

Modelling continental lithosphere thinning leading to breakup and sea-floor spreading initiation: The role of upwelling divergent flow within continental lithosphere

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The dominant deformation process for thinning continental lithosphere leading to continental breakup and sea-floor spreading initiation is not depth-uniform intra-continental extension. Depth-uniform stretching of continental lithosphere cannot explain depth-dependent lithosphere stretching observed at both non-volcanic and volcanic rifted continental margins in which stretching of the continental lower crust and lithospheric mantle greatly exceeds that of the upper crust. A new model of continental lithosphere thinning leading to continental breakup and sea-floor spreading initiation has been developed which assumes that lithosphere thinning occurs in response to an upwelling divergent flow field within continental lithosphere and asthenosphere. The new model predicts depth-dependent lithosphere stretching for both non-volcanic and volcanic margins, and mantle exhumation at non-volcanic margins. Model formulation uses corner-flow predicted by kinematic iso-viscous stream-function or finite element solutions to advect continental lithosphere and asthenosphere material and their temperature fields. Corner-flow is defined by V_x , the divergence half-velocity, and V_z , the vertical upwelling velocity. Thinning of continental margin crust and lithosphere temperature field evolution are sensitive to the velocity ratio V_z/V_x . The model predicts exhumation of continental lithospheric mantle and a diffuse ocean-continent boundary with lateral dimension ~ 100 km for non-volcanic margins (where $V_z/V_x \sim 1$). For volcanic margins (where initially V_z/V_x is large due to buoyancy assisted flow) the predicted ocean-continent transition is sharper with little or no exhumation of continental lithospheric mantle. Depth-dependent stretching of continental margin lithosphere is predicted to occur before continental lithosphere rupture, and the on-

set of sea-floor spreading. Predicted crustal thinning and lithosphere temperature are used to determine the development of margin bathymetry, top basement heat-flow and gravity anomaly. The model has been successfully applied to the Goban Spur, Grand Banks and Iberia non-volcanic margins using observed bathymetry, gravity and sediment thickness data to invert for the kinematic parameters describing lithosphere breakup deformation. The preferred models of these margins require only small components of pre-breakup depth-uniform lithosphere stretching. The new model of continental breakup and sea-floor spreading initiation has also been applied to the most recently initiated segment of sea-floor spreading within the Woodlark Basin, western Pacific, located to the east of the Moresby sea-mount and successfully predicts the observed bathymetric profile of young ocean floor and rifted continental margin. This work forms part of the NERC Margins iSIMM project. iSIMM investigators are from Liverpool and Cambridge Universities, Badley Geoscience & Schlumberger Cambridge Research supported by the NERC, the DTI, Agip UK, BP, Amerada Hess Ltd, Anadarko, Conoco-Phillips, Shell, Statoil and WesternGeco. The iSIMM team comprises NJ Kuszniir, RS White, AM Roberts, PAF Christie, A Chappell, J Eccles, R Fletcher, D Healy, N Hurst, ZC Lunnon, CJ Parkin, AW Roberts, LK Smith, V Tymms & R Spitzer.