Continental rifts: lithospheric weakness and strength contrasts as triggers for necking instabilities

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Continental rifts are the first stage in the formation of rifted margins. Since continents are far from homogeneous after multiple cycles of collision, strike-slip motion and rifting, heterogeneities can influence the location and geometry of rifting. We use 2D finite element models containing embedded finite weak zones in the crust and/ or mantle as well as a vertical lithospheric boundary across which the rheology changes to represent these heterogeneities. The resulting strength contrast at the lithospheric boundary changes the growth rate of necking instabilities on either side of it.

Necking is a mechanism that depends on the distribution of viscous and plastic layers in the lithosphere; stiff layers deform plastically and rapidly grow necking instabilities, whereas pliable, viscous, layers slowly grow necking instabilities. Additionally, the growth rate of necking instabilities is amplified by the background strain rate (the strain rate in the absence of any weak zones), which implies faster necking in parts of the lithosphere where background strain rates are highest. Considering these competing mechanisms, we recognize two controls on the location of rifting: Control 1, the stiff/pliable nature of the lithospheric layers, and; Control 2, the distribution of the background strain rate in the lithosphere.

In a laterally homogeneous lithosphere, the background strain rate is uniform along each layer and Control 1 will dominate, preferentially initializing necking in stiff layers. However, juxtaposed lithospheres with different strengths will lead to an asymmetrical strain with a higher background strain rate in the weaker lithosphere. In this case, faster necking can occur in pliable layers under a higher strain rate, even if inherited weak zones are present in stiff layers that are under a lower strain rate; Control 2 wins. Our results show that deformation localizes away from the lithospheric boundary in the lithosphere under the higher strain rate. Our model results imply Control 2 wins whenever the background strain rate contrast is larger than 1.0×10^{-16} s^{-1}. That Control 2 wins has implications for the preservation of cratons, which are cold and strong, and probably stiff. Even though they contain inherited weak heterogeneities, they are protected by Control 2, provided they are surrounded by weakling lithospheres such as younger orogens. We will also present a case where a combination of Control 1 and 2 produces a highly asymmetric margin, which we compare with the Gabon-Camamu conjugate margins in the South Atlantic.

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