Geophysical Research Abstracts,
Vol. 10, EGU2008-A-05606, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-05606
EGU General Assembly 2008

Continental lithosphere thinning leading to breakup and rifted margin formation by combined pure-shear and induced upwelling divergent flow

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Continental breakup and sea-floor spreading initiation requires the thinning and rupture of continental lithosphere. Both non-volcanic and volcanic rifted continental margins, including conjugate margin pairs, show depth-dependent lithosphere thinning and stretching. Several different models of continental lithosphere thinning leading to continental breakup prior to sea-floor spreading initiation have been proposed. Depth-uniform (pure-shear) models of continental lithosphere thinning leading to breakup fail to explain observed depth-dependent lithosphere stretching and the exhumation of continental lithosphere mantle. Decoupled pure-shear models of lithosphere thinning leading to continental breakup, while able to predict depth-dependent lithosphere stretching, require significantly larger amounts of upper crustal extension and faulting than is observed. A new model has been developed in which continental lithosphere thinning is achieved by a simultaneous combination of pure-shear and upwelling divergent flow within continental lithosphere and asthenosphere. The upwelling divergent flow is assumed to be driven by thermal and melt buoyancy initiated by pure-shear lithosphere stretching. While horizontal tensile plate forces provide the driving force for the pure-shear deformation, the induced upwelling divergent flow provides the main contribution to continental lithosphere thinning with the pure shear contribution having Beta < 1.5. The induced upwelling divergent flow model of continental lithosphere thinning successfully predicts depth-dependent stretching of continental margin lithosphere for both non-volcanic and volcanic margins and mantle exhumation at non-volcanic margins. The model predicts a simple transition from pre-breakup lithosphere thinning to sea-floor spreading, and provides an explanation for the paucity of pre-breakup brittle deformation in the upper crust as observed at rifted margins. The observed diversity of rifted continental margin structure and width of the ocean-continent transition can be explained by variability in the form of the upwelling divergent flow field. The induced upwelling divergent flow model provides an explanation for the formation of asymmetric rifted margins and pre-breakup sag basins. Crustal thinning and lithosphere temperature predicted by the new margin formation model are used to determine rifted margin bathymetry and gravity anomaly. Observed bathymetry and gravity anomalies have been used to invert for kinematic parameters describing breakup lithosphere deformation. The induced upwelling divergent flow model of continental lithosphere thinning and rifted margin formation has been successfully applied to rifted margins including conjugate pairs, and to predict rifted lithosphere structure, OCT location, subsidence and heat-flow history. For the N. Iberian - N. Newfoundland margins, pure-shear breakup lithosphere thinning model predicts that the onset of melt generation occurs prior to breakup rupture of the continental crust for normal mantle temperature and chemical composition. In contrast the upwelling divergent flow model predicts the onset of melt generation after continental crust rupture leading to ~ 100 km mantle exhumation on each margin.