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Using crustal thickness and subsidence history on the Iberia-Newfoundland margins to constrain lithosphere deformation modes during continental breakup

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Observations at magma-poor rifted margins such as Iberia-Newfoundland show a complex lithosphere deformation history during continental breakup and seafloor spreading initiation leading to complex OCT architecture with hyper-extended continental crust and lithosphere, exhumed mantle and scattered embryonic oceanic crust and continental slivers. Initiation of seafloor spreading requires both the rupture of the continental crust and lithospheric mantle, and the onset of decompressional melting. Their relative timing controls when mantle exhumation may occur; the presence or absence of exhumed mantle provides useful information on the timing of these events and constraints on lithosphere deformation modes. A single lithosphere deformation mode leading to continental breakup and sea-floor spreading cannot explain observations. We have determined the sequence of lithosphere deformation events for two profiles across the present-day conjugate Iberia-Newfoundland margins, using forward modelling of continental breakup and seafloor spreading initiation calibrated against observations of crustal basement thickness and subsidence.

Flow fields, representing a sequence of lithosphere deformation modes, are generated by a 2D finite element viscous flow model (FeMargin), and used to advect lithosphere and asthenosphere temperature and material. FeMargin is kinematically driven by divergent deformation in the upper 15-20 km of the lithosphere inducing passive upwelling beneath that layer; extensional faulting and magmatic intrusions deform the topmost upper lithosphere, consistent with observations of deformation processes occurring at slow spreading ocean ridges (Cannat, 1996). Buoyancy enhanced upwelling, as predicted by Braun et al. (2000) is also kinematically included in the lithosphere deformation model. Melt generation by decompressional melting is predicted using the parameterization and methodology of Katz et al. (2003).

The distribution of lithosphere deformation, the contribution of buoyancy driven upwelling and their spatial and temporal evolution including lateral migration are determined by using a series of numerical experiments, tested and calibrated against observations of crustal thicknesses and water-loaded subsidence. Pure-shear widths exert a strong control on the timing of crustal rupture and melt initiation; to satisfy OCT architecture, subsidence and mantle exhumation, we need to focus the deformation from a broad to a narrow region. The lateral migration of the deformation flow axis has an important control on the rupture of continental crust and lithosphere, melt initiation, their relative timing, the resulting OCT architecture and conjugate margin asymmetry. The numerical models are used to predict margin isostatic response and subsidence history.