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Post-orogenic evolution of the Southern Pyrenees: combining thermochronological data and modeling

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It is well established that the Central Pyrenees experienced a major syn-orogenic exhumation phase during late Eocene times but their post-orogenic evolution remains uncertain. In particular, there is debate about potential Neogene acceleration of exhumation and the influence of tectonic and/or climatic processes on the post-orogenic evolution of the Southern Pyrenees. A popular model suggests that the Pyrenees and their southern foreland, including both the fold and thrust belt and the Ebro foreland basin, were buried below a thick succession of conglomerates during the Oligocene. This burial was caused by closure of the Ebro Basin since Middle-Late Eocene times, leading to aggradation and backfilling by the products of Axial Zone erosion. Opening of the basin to the Mediterranean in Neogene times would have permitted incision and evacuation of the conglomerates. However, both the amount of post-orogenic fill and the timing of re-excavation remain controversial and poorly constrained. We address this question by revisiting extensive thermochronological datasets collected previously in the Axial Zone of the central Pyrenees, which partly record the post-orogenic evolution.

We use an inverse approach that couples the thermo-kinematic model Pecube and the Neighborhood inversion algorithm to constrain the history of exhumation and topographic changes since the late Eocene, by fitting the existing thermochronological (apatite fission-track and (U-Th)/He) data. Topographic changes are modeled as being controlled primarily by variations in the amount of conglomerates. The modeled study area is a 32 x 55 km box of 30 km depth, which is exhumed nearly vertically. The data are located in the Maladeta and Marimaña massifs, in the footwall and the hanging wall respectively of the Gavarnie thrust. The inversion provides best-fit solutions for the exhumation rates and topographic changes during different time periods.

Best-fit solutions suggest a two-stage tectonic scenario: very rapid exhumation (6 mm/yr) between 37 and 30 Myr is followed by a strong decrease to rates of 0.03 mm/yr from 30 Myr to the present. Therefore, the inversion does not require any post-orogenic tectonic acceleration. A clear topographic signal emerges however: the model leads to precise constraints on the maximum elevation of infilled topography required to fit the thermochronological data. The topography has to be infilled by the conglomerates to an elevation of 2.8 km from 37 to 33 Myr, followed by a progressive decrease to 2 km around 9 Myr. From that time to the present, the foreland has to be incised quickly. We interpret the last stage of the topographic history as recording major incision of the southern Pyrenean wedge, when the Ebro basin evolved from endorheic to exorheic conditions. These results thus demonstrate temporally varying controls of different processes on exhumation: during the late Eocene, exhumation is controlled by rapid tectonic rock uplift in an active orogen, whereas externally driven topographic changes control the post-orogenic evolution.

The model predicts significant exhumation of the southern foreland during late Miocene to present times, sufficient to partially or fully reset the (U-Th)/He thermochronemeter in apatite. (U-Th)/He analyses are in progress to test the model and to obtain independent estimates of the depth of burial as well as the onset of incision of the foreland.

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