrives in the northern part of the Red Sea area, the direction of the tensional stress axis has rotated towards NW-SE,

promoting rifting in the Gulf of Aqaba, rather than in the Gulf of Suez region. By a simultaneous increase in the magnitude of the compressional axis the rift is possibly redirected to form the Dead Sea transform.

We conclude that the combined rotational pattern of the tensional stress axis with time and stress concentration during rift propagation adequately account for the separation of Arabia from Africa. Whereas the basic premise of the B2003 study is confirmed to be valid, their analogue modeling results and our numerical model results differ in several aspects. In contrast with Bellahsen et al. we arrive at the conclusion that rift propagation is an essential element of the proposed plate boundary forces based mechanism in order to account for the separation of Arabia from Africa.