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Unravelling the impact of inheritance within the Wilson Cycle: a combined mapping and numerical modelling approach

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Our study aims to unravel how structural, lithological and thermal heterogeneities may influence both orogenic and rift systems within the Wilson Cycle. To do this, we map first-order rift structural domains, timing of the main rift events as well as major heterogeneities and structures inherited from previous orogenies. Besides, we design numerical modelling experiments to investigate the relationships highlighted from the comparison of these maps.

We apply this approach to the North Atlantic region, which underwent two major orogenic phases during the Palaeozoic: (1) the Caledonian orogeny – now extending from United-Kingdom to northern Norway and Eastern Greenland – resulted from the Late Ordovician closure of the large Iapetus ocean (> 2 000 km) and smaller Tornquist Seaway. It was followed by purely mechanical extensional orogenic collapse; (2) the Variscides of Southwestern Europe were essentially built from the Devono-Carboniferous suturing of several small oceanic basins (< 200 km) in addition to the large Rheic Ocean. The subsequent orogenic collapse was accompanied by significant magmatic activity, which resulted in mafic underplating and associated mantle depletion over the whole orogenic area.

Our study is twofolds: On the one hand, we investigate how the size and maturity of the intervening oceanic basins affect subduction and orogeny, considering two end-members: (a) immature oceanic basins defined as hyperextended rift systems that never achieved steady state seafloor spreading; and (b) mature oceans characterized by a self-sustained magmatic system forming homogeneous oceanic crust. On the other hand, we study how post-orogenic collapse-related underplating and associated mantle depletion may impact subsequent rifting depending on the thermal state (e.g. the duration of relaxation time between the magmatic episode and the onset of rifting).

Our results highlight a very different behaviour of the North Atlantic rift with respect to the Caledonian and Variscan orogenic lithospheres, the Variscan front appearing to be a major limit. Indeed, the rift cuts through the Caledonian orogen and parallels its structural grain, while it circumvents the core of the Variscides. In addition, rifting is protracted and polyphase, and breakup is magma-rich North to the Variscan front, as opposed to the South. These observations point to a major influence of orogenic inheritance on the characteristics of hyperextended rift systems and suggest that rifts reactivate sutures corresponding to former large (> 2 000 km) oceans, while leaving sutures of small (< 500 – 1 000 km) oceanic basins little affected.