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Lithospheric Rheological Stratification, Strain Weakening, and the Geometry of Rifts and Continental Margins

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Despite the large number of studies of continental rifts and rifted continental margins, many of which have produced high quality data, we still lack a unified understanding of the mechanical and thermal processes that control their extensional geometry. This problem is compounded by the wide range of styles that include both, non-volcanic and volcanic rifting. In addition, the relative importance of active versus passive rifting, that is whether rifting is driven by active mantle upwelling or whether mantle upwelling is a passive response to lithospheric extension remains to be determined

We use plane-strain thermo-mechanical finite element model experiments to investigate factors that are potentially important controls on the mode of lithospheric extension during non-volcanic passive rifting. We focus on processes that create shear zones and on the rheological stratification of the lithosphere in the context of 2D plane strain models of lithospheric rifting. Cases are compared where the crust is strong, weak, or very weak, and the mantle lithosphere is either strong or weak. 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 the 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.