The Mode of Continental Breakup Lithosphere Thinning and Its Implications for Rifted Margin Crustal Structure, Subsidence and Heat-Flow History

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Continental breakup is necessarily preceded by thinning of the continental lithosphere. The mode of lithosphere deformation responsible for thinning and stretching the continental lithosphere leading to rupture of continental crust and the initiation of sea-floor spreading remains a key question in understanding the structure of the ocean-continent transition and predicting its subsidence and heat-flow history. We use a generalised kinematic model of continental lithosphere stretching and thinning to investigate lithosphere response to 4 deformation modes: depth-uniform pure-shear, two-layer decoupled pure-shear, upwelling divergent flow, and buoyancy induced upwelling. The deformation model advects lithosphere and asthenosphere material and temperature in response to these deformation modes, and is used to predict the resulting rifted margin crustal structure, subsidence and heat-flow history. We apply this generalised lithosphere deformation model to the formation of magma poor margins. We compare the predictions of different modes of lithosphere deformation, and their combinations, with observations and examine the resulting sensitivities of subsidence and heat-flow history. Implications are examined for the formation of pre-breakup sag basins and asymmetric conjugate rifted margins. The dominant deformation mechanism of the topmost cool brittle 10-15 km of the lithosphere is assumed to be by normal faulting, as observed not only in intra-continental rifting but also at slow spreading ocean ridges. Beneath the 10-15 km thick cool brittle topmost lithosphere, continental lithosphere thinning can be achieved by a combination of pure-shear, buoyancy induced upwelling, or upwelling divergent flow (c.f. ocean ridge) driven by a horizontal plate boundary forces. Localised rupture of the strong topmost mantle lid immediately beneath the Moho may play an important role is localising continental lithosphere breakup rupture. Final rupture of continental crust at breakup may be controlled by very large normal faults, with tens of km of heave within the cool 10-15 km thick topmost lithosphere, giving rise to broad regions of sub-horizontal exhumed footwall of crust or mantle.