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Rifted margins archetypes and forcing parameters

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The Iberian-Newfoundland Margins have commonly been used as analogues to describe rifted margins. The Iberian margin is well constrained thanks to the DSDP-IODP wells, seismic reflection and refraction datasets. Considerable similarities are also observed within the world-class field analogues in the Swiss Alps. The resultant so called “Iberian model” can satisfyingly be applied to several cases of margins where mantle is exhumed by detachment faulting, often associated with syn-rift sediment-starved environment (Somalia, East India). However, these features do not necessarily reflect the actual diversity of margins worldwide, and may rather correspond to an end-member model.

Recent observations reveal that some margins are characterized by a continental crust that exhibits macro-ductile behavior with strong internal shear and core-complex geometries up to the final break-up which demonstrates a different kind of margin evolution. Thermomechanical numerical models suggest that this deformation is the consequence of a weak rheological behavior of the crust modeled using a thick ductile lower crust. At the foot of these weak margins, either magma-rich or magma-poor, crustal shear zones are commonly observed as the main accommodating structures for hyper-extension. They consist of large-scale low-angle normal faults in the upper crust rooting on horizontal shears in the lower crust. The deformation pattern can be either basin-ward with a migration of the deformation and associated sedimentation/volcanic activity or more diffuse and chaotic. In some cases, low-angle shear zones define an anastomosed pattern that delineates boudin-like structures inside the crust up to the basement-sediment interface. In the upper brittle crust, the maximum deformation is localized in the inter-boudin areas where lower crustal material is commonly exhumed by low-angle shear-zones (core-complexes). These observations consistently indicate an enhanced ductile behavior of crustal rocks compared to the Iberian archetypal case of margin where the brittle deformation is more expressed and normal faults couple very early in the deformation history to the mantle. This ability to couple to the mantle can also be observed in the magma-poor end member of weak margins (e.g. Gabon margin) but strongly delayed in the deformation history. We argue that a mechanically-decoupled continental crust prevents surface faults from reaching mantle rocks, delaying a proper continental rupture. This delay might be due to the fact that the upper brittle crust is the strongest layer of the continental lithosphere (”crème-brulée” rheological behavior) in the contrary to the Iberian-type margins where the upper mantle is the strongest layer of the lithosphere. Considering the tectonic and sedimentary contexts of these “wide” margins, a likely interpretation is that the thinning of the crust is triggered by a hot thermal regime (inherited or acquired).

We present and discuss a set of archetypal seismic profiles and propose a simple classification of passive margins based on the magmatic input and the rheology of the continental crust during rifting. We also discuss the parameters (structural inheritance, thermal evolution, mantle fertility, sedimentary input, magmatic history...) that might drive the development of a margin toward a weak or strong pole or a magma-rich or –poor pole.