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Retro- to pro-side migration of the main drainage divide in the Pyrenees: geologic and geomorphological evidence

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The age of the end of compressional deformation in the Pyrenees, and the existence of more recent uplift mechanisms, are currently under debate. Also debated is the role of rock/surface uplift in the high elevation of the low-relief erosional surfaces that exist in the Axial Zone of the chain. Recent apatite fission track data from the west-central Axial Zone reveal a late episode of exhumation related to compressional deformation during the early Miocene, whereas a recent episode of surface uplift related to mantle delamination has been proposed, which is in contradiction with other geological and geophysical evidences indicating the absence of significant uplift; the absence of significant rock uplift of the marine/continental Pliocene limit in the adjacent foreland and the preservation of lithospheric roots.

Contradictory interpretations have been proposed for the recent evolution of exhumation and relief of the Pyrenean orogen: it has been proposed by some authors that ∼2-3 km of slow and continuous exhumation in the Axial Zone occurred since the Miocene, while others consider that rocks outcropping on the low-relief, high-elevation erosional surfaces of the Axial Zone already reached the surface during the Miocene, the recent evolution having consisted only in the ∼1 km-deep incision of the main valleys. The rejuvenation of the relief of the southern Pyrenees has been attributed to the connection of the Ebro basin to the Mediterranean before the Messinian Sality Crisis (MSC), an interpretation challenged because such connection would have implied a huge incision of the Ebro network during the MSC, which is not observed. Moreover, enhancing of erosion activity leading to the rejuvenation of relief has been attributed to global climate change from the late Pliocene onward. If the later interpretation is correct, it should apply to the rejuvenation of the whole mountain belt, and hence must also be recorded in the morphology of the northern flank.

Based on a geomorphological approach, we show that the main drainage divide of the Pyrenees is migrating from North to South, i.e. from the retro-side to the pro-side of the orogen. Divide migration is achieved by captures of the southern drainage network by the northern rivers. From published data, we interpret that the original position of the divide in the mid-Eocene was located in the retro-side of the belt (southern North Pyrenean Zone), where exhumation was centered at that time before erosion migrated southwards by tectonic control. We show that the divide and its associated drainage reorganization passed through the Axial Zone of the central Pyrenees (Vall d'Aran) at least after the Tortonian (∼11-7 Ma), in post-orogenic times. Moreover, divide migration was stronger in the western than in the eastern Pyrenees, indicating an uneven geomorphic rate, likely reflecting a dominant moisture supply from the west.

As a consequence, knickpoints associated to the deep incisions (∼1000 m) of the highly elevated, low-relief erosional surfaces in the northern flank of the Pyrenees should not be considered as a river response to an enigmatic recent surface uplift, but rather as the consequence of captures and divide migration, an inevitable geomorphic response overprinted to the effect of late Neogene climate change. In the case of the Pyrenees captures and divide migration have been enhanced by the significant difference of mean slopes between an abrupt northern flank and a smooth and highly elevated southern flank (as it was before its rejuvenation). Sedimentary flux on both sides must have been controlled by this drainage reorganization, controlling events as the Lannemezan megafan for example.