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Insight into tectonically coupled sediment routing systems of the south Pyrenean fold-thrust belt via integration of field analysis with thermochronology

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The dynamic coupling between tectonics and surface processes is particularly evident in compressional mountain belts. Numerical models clearly demonstrate the fundamental control exerted by surface processes on orogen evolution, with recent studies emphasising the importance of sedimentation and mass redistribution in determining the style and timescale of landscape response to tectonic convergence. Efficient surface processes are shown to promote filling of well-developed foredeeps, fold-thrust belt exhumation and draping and slowing of frontal thrust propagation. However, these predicted relationships have proved harder to demonstrate in field and analytical studies. Here we attempt to better understand tectonic and surface process coupling and the importance of sediment mass transfer on orogenic development, using field and thermochronological analyses to reconstruct the complex evolution of the south-central Pyrenees. Trending east-west, the Pyrenees formed due to collision between the Iberian and European plates during the Late Cretaceous through Oligocene to early Miocene. Previous work demonstrates that the cessation of thrust front propagation is synchronous with the deposition of a thick piedmont of conglomerate over the foreland fold-thrust belt during the Oligocene. By integrating field observation with thermochronological analyses of detrital zircon fission track and U-Pb age dating of syn-orogenic strata, we can therefore reconstruct the long-term exhumational history of the Pyrenees in relation to the tectonic and stratigraphic evolution of its wedge-top and foreland basins.

Results from our field and laboratory analyses support initiation of the Pyrenean orogeny during the Late Cretaceous, with the division of detrital zircon fission track ages into four basic tectonic events that have been previously described for the Pyrenean region: the main orogenic phase (- 50-30 Ma); the early orogenic phase (- 90-50 Ma); the opening of the Bay of Biscay (- 110-90 Ma); and the Hercynian period (- 340-290 Ma). Our data indicate deep, rapid exhumation during the early orogenic phase of the Late Cretaceous – Palaeocene (- 72-50 Ma). Sediments were derived from eastern source areas initially, recording early cooling of the eastern Pyrenees and supporting interpretation of east to west ‘zipped closure’ of the mountain belt. The main orogenic phase records rapid cooling of the central Pyrenees during the late Eocene - Oligocene, with short lag-times (15-20 Myr) associated with high exhumation rates. Field investigations show this reflects a period of coarse-grained, alluvial-fluvial sedimentation with provenance indicators suggesting the progressive enlargement of catchments northwards through the Pyrenean Axial Zone, coincident with a progressive shift in deposition from the wedge-top basins, into the Ebro foredeep in the south. As is predicted by numerical models, our results reveal this period of rapid exhumation and efficient surface processes is associated with the large-scale transfer of mass from the orogenic wedge into the foredeep, coincident with halting of the thrust front. The detailed history of tectonic, sedimentological and exhumational Pyrenean evolution presented therefore provides an independent test of the existing numerical models of fold-thrust belt evolution.