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WHY ARE CONJUGATE PASSIVE MARGINS OFTEN ASYMMETRIC? – A NEW ANSWER TO AN OLD QUESTION

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During passive margin formation, continental crust and lithosphere are stretched and thinned until break-up takes place and a new oceanic basin is formed. Many rifted margins feature highly thinned continental crust (thickness <10 km) that is divided between conjugate margin pairs with striking asymmetry. While highly thinned crust can be very wide on one margin (e.g. 70 km in Iberia, 200 km off Angola) it is restricted to few tens of kilometres on the conjugate side. Similar margin asymmetry is evident at many passive margins pairs like Australia/Antarctica, East Australia/Lord Howe Rise, India/Antarctica, Europe/North America, the Central South Atlantic conjugates and possibly at the Australian North West Shelf. Here we suggest that a new process ‘steady-state rift migration’ is the key for understanding both margin asymmetry and the generation of highly thinned crust.

We combine observation form the well-studied Iberia/Newfoundland and Angola/Brazil margins with thermo-mechanical forward models. Our numerical code involves an elasto-visco-plastic rheology formulation that allows for self-consistent generation of faults and ductile shear zones as well as stress- and temperature-dependent viscosity.
We constrain our experiments with detailed plate kinematic history of the pre-break up and early seafloor spreading phase, laboratory-based rheology, and melt fraction evaluation of mantle upwelling. Our results are consistent with observed fault patterns, crustal thickness, and basin stratigraphy.

We find that rift migration is induced by strengthening in the rift centre and weakening of a rift side. Both effects generate a lateral strength contrast that forces motion of the rift centre in a steady-state manner. Rift migration is accommodated by sequential faulting in the brittle crust and controlled by lower crustal flow. Thus the extent of rift migration depends on lower crustal viscosity near the rift centre, which in turn is a function of extension velocity, lower crustal composition and initial thermal structure. By demonstrating how lower crustal viscosity and the rate of extension affect the final margin width, we explain the formation of highly thinned crust and the degree of asymmetry in the Central South Atlantic and Iberia/Newfoundland within a single model framework.

Our model holds important implications for deep-water hydrocarbon exploration. It displays sustained transfer of material across the extensional plate boundary predicting that large portions of a wide margin originate from its conjugate side. Moreover, lateral motion of the rift centre causes oceanward migrating peak heat flow, affecting the spatio-temporal hydrocarbon maturation patterns.