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Dynamics of slow continental rifting: influence of gravity and rheology

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Lithospheric thinning due to rifting creates steep density and viscosity contrasts between the deformed mantle/crustal lithosphere and the upwelling asthenosphere. This provides conditions for development of Rayleigh-Taylor instabilities. Since the evolution of many continental margins (e.g., Newfoundland/Iberian Margin) and rifts (e.g. Baikal) is characterized by slow spreading rates, it allows the RT instabilities to grow at time scale of rifting. Whereas the impact of positive RT instabilities (asthenospheric upwelling) is well-studied, the negative RT instabilities, associated with lithosphere mantle downwelling, is an overlooked factor. These instabilities may control rift evolution, in particular, mantle thinning or thickening below the rift flanks. Our numerical experiments, based on thermo-mechanically and thermo-dynamically coupled numeric modeling assuming representative visco-elasto-plastic rheological profiles, show that the ratio of the RT-growth rate to the extension rate controls rift geometry and evolution. The effect of negative RT instabilities is most important for slow extension rates (10 mm/y, Deborah number, De $<$ 1) but it is still significant for 2-3 times higher extension rates (30 mm/yr, De $<$ 10). The numerical experiments for extension rates of 20-30 mm/yr and mantle-asthenosphere density contrasts of 10-30 kg/m3 demonstrate a number of structural similarities with slow continental margins (e.g., Flemish Cap and Galicia margin). Rift asymmetry results from interplay between the RT instabilities and differential stretching at De $<$ 1. Formation of interior basins (strong thinning) occurs at De = 1-3. The best correspondence with the observed geometry of rifted margins is obtained for mantle-asthenosphere density contrast of 20 kg/m3. The influence of RT instabilities is strongly controlled by extension rate, density, rheology and thermal structure of the lithosphere.