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The stratigraphic architecture of hyper-extended rift systems: A field perspective from Aps, Pyrenees and Baja-California

Emmanuel Masini (1), Gianreto Manatschal (1), Julie Tugend (1), Geoffroy Mohn (2), Cécile Robin (3), Laurent Geoffroy (4), and Patrick Unternehr (5)

(1) University of Strasbourg-CNRS UMR 7516, IPGS/EOST, Strasbourg, France (masini@unistra.fr), (2) Université de Cergy-Pontoise, Laboratoire Géosciences et Environnement, Cergy Pontoise, France, (3) Université de Rennes, Géosciences Rennes, Rennes, France, (4) IUEM, Brest, France, (5) Total SA, PN, Paris-la-Défense, France

The discovery of hyper-extended domains in deep water rifted margins challenged the classical view of the evolution of rift systems leading to continental breakup. In these hyper-extended domains, rift basins occur over less than 10km thick extended continental crust or exhumed subcontinental mantle. Neither their imaged stratigraphic architecture and drilled facies nor the subsidence history can be explained by classical McKenzie-type rift models. Studies performed on off- and on-shore examples demonstrate the importance of tectonic exhumation by detachment faulting. However, despite their apparent widespread occurrence in present-day rifted margins, the overall tectono-sedimentary evolution of these systems remains poorly understood.

In this study we review and compare key multi-scale observations from 3 different hyper-extended rift systems. 1) The first example, in the Western Pyrenees, corresponds to a complete sediment-rich Cretaceous hyper-extended rift system that can be investigated. 2) The second example in the Swiss Alps, gives the access to supra-detachment sedimentary evolution in a sediment-starved context. 3) The last example exposed in Baja California Sur, shows supra-detachment sedimentary evolution in sediment-rich and shallow water environment. Based on these studies in three different settings, we conclude that the basins forming in the lower and upper plate position respective to detachment fault polarity develop as two different types of basins.

Lower plate basins develop over top-basement detachment systems and discontinuous pieces of pre-rift strata (extensional allochthons). In this setting, the sequential development of low-angle detachment systems implies the creation of new real estate crust (new seafloor surfaces) and a complex syn-rift stratigraphic architecture. Through this domain, the deposition of syn- and post-tectonic sediments above exhumation surfaces are diachronous along stretching direction illustrating relative migration of exhumation processes. Syn-tectonic deposits correspond to the erosion of exhumed material and mass-wasting processes along active detachment fault scarps. Once active exhumation migrates, inactive parts of detachment merge to form a lower plate sag basin under thermal subsidence. In contrast, the upper plate basin records a single isochronous sag phase over weakly extended pre-rift strata. This observation suggests that upper plate sag formation is controlled by depth-dependent crustal extension. As illustrated by the different study cases, the sag phase sedimentary record of upper and lower plate settings strongly depends on their respective connection with sediment sourcing systems.

Finally, we used the Rifter software developed within the Margin Modelling Phase 3 (MM3) consortium to generate equilibrated lithospheric sections based on our observations. Through these kinematic numerical experiments, we aim to quantify the tectonic, thermal and isostatic evolution of hyper-extended rift systems.