GLORY — Global Tectonics With Realistic Lithospheric Rheology

MARIE CURIE OUTGOING FELLOWSHIP
FINAL PUBLISHABLE SUMMARY REPORT

The theory of plate tectonics explains a multitude of geological and geophysical phenomena, however, several first order features of plate tectonics are still poorly understood. The overarching aim of this proposal is to explain how the interaction between the deep mantle and the lithosphere affects Earth's plate motions, lithosphere deformation, and topography. The tool to achieve this goal is numerical geodynamic modelling in combination with plate tectonic reconstructions, mirroring the expertise of European and Australien host institution, GFZ Potsdam and University of Sydney, respectively.

This project extensively relied on cutting-edge 2D and 3D numerical models on lithospheric and global scale in order to addressing aspects like lithosphere deformation, rift strength, and crustal stress field, in settings ranging from oblique rifting over rift propagation to plume-lithosphere interaction (Brune et al., 2013; Brune and Autin, 2013; Koopmann et al., 2014; Clift et al., 2015; Brune, 2016; Díaz-Azpiroz et al., 2016). The insight that oblique rifting is mechanically favoured over orthogonal rifting (Brune et al., 2012) was corroborated in a multidisciplinary study of the obliquely rifted Equatorial Atlantic (Heine and Brune, 2014). In a recent single-author study (Brune, 2014), I investigated crustal stress patterns and fault orientations with a laterally homogeneous 3D model setup, which generates a surprising variety of fault orientations that are solely caused by the three-dimensionality of oblique rift systems.

One of the most remarkable and least understood structures at magma-poor margins are up to 200 km wide areas of hyper-extended continental crust, which are partitioned between conjugate margins with pronounced asymmetry. Together with colleagues from the University of Sydney and the University of London, I used high-resolution 2D modelling to show that hyper-extended crust and margin asymmetry are produced by steady-state rift migration (Fig. 1), which explains key findings from the South and North Atlantic (Brune et al., 2014).

Apart from numerical modelling, the fellowship comprised the analysis of geological observations and geophysical data. By developing and applying a new tool ‘pyGPlates’ to analyse rift history in global plate reconstructions, we established a global rift database that contains the history of extension velocity and obliquity for all points of major passive margins. Analysing this database we showed that the decreasing strength of the rift centre generates abrupt plate accelerations long before break-up (Fig. 2). In a manuscript that was recently published in Nature (Brune et al., 2016), we illustrate that this plate speed-up significantly shaped Earth’s rifted margins and that the abrupt plate acceleration is caused by the non-linear rheology of Earth’s crust and mantle rocks.

