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Capturing Continental Rupture Processes in Afar

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Both continental and oceanic rifting processes are highly 3D, but the stability of the along-axis segmentation from rifting to breakup, and its relationship to seafloor spreading remains debated. Three-dimensional models of the interactions of faults and magmatism in time and space are in development, but modelling and observations suggest that magmatic segments may propagate and/or migrate during periods of magmatism.

Our ability to discriminate between the various models in large part depends on the quality of data in the ocean-transition zone, or, observations from zones of incipient plate rupture. Largely 2D crustal-scale seismic data from magmatic passive margins reveal large magmatic additions to the crust, but the timing of this heat and mass transfer is weakly constrained. Thus, the lack of information on the across rift breadth of the deforming zone at rupture, and the relationship between the early rift segmentation and the seafloor spreading segmentation represent fundamental gaps in knowledge. Our study of Earth's youngest magmatic margin, the superbly exposed, tectonically active southern Red Sea, aims to answer the following questions: What are the geometry and kinematics of active fault systems across the 'passive margin' to zone of incipient plate rupture? What is the relationship between the initial border fault segmentation, and the breakup zone segmentation? What is the distribution of active deformation and magmatism, and how does it compare to time-averaged strain patterns? We integrate results of recent experiments that suggest widespread replacement of crust and mantle lithosphere beneath the 'passive' margin, and explain the ongoing seismic deformation as a consequence of bending stresses across the ocean-continent transition, with or without a dynamic component.