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Relict landscapes in active mountain belts: their age, interpretation and geodynamic significance

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Planar topographic markers have been widely used to infer the topographic and erosional history of mountain belts. During the last two decades, attention has focused on high-elevation low-relief surfaces in orogenic belts, the interpretation of which has generated considerable controversy regarding their age, mechanism of formation and tectonic or climatic significance. I will review three case studies to illustrate these issues.

In the Pyrenees, high-elevation, low-relief surfaces have been mapped throughout the mountain belt and were suggested to have developed at high elevations due to significant base-level rise as a result of backfilling of the southern foreland basin, which developed under endorheic conditions between Late Eocene and Late Miocene times. Isolation of these surface remnants has been suggested to result from a more erosive climate since the Pliocene. However, an alternative study suggests that such relict landscape elements are restricted to the Eastern Pyrenees, developed at low elevations during the Miocene and were subsequently tectonically uplifted. This second hypothesis appears to be comforted by a suite of thermochronological, stratigraphic and geophysical data from the Eastern Pyrenees. We have used a thermo-kinematic model integrating the existing thermochronometry data from the central Pyrenees to constrain the amount and timing of base-level change in that area and find that, while significant filling and re-excavation of the southern flank must have occurred, the timing of exhumation is Late Miocene rather than Pliocene-Quaternary and the relationship with hypothetical relict landscape elements in the high chain remains unclear.

In the western European Alps, widespread high-elevation low-relief surfaces develop close to the interface between crystalline basement and sedimentary cover in the "external crystalline massifs" (e.g., Pelvoux-Ecrins, Belledonne, Aar). These surfaces clearly appear to be lithologically controlled and to have been extended by cirque retreat where they occur in an elevation range around the glacial equilibrium line altitude, giving rise to apparently paradoxical observations of "paleosurface" preservation concurrent with widespread glacial erosion. Recent high-resolution thermochronology data suggests the final exhumation of these surfaces to be of Pliocene age. While they can be used as markers of glacial incision as well as integrated vertical motions since their formation in Triassic times, their use as markers of tectonic uplift during mountain building is limited.

Finally, we have recently described high-elevation relict landscape elements dating from Eocene times in the northwest Himalaya. We interpret these as remnants of a once more widespread Tibetan Plateau, which was subsequently incised due to onset of large-scale strike slip faulting and drainage rearrangement. These surfaces have previously been suggested to result from efficient glacial erosion, but thermochronological data imply a much older age of formation. As is generally the case, the thermochronology data do not provide any constraint on the uplift history of the surfaces, but the simplest scenario suggests they were formed at high elevations and have since been passively eroded. The question remains as to how their morphologies have survived despite km-scale exhumation since Eocene times, as recorded by the thermochronology data.

The above examples illustrate the conceptual and interpretational problems generally encountered when dealing with relict landscapes in mountainous regions. Similar arguments and controversies have developed for the Rocky Mountains and Sierra Nevada in the western US. Thermochronology data can put bounds on the age of exhumation of such landscape elements but the resolution of most thermochronological methods

remains rather coarse and no direct information on uplift history is gained. The data do show that high-elevation low-relief landscape elements can record substantial amounts of exhumation, justifying their description as “relict landscapes” rather than “paleosurfaces” sensu-stricto. New high-resolution thermochronometers, combined with isotopic or environmental paleo-elevation indicators may provide better insight in their formation and evolution if they can be applied.