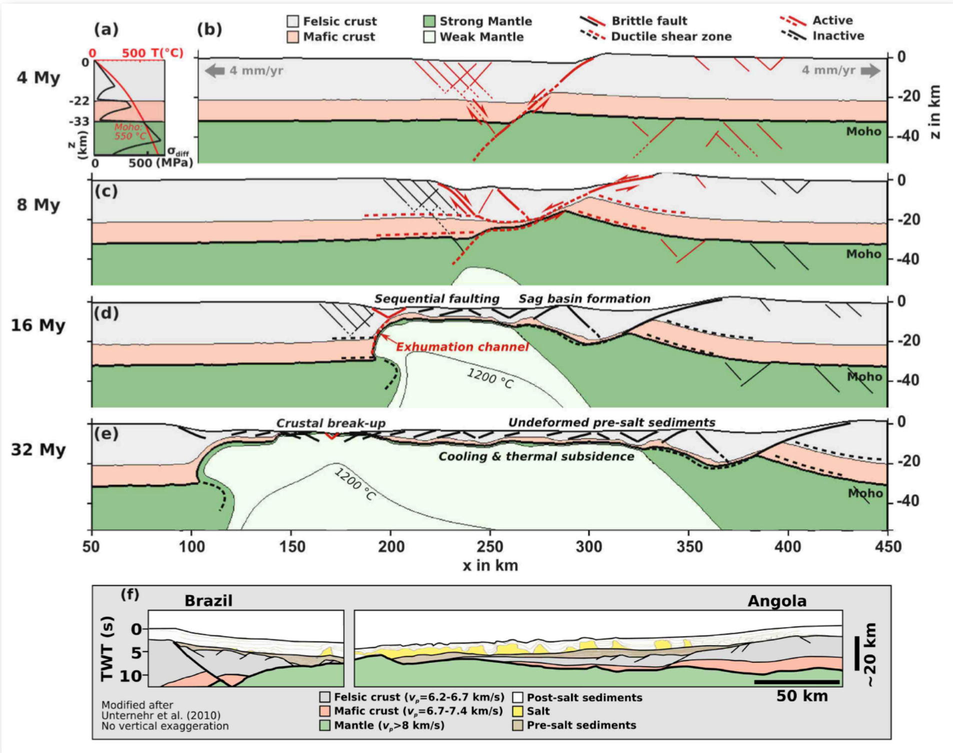

***Fig. 1:** Numerical forward models of the Central South Atlantic margins that formed between 145 and 120 million years ago **(a-e)** A narrow, asymmetric rift generates a conjugate margin pair with a wide and a narrow margin. [after Brune et al., 2014]*

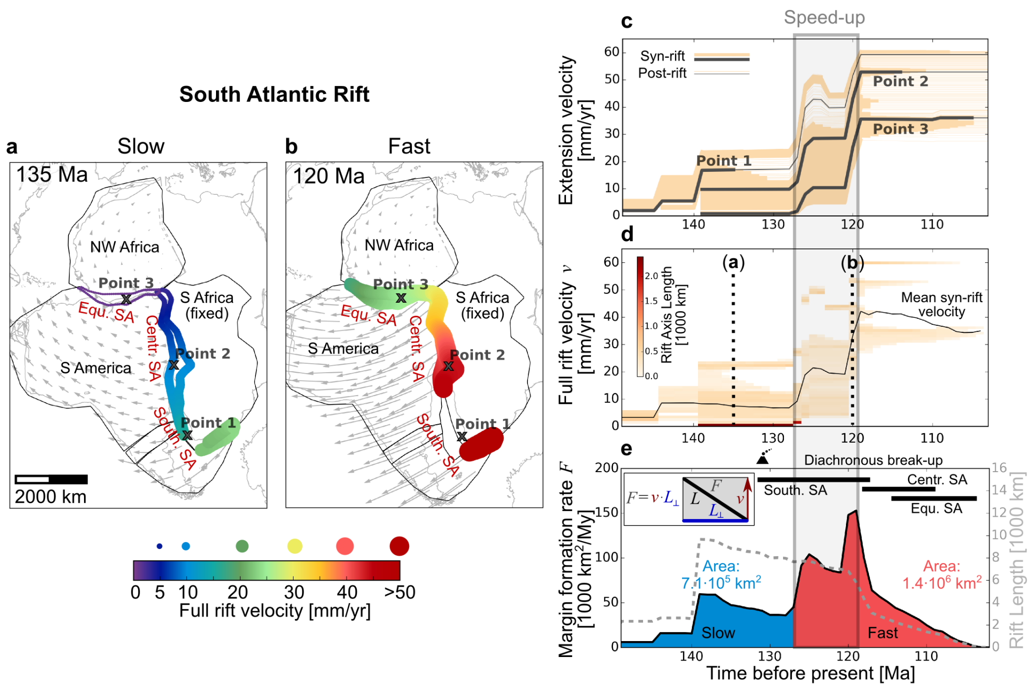

Fig. 2: Plate kinematic evolution of the South Atlantic rift system. The rift velocity increases within few Million years between 126 and 120 million years ago, when the strength of the lithosphere in the Equatorial Atlantic is significantly reduced. (For more details see Brune et al. 2016, Nature)

The results of this project have important implications for our understanding of rifted margin evolution. We provide insight in processes that shape Earth's rift and its rifted margins, such as rift migration, asthenospheric flow and time-dependent evolution of the stress field within an oblique rift. But we also found that geodynamic processes within a rift system are capable to feed back on large-scale plate motions: during the breakup of continents, rapid plate accelerations are controlled by the weakening of the rift system itself. This result begs to reinterprete the underlying processes of margin formation during basin-ward localization. We suggest that the slow phase shapes the proximal margin, while the fast phase dominates the distal margin where our analysis explains larger fault-slip rates, faster subsidence, higher heat flow, enhanced partial melting and associated underplating or volcanism. This new understanding has direct implications for the maturation of georesources at Earth's rifted margins.

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