



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 modelling to characterise the evolution of the structural style associated with moderately oblique rifting in the continental lithosphere. Automatic analysis of the distribution of active extensional shears at the surface of the model demonstrates a characteristic sequence of deformation. We show that upon localisation, Phase 1 wide oblique en-échelon grabens develop, limited by extensional shears oriented orthogonal to σ_3 . Subsequent widening of the grabens is accompanied by a progressive rotation of the Phase 1 extensional shears that become sub-orthogonal the plate motion direction. Phase 2 is marked by narrowing of active deformation resulting from thinning of the continental lithosphere and development of a second-generation of extensional shears. During Phase 2 deformation localises both on plate motion direction-orthogonal structures that reactivate rotated Phase 1 shears, and on new oblique structures orthogonal to σ_3 . 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 normal to σ_3 in an oblique rift, progressive rotation and long-term reactivation of Phase 1 structures promotes orthorhombic fault systems, critical to accommodate upper crustal extension and control oblique passive margin architecture. The distribution, orientation, and evolution of frictional-plastic structures observed in our models is remarkably similar to 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.