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The role of long-term strain history on the generation and amplification of inherited heterogeneities in continental lithosphere extensional settings

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The Earth's lithosphere is characters by various types of heterogeneities, at different scales and located at variable depth. They can be represented at crustal level by remnants of earlier tectonics evolution, such as previous orogenetic structures, remains of passive margins and magmatic bodies intrusion, or at deeper level by mantle anisotropies. These heterogeneities can severely affect the stress and strain localization in subsequent continental lithospheric extension and rift basins evolution, hence contributing to the formation of diverse and complex rift basin types and architectures.

In order to explain the difference in rift basin and passive margin types, their subsidence patterns and melt production, previous studies have exanimated the role of initial heterogeneities, rheological layering, geothermal gradients, and extension rates during a single rifting event.

However, this approach does not consider the previous strain history of many basins that are characterized by multiple rifting events. In this study we use numerical models of a pristine lithosphere undergoing two rifting events separated by cooling, to show the effect of early events on later evolution. The strain histories are controlled by the variation of velocity of boundary displacement during two rifting events. We use both fast and slow first rifting events, followed by a cooling period, producing diverse mechanical heterogeneities at Moho level that represent inherited initial conditions for the second rifting event. These inherited heterogeneities range from several small perturbations distributed along the numerical domain at the end of the slowest first rifting event, to a single large perturbation at the end of first fastest rifting event. In the second rifting event, the inherited heterogeneities are amplified at different degree and time, depending on the velocity of boundary displacement used.

To highlight the role of previous strain history, we parametrize the inherited heterogeneities by calculating localization indexes for all the models at the onset of the second rifting event. This calculation embeds the inherited rheology from the previous rift event.

We show that the lithosphere progressively localises along the inherited heterogeneities leading to the formation of various rift basin types, ranging from narrow to wide to hyperextended and with variation degrees of symmetry. Our result show that rift basin types and structural styles are strongly affected by inherited heterogeneities generated from previous rifting events, showing cases in which the previous strain history cannot be neglected. The subsidence patterns and melt production result to be very sensitive to the strain history, the type of inherited heterogeneities and their interplay with variation of boundary displacement velocity. Our numerical simulations replicate the first-order features of rift basins and provide a general framework to assess the inherited heterogeneities' role in the interpretation of extensional basins and their evolution.