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Alpine exhumation history of the eastern Basque-Cantabrian Zone–western Pyrenees from low-temperature thermochronology

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The Pyrenean-Cantabrian mountain belt extends in an E-W direction along the northern border of Spain and resulted from the convergence between the Eurasian plate and the Iberian subplate from Late Cretaceous to Miocene times. In the central part of this belt, the Basque-Cantabrian Zone (BCZ) developed as one of the most subsiding Cretaceous basins of the Iberian periphery, formed in a rift-related hyperextended margin. The Alpine orogeny resulted in the subsequent tectonic inversion of the Cretaceous basins and in the exhumation of basement rocks forming the Basque Massifs (Cinco Villas, Alduides and Oroz-Betelu Massifs) in the eastern BCZ and the western Pyrenees. However, the detailed thermo-tectonic evolution of this area remains incompletely understood, prompting the present study integrating structural and new low-temperature thermochronology data around the Basque Massifs and the Leiza thrust sheet. The Leiza thrust sheet is a major fault that superposes a band of Mesozoic rocks that experienced Cretaceous metamorphism (Marble Unit), on top of another Mesozoic sub-basin (Central Depression) with evidence of hydrothermalism.

Here, we provide the first apatite fission-track (AFT) and zircon (U-Th)/He (ZHe) low-temperature thermochronology dataset for the eastern BCZ. AFT ages range from 40 to 23.7 Ma while ZHe ages are more dispersed. Samples can be separated into two groups according to their ZHe age-eU correlations: three samples from the Cinco Villas Massif (group 1) depict clustered ZHe ages and eU concentrations. One sample from the Alduides Massif and another sample from a Paleozoic rock pinned along the Leiza thrust sheet (group 2) depict dispersed ZHe ages and eU concentrations. A sample from the Oroz-Betelu Massif shows slight dispersion of the ZHe ages and eU concentrations. Forward and inverse modelling provides insights into the maximum temperatures achieved prior to the Alpine orogeny. Samples from group 1 may have reached maximum temperatures of 300 ºC in the Late Cretaceous, whereas the rest of the samples reached temperatures <240 ºC before alpine exhumation. The sample from the Leiza thrust sheet was exhumed since the early Eocene, reaching a rate of 0.43 km/Myr between 52 and 40 Ma. Samples from the Cinco Villas and Alduides Massifs were exhumed constantly from the Late Cretaceous to present, with higher rates in the former (0.13-0.18 km/Myr) than in the later (0.07 km/Myr) from 55-50 Ma to the present. Finally, the sample from the Oroz-Betelu Massif, buried below the South-Pyrenean Zone, was exhumed at a rate of 0.77 km/Myr between 40 and 30 Ma.

Our results also show that the sample in the Leiza thrust sheet experienced rapid cooling prior to 40 Ma, with almost no cooling since then to ∼10 Ma, while samples in the Cinco Villas Massif experienced rather monotonic cooling since 80-60 Ma. This suggests that the south-verging Ollín reverse fault uplifting the Cinco Villas Massif was active after the main activity of the north-directed Leiza thrust system, located a few km to the south.