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Numerical Experiments of Rifted Margins Built on Ancient Orogens

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Many continental rifted margins were built on ancient suture zones. Examples in the North Atlantic region are the Greenland-Norway conjugate margins which developed on the Caledonide mountain belt and the Iberia-Newfoundland margins which formed on the closure zones of the Iapetus and Rheic oceans. Rifted margins preferentially arise on ancient collision zones because their structural, thermal and compositional inheritance favours localization of deformation. Orogenic thrust faults, sedimentary covers or magmatic sequences provide local to large scale heterogeneities that affect lithospheric strength and help localize extensive stresses. Thickening of continental crust also promotes deformation by gravity driven flow that may trigger extension or by long-term thermal weakening due to a higher concentration in heat producing elements. Taking the above mechanisms into account in numerical simulations of rifted margins is key to characterization of the initial stretching phase of the rifting process.

We use the thermo-mechanical finite element code SULEC to examine the impact of the style of collision on rifted margin formation. We first built continent-continent collision zones from different lithospheric strengths and compression velocities. We ignore oceanic subduction. We obtain three different types of orogenic structures: 1) at low velocities and low strengths, pure shear thickening is the preferred mode of deformation without any particular fault activity; 2) at high velocities and high strengths, a single asymmetric continental subduction interface develops leading to the progressive formation of thrust nappes; and 3) intermediate velocities and strengths lead to ablative subduction of both sides of the lithosphere with thrust faults formed in-sequence towards the foreland in a perfectly symmetric pattern. These last two collision modes dynamically create structural, compositional and thermal inheritance.

We then extend the continental lithosphere in a second phase when a certain amount of convergence was achieved and after an eventual kinematic pause. This stage is dominated by the reactivation of inherited crustal-scale faults and the former subduction interface, but also by partial localization in the warm, weak orogen, especially after a long kinematic quiescence. The final margins are mostly asymmetric with hyper-extended crust. Extension of the single subduction type of collision shows progressive seaward formation of fault-bounded extensional half-graben basins, core complexes and crustal allochtons. Extension of the ablative subduction type of collision leads to viscous stretching with new faults being created mostly close to break-up.

The inherited structure of collision zones leads to a much richer structural and stratigraphic architecture of rifted margins. Our results provide a promising physical framework for a more detailed comparison with geophysical observations of offshore Atlantic margins.