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Interaction of global mantle convection with continental rift dynamics

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Continental rifting from inception to break-up is shaped by processes acting on different scales: from faults and partial melting to global scale mantle dynamics including plume rising and slab sinking. Here, we study continental rifting using 2D global-scale numerical simulations. In our models, plate boundaries evolve self-consistently and we do not prescribe any external forcing. Continental break-up emerges spontaneously due to slab pull, mantle basal drag and trench suction.

We show that continental separation follows a characteristic evolution with three distinctive phases: (1) A pre-rift phase that typically lasts for several hundreds of millions of years with tectonic quiescence in the suture and extensional stresses that are slowly building up. (2) A rift phase that further divides into a slow rift period of several tens of millions of years where stresses continuously increase followed by a rift acceleration period featuring an abrupt stress drop within several millions of years. The speed-up takes place before lithospheric break-up and therefore affects the structural architecture of the rifted margins. (3) The drifting phase with initially high divergence rates persists over tens of millions of years until the system adjust to new conditions and the spreading typically slows down.

By illustrating the geodynamic connection between subduction dynamics and rift evolution, our results allow new interpretations of plate tectonic reconstructions. Rift acceleration within the second phase of rifting is compensated by enhanced convergence rates at subduction zones. This model outcome predicts enhanced subduction velocities, e.g. between North America and the Farallon plate during Central Atlantic rifting 200 My ago, or closure of potential back-arc basins such as in the proto-Andean ranges of South America during South Atlantic opening. Post-rift deceleration occurs when the global plate system re-equilibrates after continental rupture. This phenomenon of a plate slow-down after mechanical rupture is corroborated by observations from rifted margins between Australia-Antarctica and Greenland-Eurasia.