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Dynamical Models of Depth-Dependent Lithospheric Extension at Rifted Continental Margins: Effects of Strong and Weak Lower Crust

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Contrasting end members of volcanic and non-volcanic passive margin formation show a large variability in structural style and associated subsidence history that imply strong variability in the underlying thermo-mechanical conditions at the time of rifting. For instance the Iberia-Newfoundland non-volcanic conjugate margin system has evolved from initial wide to late stage narrow, most probably asymmetric rift, leading to exhumation of mantle lithosphere and sub-lithospheric mantle in a wide ocean-continent transition zone under essentially cold conditions. In contrast rifting in the non-volcanic Central South Atlantic conjugate passive margins resulted in very wide (> 250 km) strongly thinned crustal conjugates which remained close to sea level until break-up providing conditions for the late syn-rift shallow water salt basin, implying high thermal gradients at the time of rifting. Volcanic rifted margins such as in the North and South Atlantic show excess magmatic activity and shallow water conditions at the rift-drift transition implying even higher geothermal gradients.

We use thermo-mechanical finite element model experiments to investigate factors that are potentially important controls during volcanic and non-volcanic passive margin formation which may explain these characteristic differences including processes that create shear zones, on the rheological stratification of the lithosphere, and on processes that lead to differential thinning of upper and lower lithosphere during rifting. Dynamic modeling 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.