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The Importance of Rift Inheritance in Orogeny: the Western Pyrenees Case-study

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Fold and Thrust Belt (FTB) foreland basin evolution is assumed to be controlled by the propagation of thrusting and folding, isostatic-flexure and the interaction of erosion and sedimentation. In many cases, both basin modeling as well as structural reconstructions consider the pre-convergent geology as a simple layer-cake at both crustal and basin scale. However, it is commonly accepted that most orogens are initially reactivated former continental rifted margins. Rifted margins are formed by progressive stretching and thinning of continental lithosphere. It is during this extensional tectonic deformation that most of the key parameters of FTB petroleum systems are formed, and also the extensional structures that will be reactivated during the early stages of orogen formation. A typical present-day rifted margin architecture shows continental crust of approximately 30 km thickness in the proximal area which is thinned through the necking and hyper-extended zones to less than 10 km thick. The pre-orogenic geological template is not therefore a simple set of horizontal layers with uniform thicknesses. In order to understand the evolution of FTB basins, it is thus essential to also have knowledge of the earlier extensional tectonic history as well as the subsequent compressional tectonics.

We use the Western Pyrenees as a study area to investigate the role of rift inheritance in orogeny and how this controls the formation of collisional orogens. The Western Pyrenees underwent complex Lower Cretaceous hyper-extended rifting which was reactivated during a Late Cretaceous early orogenic phase followed by Eocene to Miocene continental collision.
To achieve our aim, we use a kinematic structural-stratigraphic forward model (RIFTER). Lithosphere deformation is achieved by extensional and compressional faulting in the upper crust and distributed deformation in the lower crust and mantle. RIFTER incorporates the flexural isostatic response to extensional/compressional faulting, crustal thinning/thickening, lithosphere thermal loads, sedimentation and erosion. RIFTER is used to model and predict the structural and stratigraphic development of both rifted margins and orogens.

Using RIFTER we model both the rifting and the orogenic evolution of the Western Pyrenees across the hyper-extended Mauléon Basin including the northern (Arzacq Basin) and the southern (Ebro Basin) foreland basins. Field observations from literature review and seismic data on the Arzacq Basin are used to constrain two crustal sections together with the detailed sedimentary record.

We show that the present-day structure of the Western Pyrenees was formed by the inversion of the Upper Cretaceous rift system using reactivated extensional structures, followed by the collision stage which used a new generation of thrust structures resulting in the formation of the axial zone. The RIFTER model allows us to produce flexural isostatically compensated and balanced cross-sections showing the main structural and stratigraphic architecture of the Western Pyrenees. The importance of rift inheritance during orogenic processes demonstrated by our study-case is not restricted to this example and has general applicability to many other FTB basins globally.