Geophysical Research Abstracts, Vol. 7, 07102, 2005
SRef-ID: 1607-7962/gra/EGU05-A-07102

Rifting continental lithosphere: from observations to modelling

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Rifted margins result from extension and final rupturing of continental lithosphere, which involves the interaction of mechanical, thermal and magmatic processes within a pre-structured and highly heterogeneous lithosphere. This explains that rifted margins may evolve in different ways leading to different types of margins. However, comparing the Iberia/Newfoundland and Alpine Tethys margins shows that although they are of different ages and ultimately had a different fate, they share remarkable similarities. These similarities do not only permit to compare direct observation and unlimited sampling in the ancient Alpine margins with the drill-hole and geophysical data from the present-day Iberia/Newfoundland margins but also suggest that the underlying processes controlling rifting are similar. The key observations made for these two margins, which have to be explained by the models are: (1) the different stratigraphic record and tectono-metamorphic evolution of lower crustal rocks observed in the distal and proximal margins; (2) the transition from distributed to localized extension during rifting; (3) the increasing importance of exhumation processes towards the end of rifting; and (4) deformation, isostasy and geometry of fault systems changing during rifting.

Based on these key observations a conceptual model has been proposed to explain the temporal and spatial evolution from onset of rifting to seafloor spreading for the Iberia/Newfoundland and Alpine Tethys margins. Within this model, three modes of extension can be identified: a stretching mode; a thinning mode; and an exhumation mode. The three modes are characterized by the isostatic response to extension, the basin architecture, and the fault geometry, which depend on the bulk rheological evolution of the extending lithosphere.

The stretching mode is characterized by upwards listric faults that sole out in the mid to lower crust, subdued rift-shoulder uplift and a regular spacing of the tilted fault blocks. Deformation in the crust is decoupled; thinning and exhumation are of minor importance.

The thinning mode is characterized by faults that cut across the crust, exhume and thin the crust significantly and produce major rift-shoulder uplift. Deformation in the crust is localized and coupled, high-angle faulting in the hanging wall are subdued and tilted blocks are absent.

The exhumation mode is characterized by downward-concave faults that exhume mantle rocks at the seafloor and leads to the accretion of tens to hundreds of kilometres of new “crust”. The creation of fault related topography is subdued.

The three modes explain particular behaviour of the extending lithosphere such as coupling or decoupling of extension and the geometry of faults controlling the stratigraphic evolution and architecture of the margin. These modes enable to link observations and processes and to discuss the underlying physics controlling lithospheric extension. We believe that in other margins, these modes may interact in a different way depending on the pre-rift conditions and the evolution of the rheology during rifting.