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Evolution and segmentation of oblique rift in a cold lithosphere: Insights from analogue modeling

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New lithospheric analogue models of oblique rifting provide insights into the fault evolution, basin segmentation, and mantle exhumation during rift localization and capture main characteristics of natural oblique rifts. We present two models of oblique rifting: an oblique rift (obliquity about 50°) with a pre-existing lithospheric weakness (heterogeneous model) and one homogeneous. The following evolution is observed:
(i) The fault populations, especially in early stages of deformation, are composed of faults that are, in strike, intermediate between the rift-parallel trend and the perpendicular to the opening direction. This fault population is characteristic of oblique rifts as in previous studies.
(ii) In later stages, faults parallel to the rift become numerous in both models. In the homogeneous model, displacement-normal faults also play a major role. The rift localization in an oblique direction involves a thinning in an oblique direction and variations of crustal thickness. The induced local (extensional) stresses seems to control the formation of rift-parallel faults.
(iii) During final stages of extension, in the heterogeneous model, the crust is deformed by rift-parallel faults, and in the basins, displacement-normal faults compose the small-scale deformation pattern.

Other main result is the complete different pattern of deformation of the entire lithosphere with or without pre-existing lithospheric weakness. Indeed, the heterogeneous model shows the start of mantle exhumation in an oblique direction whereas in the homogeneous model the extension is accommodated in en-echelon displacement-normal graben. The probable direction of ocean-continent transition, mantle exhumation if any, and the geometry of oceanic accretion centres would thus be very different according to the presence of a pre-existing lithospheric oblique weakness. Moreover, counterclockwise rotations of horsts are observed mainly in the homogeneous models. They result in the initiation of transfer zones. Such structures are parallel to the extension direction, particularly observed in the brittle mantle layer. We propose that they could represent proto-transfer/transform fracture zones observed in oblique rifts and oceanic basins. Those results may provide insights into the possible evolution of the Gulf of Aden conjugate margins.