Strain Partitioning across Rifted Continental Margins as a Function of Space and Time

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Presentation Plan

Part 1

- Observations of stretching as a function of depth at rifted continental margins
- Mechanics of depth dependent stretching
- Mantle exhumation and the development of sea-floor spreading

Part 2

- Observations of strain rate ($d\varepsilon/dt$) and stretching factor (β) at rifted continental margins
- The $d\varepsilon/dt$ versus β relationship at rifted margins
- Comparison of rifted margin results with $d\varepsilon/dt$ versus β relationship for intraplate rift basins
- Are Buoyancy Forces Important During the Formation of Rifted Margins?

1. Depth-dependent Lithosphere Stretching and Mantle Exhumation at Rifted Continental Margins

Depth-dependent stretching of the continental lithosphere appears to be a consistent observation at the outer ~ 100 km of rifted margins. Extension estimates have been independently determined from faulting, crustal thickness and post-rift thermal subsidence for the Goban-Spur, South China Sea, Vøring, Møre, Galicia and NW Australian rifted margins. Upper-crustal extension (derived from faulting) is significantly lower than estimates of crustal extension (from crustal thinning) or whole-lithosphere thinning (from post-rift thermal subsidence). We do not attribute the observation of depth-dependent stretching to be solely a result of second generation faulting, aseismic extension, sub-seismic resolution faulting, or simple shear. Stratigraphic evidence suggests that depth-dependent stretching of rifted margins and mantle exhumation does not occur during pre-break-up rifting, but rather occurs during early sea-floor spreading.

Both analytical and finite-element models of the early sea-floor spreading process generate depth-dependent stretching, and suggest that depth dependent stretching at rifted margins is an inevitable consequence of early sea-floor spreading. Depth dependent stretching also predicts that lower continental crust and mantle are pulled out from beneath the continental crust during early sea-floor spreading generating a transitional 'continent-ocean boundary' that exposes continental mantle at the surface. Exhumation of continental mantle at rifted margins is supported by independent evidence from wide-angle seismology (Pickup et al), direct sampling and geochemical analysis, magnetic anomaly analysis, and geological mapping of orogenically exhumed rifted margins. In terms of a detachment model all margins (i.e. both conjugate margins) appear to be 'upper plate'.

2. Are Buoyancy Forces Important During the Formation of Rifted Margins?

Crustal stretching factor profiles from rifted continental margins supplemented by isochron data for early sea floor spreading have been used to extract a relationship between strain rate ($d\varepsilon/dt$) and stretching factor (β). Despite the different methods, assumptions and observations, our $d\varepsilon/dt$ versus β relationship for rifted margins is consistent with that observed by Newman and White (1997, 1999) for intra-continental rift basins. The $d\varepsilon/dt$ versus β relationship we derive is also consistent with the dynamic models of Newman and White which include thermo-rheological strain-hardening and -softening, but omit crustal buoyancy forces. Whilst crustal buoyancy forces are not included in the above dynamic models, the $\dot{\varepsilon}-\beta$ data do not necessarily preclude their importance.

Simple numerical models of buoyancy force evolution show that for the first 30 Ma after rifting the thermally-derived buoyancy forces within the upper mantle that assist extension are larger than the crustal buoyancy forces that oppose extension. This ‘rift push’ acts as a positive feed-back mechanism and is of the order of 3×10^{12} Nm^{-1}. The dominance of the thermal buoyancy force at early times may explain why our $\dot{\varepsilon}-\beta$ observations are consistent with thermo-rheological models which exclude crustal buoyancy forces.

Analysis of observed crustal thinning factor ($1-1/\beta$) profiles for rifted margins suggest that lateral crustal pressure gradients have a dominant peak at 0.05 ± 0.3 kPa m^{-1} and a distinct secondary peak at 1 ± 0.1 kPa m^{-1}. The pressure gradient peak at 0.05 ± 0.3 kPa m^{-1} corresponds to thinned continental crust which is terminated on the unstretched continental side by the secondary pressure gradient peak which may define the edge of a zone of thermal strain-softening. Independent observations show that narrow margins are associated with rapid strain rates and are consistent with thermal strain-softening predicted by conductive cooling models. However the dominant near-zero pressure gradient peak is consistent with the operation of buoyancy force processes during rifting, generating thickness "leveling" of thinned crust.

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