EGU21-2907
https://doi.org/10.5194/egusphere-egu21-2907
EGU General Assembly 2021
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The role of tectonic inheritance during multiphase rifting: insights from analogue model experiments

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Rift systems worldwide are influenced by pre-existing crustal or lithospheric structures. Here, we use brittle-viscous analogue models to examine the role of tectonic inheritance on fault evolution during two non-coaxial rift phases. In our experiments the tectonic inheritance is a linear crustal weakness zone consisting of two offset and parallel linear segments connected by a central oblique linear segment. The first phase of rifting is either orthogonal and followed by a second phase of oblique rifting or vice versa.

The experiments reveal that the tectonic inheritance localizes initial faulting during early rifting, with faults in the domains away from it forming later. The nature and orientation of early faults depends on first-phase rift obliquity, with a progressive switch from dip-slip dominated faulting to strike-slip dominated faulting with increasing obliquity, even resulting in local transpressional structures at very high rift obliquities. First-phase rift structures, in particular those above the tectonic inheritance, exert an important control on the overall fault geometry during the second phase of rifting. Our experiments show that two-phase rifting results in fault patterns evolving by the formation of second-phase new faults and the reactivation of first-phase faults. Irrespective of the order of the applied two phases of non-coaxial rifting and the difference in rift obliquity angle between the two phases, a major rift (master rift) forms above the tectonic inheritance, underlining its strong control on fault evolution despite markedly different multiphase rift histories.

Nevertheless, close inspection of the master rift reveals differences related to the relative order of the two rift phases: (i) Oblique rifting superseding orthogonal rifting results in a major master rift, whose rift-boundary faults are not reactivated during second-phase rifting. Instead, first-phase intra-rift normal faults are being reactivated with an important strike-slip component of displacement.

Above the oblique segment of the tectonic inheritance, first-phase en echelon intra-rift normal faults are mostly reactivated and propagate along strike reorienting their tips into high angles to the local principal stretching direction (ii) Orthogonal rifting overprinting oblique rifting, on the other hand, produces first-phase strike-slip faults that link up and trend (sub)-parallel to later formed rift-boundary faults and intra-rift normal faults.

Away from the tectonic inheritance faults have more freedom to evolve in response to the regional rift obliquity, and although they may reactivate, propagate sideways and slightly reorient their fault tips during the second phase of rifting, their trend at the end of the second-phase of rifting with respect to the orientation of the master rift reflects whether first-phase rifting was orthogonal or oblique. Our model results can be used to assess the influence of tectonic inheritance on faulting, the relative order of rifting and the relative difference in obliquity in natural settings that have undergone two phases of rifting.