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The evolution of fault geometry and lithosphere mechanical response to faulting during lithosphere hyper-extension at magma-poor rifted margins

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The geometry of upper lithosphere extensional faulting and the mechanical response of the lithosphere during continental breakup are controversial. The lithosphere response to extensional faulting at magma-poor rifted margins controls the distribution of thinned continental crust, exhumed mantle, continental allochthons and syn-tectonic sediments leading to the complexity of heterogeneous structure of hyper-extended domain at these margins. In order to better understand the evolving fault geometry and lithosphere mechanics during magma-poor rifted margin formation, we investigate extensional faulting for the tectonic end-members of continental rifting and slow sea-floor spreading. We presume that these end-members faulting styles both contribute to lithosphere thinning during rifted margin evolution as continental rifting evolves into sea-floor spreading.

For continental rifting, large extensional faults that rupture the seismogenic brittle upper lithosphere have been shown to be planar and steeply dipping by earthquake seismology and geodesy (Stein and Barrientos 1985; Jackson 1987). These results are supported by seismic reflection imaging and structural modelling of rift basins (Kusznir et al., 1991, 1995). Individual fault heaves for continental rifting seldom exceeds approximately 10 km. The effective elastic thickness, used to parameterize lithosphere flexural strength for syn-tectonic response to extensional faulting during continental rifting, are typically between 1.5 and 3 km. For slow-spreading ocean ridges we examine extensional fault geometry and lithosphere flexural response to cumulative faulting. We focus on the TAG area (deMartin et al., 2007) and the 15°N area (Schroeder et al., 2007) of the Mid-Atlantic Ridge using a flexural isostatic extensional faulting model (Buck 1988; Kusznir et al., 1991). Modelling of fault controlled bathymetry at slow-spreading ocean ridges shows that active extensional faults at depth have a steep dip (50° - 70°), similar to that observed for continental rift faulting. The heaves of the main modelled faults are typically between 2 and 15 km with a maximum of 25 km. In contrast to extensional fault geometries at continental rifting, slow spreading ocean ridges show a concave down fault geometry at shallower depth (between 0 and 2 km depth) and an emergence angle of exhumed fault footwall between 15° and 20°. This rolling-hinge response to extensional faulting (Buck 1988) requires a low effective elastic thickness for the flexural isostatic response, typically ranging between 0.25 and 1 km. Some ambiguity exists when modelling bathymetry at slow spreading ridges; in some cases the same bathymetric profile can be modelled with low effective elastic thickness and high fault extension, or with higher effective elastic thickness and lower extension. This ambiguity arises because of the difficulty in distinguishing an extensional break-away for a large fault from a simple footwall uplift of a smaller fault.

Future work will focus on developing and applying a unified model of extensional fault geometry and lithosphere mechanical response to the development of hyper-extended domains at magma-poor rifted continental margins.