Effect of Lithospheric Stratification on Extensional Styles and Rift Basin Geometry

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Plane-strain thermo-mechanical finite element model experiments of lithospheric extension are used to investigate the effects of strain softening in the frictional-plastic regime and the strength of the lower crust and mantle lithosphere respectively on the style of extension. Crust and mantle lithosphere strength are varied independently. A simple scaling of wet-quartz and dry olivine rheologies is used to examine crust and mantle lithosphere strength variations. Cases are compared where the crust is strong ($\eta_{wet\ quartz}$ x 100), weak ($\eta_{wet\ quartz}$), or very weak ($\eta_{wet\ quartz}$ / 10), and the mantle lithosphere is either strong ($\eta_{dry\ olivine}$) or weak ($\eta_{dry\ olivine}$ / 10). Strain softening takes the form of a reduction in the internal angle of friction with increasing strain. Predicted rift modes belong to three fundamental types: 1) narrow, asymmetric rifting in which the geometry of both upper and lower lithosphere is approximately asymmetric; 2) narrow asymmetric upper lithosphere rifting concomitant with narrow symmetric lower lithosphere extension; 3) wide symmetric crustal rifting concomitant with narrow mantle lithosphere extension. The different styles depend on the relative control of the system by the frictional-plastic and ductile layers, which promote narrow, localized rifting in the plastic layers and wide modes of extension in the viscous layers, respectively. A weak ductile crust-mantle coupling tends to suppress narrow rifting in the crustal layer. This is because it reduces the coupling between the frictional-plastic upper crust and localized rifting in the frictional-plastic upper mantle lithosphere. The simple strength variation may be taken to represent end-member thermal and/or compositional conditions in natural systems and the relevance for rifting of old, strong, and cold cratonic lithosphere as compared to young, standard, and moderately weak Phanerozoic lithosphere is discussed.