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Evolution of heat-flow, subsidence, faulting and sedimentation patterns during extension at magma-poor, hyper-extended margins.

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In this work we present the results of a new methodology to numerically model continental extension. The numerical model combines a kinematic description for sedimentation and upper crustal faulting with a dynamic description for lower crust and mantle flow. This allows us to accurately understand how lower crust and mantle deform in response to different patterns of faulting in time and space and can be used to accurately model the subsidence, heat flow and sedimentary responses to extension along a given seismic profile. Faulting geometries and timings must be interpreted from the seismic profile and input into the numerical model. We have calibrated these models with fully dynamic numerical models to validate our solutions.

Here we focus on using this numerical model to understand the quantitative predictions of the "sequential faulting" model published by Ranero and Pérez-Gussinyé (Nature, 2010). This conceptual model suggests that the architecture of magma-poor margins can be explained by assuming that faulting and lower crustal deformation are tightly coupled in time and space. As extension progresses faulting becomes sequential in time and incorporates the embrittled lower crust at high extension rates. These processes acting in concert: i) reconcile the horizontal extension on faults with crustal thinning, ii) explain the change in fault geometry from planar to listric to detachment-like with increasing extension, and iii) generate the tectonic asymmetry observed between conjugate margin pairs.

Our numerical model shows that the upper and lower crustal deformation patterns predicted by the "sequential faulting" model leads to a peak heat flow that moves oceanwards with increasing extension. This implies that less extended sectors are thermally subsiding and depositing sediment with post-rift like geometries as the basin centre is actively faulting. Active sequential faults must accommodate huge slip velocities ($\sim$20 km/Myr) to take up the whole extension, a fact that this is corroborated by fully dynamic models, and has importance for syn-rift sediment accumulation and distribution. Active faults are planar but become listric, due to flexural rebound produced by activity on the newer fault in their hanging wall. Spatially close faults merge at depth forming detachment-like structures. The precise shape of these apparent detachments depends on the spacing and timing of activity of each of the sequential faults. We show how small variations in these parameters lead to different detachment shapes or even the occurrence of no detachments, explaining the 3D variability of these structures along magma-poor margins such as the West Iberia one.