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The impact of structural inheritance in the Malawi Rift, East Africa

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The Malawi Rift lies within rocks of Precambrian orogenic belts in the southern, amagmatic part of the East African Rift System, and comprises a series of asymmetric border faults with lengths on the order of 100 km. On the rift valley scale, the border faults exploit pre-existing weaknesses in Precambrian rock assemblages; however, at the scale of single faults, recent fault scarps locally crosscut surface expressions of pre-existing foliations and rock unit boundaries. It is therefore unclear how pre-existing heterogeneities have influenced the development of the rift through geological time, and how, in the shorter term, they may control the location and magnitude of earthquakes.

To test the fault-scale effect of pre-existing weaknesses on rift evolution we studied the $\sim$110 km long Bilila-Mtakataka fault in detail, a major fault in the Malawi Rift that is exposed on land south of Lake Malawi. We find that although this fault locally exploits metamorphic foliations, this only occurs if the foliations are well oriented in 3D for frictional reactivation. Elsewhere, the fault follows an orientation that is neither consistent with pre-existing fabrics nor with current rift kinematics. Alternatively, the orientation of the surface scarp is well fitted with upward propagation of a planar or tabular structure extending from a depth of $\sim$ 10 km.

On the larger scale, the Bilila-Mtakataka fault fits a pattern where active normal faults south of Lake Malawi locally crosscut metamorphic fabrics, and have a range of NW-SE to NNE-SSW strikes that are oblique to seismologically, geodetically, and structurally determined extension directions. Nevertheless, these active faults are sufficiently well oriented to reactivate and grow in preference to nucleation of new optimally-oriented faults. Given spatially homogeneous joint orientations, which indicate little local stress rotation, this range of normal fault orientations appear active in the same regional stress field.

The rocks in the Malawi rift have previously been buried, heated, and dehydrated under at least amphibolite facies conditions in up to three orogenic events. Therefore, hydrous minerals with low friction coefficients have largely been broken down, and the range of active fault orientations are not caused by pre-existing frictionally weak planes. However, pre-existing ductile shear zones may represent significant zones of lower viscosity in the lower crust. A hypothesis is therefore that the range of fault orientations in Malawi is controlled by lower crustal weaknesses, above which faults propagate and reactivate whilst striking oblique to the regional extension direction. In this model, the surface geometry of the current rift fault system is determined by viscous reactivation of a, likely anastomosing, shear zone system in the underlying viscous lower crust. This hypothesis implies that local stress interactions control the propagation and linkage of upper crustal fault segments, and allows long faults to develop fast, potentially hosting large earthquakes within a relatively immature rift.