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Numerical experiments investigating the effects of North Atlantic plate motion histories on rifted margin architecture

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Numerical experiments show how variations in extension velocity, crustal rheology, and crustal thickness impact the geometry of continental rifted margins. An initially strong ductile lower crust and/or high extension rates lead to short, symmetric margins. In contrast, an initially weak ductile lower crust at moderate to high extension rates may form hyper-extended crust over more than 200 km. Such variations in numerical margin width resemble natural variations as seen in, for example, the narrow margins of the northern Norway and Flemish Cap regions and the wide margins of mid Norway and Iberia. However, a resemblance in shape does of course not necessarily imply that the controlling formation mechanism is uniquely identified. Unravelling the cause of margin width changes is made more difficult by the little constraint we commonly have on crustal thickness and rheology at the onset of rifting and velocities before break-up. For this reason, numerical experiments often use relatively simple initial setups and driving conditions, with laterally homogeneous materials and extension velocities that are constant through time. This has been a very useful approach that has increased our understanding of the sensitivities of a rift system to imposed parameter variations.

Here we present rift experiments that take these previous experiments a step further by considering variations in extension velocities during rifting for different initial geometries. Our approach follows observations from plate reconstructions that rifting proceeds through slow and fast phases and that rifting often initiates on old continental collision zones, implying a lithosphere that is not initially laterally homogeneous. We examine alternative velocity histories for the Norway-Greenland rift system based on different regional plate reconstructions and contrast these with a constant velocity model. For each set we vary in addition the initial crustal thickness. Our experiments of rifted margin formation use the 2D version of SULEC (developed by Buiter and Ellis), an arbitrary Lagrangian-Eulerian finite-element code that solves the incompressible momentum equation coupled with the energy equation. We find a wide range of rift-to-breakup durations between 20 to 160 Myr. A long phase of initially low magnitude extension rate can cause rift jumps when thermal cooling and associated ductile strengthening render the rifting region too strong for continued rifting. Ramping up of rift velocities then causes continental break-up in the new rift region.