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Tectono-sedimentary processes at hyper-extended rifted margins: the Alpine and Pyrenean analogues

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The discovery of hyper-extended crust at deep-water rifted margins challenged the way of interpreting rifting and continental breakup. Indeed, syn-rift sedimentary basins, also referred to as either "supra-detachment basins" or "hyper-extended sag basins" are observed over thin hyper-extended crust that tapers oceanwards and is laterally replaced by exhumed subcontinental mantle. Studies performed off- and on-shore have shown that hyper-extended domains are formed by a complex interplay of exhumation faults leading to characteristic basin architectures. Despite of numerous interpretations of seismic sections across passive margins, the stratigraphic architecture of hyper-extended rift domains and their tectono-sedimentary evolution remain little understood.
In this presentation, we present field-data from two well-preserved fossil hyper-extended domains exposed in the Alps and Pyrenees analogues that show some insights into the tectono-sedimentary evolution of hyper-extended rifted margins. Despite these two examples show a different sedimentary evolution, they exemplify how detachment systems can control accommodation space and sedimentary architecture. In both cases, the syn-rift sedimentary record can be studied in 3D allowing to evolutionary steps of supra-detachment basins to be identified. The study of these two field examples enables to identify key architectural elements of supra-detachment basins. These are detachment breakaway block and extensional allochthons, both controlling the first-order architecture of the basins. The former is the consequence of two successive low-angle detachment faults separated by a delaminated upper crustal block, whereas the latter results from the delamination of hanging-wall blocks and its emplacement over exhumed footwall. Exhumation along active detachment systems implies a very efficient creation of new real estate seafloor and results in a very specific stratigraphic record that includes from base to top: 1) a syn-tectonic hangingwall-derived basal facies-tract; 2) a poorly organized facies tract that derived from the erosion of the exhumed and tectonized footwall that is re-deposited over the new real estate seafloor during active exhumation, and 3) deposition of a post-tectonic facies tract that results from the migration of active exhumation towards the area of future breakup and passive thermal subsidence. This "sag" phase sedimentary record is strongly dependent of the background sediment flux and may result in either starved pelagic sequences (e.g. Alps) or prograding siliciclastic sedimentary systems (e.g. Pyrenees).
This scheme differs strongly from those developed for usual half-graben basins and has possible implications for present-day deep-rifted margin exploration. Last but not least, to better understand the 3D morphology of distal margins can help to understand the observed complex architecture of internal orogenes by return, the latter being the compressional result of former hyper-extended rifted margins.