

Rotation, narrowing, and preferential reactivation of brittle structures during oblique rifting

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Occurrence of multiple faults populations with contrasting orientations in oblique continental rifts and passive margins has long sparked debate about relative timing of deformation events and tectonic interpretations. Here, we use high-resolution three-dimensional thermo-mechanical numerical modeling to characterize the evolution of the structural style associated with varying geometries of oblique rifting in a layered continental lithosphere. Automatic analysis of the distribution of active extensional shear zones at the surface of the model demonstrates a characteristic sequence of deformation. Phase 1 with initial localization of deformation and development of wide moderately oblique en-échelon grabens limited by extensional shear zones oriented close to orthogonal to σ_3 . Subsequent widening of the grabens is accompanied by progressive rotation of the phase 1 extensional shear zones to an orientation sub-orthogonal to the plate motion direction. Phase 2 is characterized by narrowing of active deformation resulting from thinning of the continental mantle lithosphere and development of a second-generation of extensional shear zones. During phase 2 deformation localizes both on plate motion direction-orthogonal structures that reactivate rotated phase 1 shear zones, and on new moderately oblique structures parallel to σ_2 . Finally, phase 3 consists in the oblique rupture of the continental lithosphere and produces an oceanic domain where oblique ridge segments are linked with highly oblique accommodation zones. We conclude that while new structures form and trend parallel to σ_2 in an oblique rift, progressive rotation and long-term slip along phase 1 structures promotes orthorhombic fault systems, which accommodate upper crustal extension and control oblique passive margin architecture. The distribution, orientation, and evolution of frictional-plastic structures observed in our models consistent with documented fault populations in the Main Ethiopian Rift and the Gulf of Aden conjugate passive margins, both of which developed in moderately oblique extensional settings.

Mots-Clés : Oblique rifting, 3D numerical modelling, strain partitioning, transtension