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A solution for the stretching value paradox

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Results of numerical experiments are compared with the evolution and architecture of continental margins and rift zones such as the Iberian margin and the northern Red Sea rift. A frequent observation at distal rifted margins is that stretching factors inferred from mapped faults are much smaller than stretching factors derived from the amount of crustal thinning (Driscoll and Karner 1998). Thin crust at distal margins is derived from the uppermost section of the unstretched crust (often with pre-rift sediments being preserved on top of the fault blocks) whereas the lower crust apparently has vanished. At the Iberian margin this has been explained by means of asymmetric rifting models. The Iberian margin was construed as the upper plate of a lithospheric detachment accommodating extension and leading to continental breakup. However, apparently stronger stretching of the lower crust is observed on both conjugate margins where they both are studied. Hence, geologists focusing on stretching and subsidence, commonly find upper plate margins in terms of asymmetric rifting models, a phenomenon known as “upper plate paradox” (Driscoll and Karner 1998). There is jet another paradox. Structural geologists commonly come to the conclusion that a studied margin is a lower plate margin if they favor asymmetric rifting models (e.g. Manatschal 2004). This conclusion is mainly based on the observation of tilted blocks separated by parallel-dipping normal faults and resting on top of a bright reflector at the base of the thinned crust (s-reflector). At the Iberian margin, the s-reflector reaches the surface at the tip of the continent where upper crust lies directly on exhumed subcontinental mantle. Mid crustal rocks sheared with a top to the ocean sense of shear have been sampled from that location (Boillot et al. 1995). The s-reflector has been interpreted as a lithospheric detachment and hence, the margin was viewed as to represent a lower plate margin.

Our models reproduce both sets of observations in an overall symmetric rifting geom-

etry if the model has a particular vertical and horizontal stratification (Nagel and Buck 2004). First, a thin and weak mid crustal layer has to be sandwiched between the brittle upper portion of the crust and a lower crust that is considerably stronger. Second, a pronounced horizontal (thermal) weakness has to be predefined at the onset of rifting. With these conditions met, deformation in the lower lithosphere is accommodated by localized necking at the site of the thermal weakness. The brittle crust fails through distributed collapse and is spread over the weak middle crust into the opening gap in the rift center. The apparently stronger stretching of lower crust at the distal margin results from the wider distribution of upper crustal extension as compared to the lower crust and upper mantle. The rift shoulder is found at a location where the lower crust is not stretched at all.

The applied horizontal and vertical stratification seems realistic in many rift systems. Middle crust considerable weaker than lower crust has been inferred on the basis of compositional differences or the lack of water in the lower crust. In the Red Sea, the onset of rifting was accompanied by a pronounced magmatic event. Margin and rifting architecture predicted by models with weak lower crust differ significantly from observed ones. In particular, lower crustal rocks should be abundantly present at the surface on one side of the rift.

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