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Unravelling early growth of a collisional orogen using in situ laser ablation double dating on detrital zircon, eastern North Pyrenees, France

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In the classic Wilson plate-tectonic cycle, plate convergence and orogenesis follow plate divergence. This results in an asymmetric doubly vergent collisional orogen with pro- and retro-wedge/foreland basin systems (lower and upper plate, respectively). Conceptual models propose that an orogen evolves as a single dynamic system from an early, non-equilibrated, growth stage to a late, mature, steady-state stage. Yet, early convergence processes and mechanisms responsible for the transition from rift to collision are, as yet, little known and quantified. In particular, most of our understanding of wedge/foreland dynamics comes from the pro-wedge, where mainly late orogenesis is well preserved. In contrast, the retro-foreland basin is believed to preserve the full orogen history due to lower shortening and translation values. This is the case in the NE Pyrenean retro-wedge, where recent studies suggest that during early orogenesis the Pyrenees never reached a steady-state configuration.

Our work aims to constrain the timing and rates of orogenic episodes as well as timescales for sediment transport from source to sink in the Eastern Pyrenees. We apply coordinated U-Pb and (U-Th)/He dating methods on detrital zircon to ten samples through the syn-orogenic Upper Cretaceous to Eocene succession. We use the recently developed in situ double dating approach to address firstly, a two-fold shortcoming in quantifying syn-orogenic denudation and secondly, an issue with recognising the signature of early Pyrenean convergence in source-to-sink processes. Firstly, most previous regional exhumation studies have focused on reconstructing thermal histories for currently exposed bedrock, which has led to sparse constraints on the initiation and early phase of convergence. Moreover, regional detrital double dating has until recent years been performed either on distinct batches of grains or statistically non-representative numbers of grains or samples. Secondly, in the Pyrenees, the delay between the end of rifting (and associated HT metamorphism, early Cenomanian) and the onset of convergence (end Santonian) is short, leading to difficulties in recognising a clear thermal signature of early orogenesis.

Our results show that lag times (the difference between the age of apparent cooling and deposition, assuming instantaneous transport) sharply decrease during the Maastrichtian, passing from >50 Myrs to <20 Myrs. This indicates a significant increase in denudation rates. Around this time we also note a marked increase in the proportion of Early Cretaceous rifting and Hercynian source signals, indicating a change in source area(s) and/or progressive unroofing of thermally reset rifted Pyrenean crust. All these changes are recorded over <2 Myrs and are synchronous with changes in paleo-current directions. We interpret these results as recording the sedimentary response to the onset of Pyrenean orogenesis. Our data suggest that the early orogen and the Early Cretaceous rift extended further east, in an area which has since been destroyed by the Oligo-Miocene opening of the Gulf of Lion. Our work clarifies early growth in the Pyrenees, providing new evidence for dynamic coupling between range and foreland basin(s), and contributing to the debate on the role of rift inheritance into early orogenic processes.