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How can hyper-extension be integrated into kinematic plate reconstructions? The example of the southern North Atlantic

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Plate kinematic models aim to perform palinspastic fits of continental blocks and to restore their motion through time using isochronal features such as oceanic magnetic anomalies. In the absence of oceanic magnetic anomalies, restorations suppose a continuous motion between a full fit position (tidiest/maximal fit) and the position determined by the first oceanic magnetic anomaly. However, recent studies show that the domains between undeformed continental crust and unequivocal oceanic crust can be several hundreds of kilometers wide at magma-poor margins, formed by so called hyper-extended rift domains. The kinematics, rates and processes forming these rift domains are as yet not well understood leading to problematic integration into plate kinematic reconstructions. In this study, we propose a new restoration methodology that integrates the spatio-temporal evolution of hyper-extended domains into kinematic plate modeling. To do so, we use the example of the well constrained southern North Atlantic magma-poor rifted margins. The extensive dataset, including deep ODP drill holes and high quality public available seismic data, enables good spatio-temporal calibrations.

This new approach is based on the mapping of different rift domains, including un-deformed continental crust, thinned crust, exhumed mantle and oceanic crust. In order to account for the continental crust extension and to define the limit of the reconstruct continental crust, the volume of deformed continental crust is restored back to its initial thickness, enabling pre-deformation continental polygons and a pre-rift continental fit to be defined. Crustal thickness maps are determined by 3D gravity inversion which includes lithosphere thermal gravity anomaly correction and magmatic additions. Time constraints, if available, may be obtained from the dating of the necking age, mantle exhumation and lithospheric breakup using geochronological or stratigraphical methods. We use the plate reconstruction software Gplates into which we incorporate pre-deformation polygons, mapped domain boundaries, dated events on some locations and transfer fault orientation. The aim is to use all available data to constrain polygon deformation from full-fit to the first oceanic crust.

The new plate model for the opening of the southern North Atlantic is non-unique and needs to be further tested with new complementary data. However this model highlights the importance of the partitioning of the rift deformation between different segments or rift systems. Our modelling suggests that continental rift deformation is segmented by fracture zones controlling the timing of deformation propagation from south to north. In contrast, mantle exhumation and seafloor spreading propagate northward with a V-shaped geometry. These different propagation styles may be correlated to the influence of crustal inheritance on the extensional processes.