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Evolution of lithospheric deformation during multi-phase extension

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Lithospheric extension may be achieved in multiple phases of deformation separated by periods of relative tectonic quiescence. Such multi-phase extension may help explain the architecture of continental margins (e.g., the margins of Norway, Newfoundland, W. Africa, and S. China Sea) that exhibit complex structural and sedimentological histories and that are characterized by multiple basins. Previous numerical studies have highlighted the strong effect of thermal cooling on lithospheric strength during multi-phase or slow extension. During cooling periods, the weakest and thinnest regions of lithosphere along the central rift axis may strengthen more than the surrounding regions with thicker crust, leading to lateral rift migration once extension resumes.

Whether or not rifting will resume close to the previous rift or jump laterally will depend on the amount of extension and asthenospheric upwelling that occurred during rifting and the duration of the subsequent tectonic quiet phase. In addition to the duration and initiation of tectonic quiescence, sedimentation and erosion processes, rates of strain weakening and hardening, and initial lithospheric structure all combine to govern rift evolution. Multiple episodes of tectonic quiescence add further complexity to rift evolution. Our goal is to explore such key parameters and processes during multi-phase extension and carefully examine the factors controlling lateral rift migration.

We examine multi-phase rifting using a 2D version of the finite-element, thermo-mechanical code SULEC. All models maintain a geometry of 800x240 km, with the continental crust and lithosphere (viscous-plastic), respectively, extending to 40 km and 120 km depth. Outward velocities drive lithospheric extension, which is exactly balanced by astenospheric inflow. Intermittent tectonic quiescence is introduced by stopping and restarting extension for prescribed periods of time. During periods of no extension, the lithosphere and asthenosphere undergo cooling. In addition, we examine the effects of healing of strain-weakened extensional shear zones on rift localization in resumed rifting. We compare our results with continuous rifting models at 1 to 2 cm/yr.

Preliminary results highlight the importance of thermal hardening in interplay with the amount of extension achieved in the first rift phase. Failed rifts at small amounts of extension may remain abandoned even for short tectonic quiet phases, whereas longer post-rift phases are required for lateral rift migration after strong initial rifting.