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V-shaped propagators, transform margins and wide rifts: A single dynamic process ?

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The formation of passive margins has been extensively modelled in two dimensions. Effect of the thermo-rheological stratification of the lithosphere, rate of extension, and lithosphere-mantle interaction (plumes or RT instabilities) in 2D on rifting and break-up are to first order well understood. Weaker lithosphere and small rate of extension lead to wider margins as it is more difficult to focus deformation, plumes on the other hand permit to break the lithosphere as very small rates of extension.

Yet, the simpler 2D models struggle at capturing the widest margins observed on Earth. In order to reproduce wide rifts and hyper-extended margins in 2D, modellers have added a lot of complexity like structural inheritance, rate weakening rheologies, multiple phase rifting in their model set up.

Over the last 5 years, technology has made it possible to model continental rifting and passive margin formation in 3D. Many contributions have been focused on modelling oblique rifting and transform margins and other separately on V-shaped propagators.

However, in Nature, propagators, transform margins and hyper-extended margins are closely linked. The South China Sea, one of the widest continental rift in the world, display a propagator stopping on a transform margin which separates the oceanic domain from a wide rift domain. Similar pattern has been highlighted recently by Nirrengarten et al. (2017) at the time of the opening of the North Atlantic. In both case the transform located at the tip of the propagator marks actually the limit between an oceanised rift and a wide continental rift, which is impossible to reconcile with a scissor opening kinematic. Indeed this type of kinematics would produce shortening in the continental rift domains, which is not observed. The only way to explain the geological observations is to consider that within a domain of lithosphere, which is stretched at almost constant rate continental break-up propagation is very slow.

Here, after introducing the key observation, I will first show that with cylindrical boundary condition or small change in stretching rate along strike, continental break up propagates hundred times faster than tectonic plate velocity. I will then show that topographic gradients, out-of-plane compression and large off-set between propagating rift permit to slow down drastically (down to tectonic plate rates) the oceanic propagators and finally that stalled oceanic propagators lead to the formation of transform margins and, when the crust is weak, extremely wide rift zones.

Finally I will discuss how these new findings shade new light on our understanding of passive margins from 2D models. The width and architecture of passive margin in 3D is to first order controlled by break-up propagation rate rather than rheology or extension rate, more over, in 3D, asymmetry of margin emerges from obliquity rather softening or mechanical decoupling in 2D.

References:
Nirrengarten, M., et al. "Kinematic evolution of the southern North Atlantic: implications for the formation of hyper-extended rift systems." Tectonics (2017).