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The crustal evolution of the west-central Pyrenees revisited: Inferences from a new kinematic scenario

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ABSTRACT

New evolutionary models for the Pyrenean orogeny must consider feedbacks between the Mid-Cretaceous hyperextension postulated recently and the Pyrenean inversion. We present a new crustal section of the Pyrenees through the Jaca Basin, the western Axial Zone and the Chaînons Béarnais, which allows identifying the ancient continental margins of the Iberian and European plates and a suture. A sequential restoration allows a reassessment of the style of convergence through time. Restoration leads to a progressively thinned crust in narrow continental margins separated by a domain of exhumed mantle peridotite and overlain by a detached sedimentary lid. Early convergence during the Late Cretaceous and the Earliest Paleogene was accommodated by subduction of the peridotite domain. This was followed in the Eocene by initial collision involving overriding of the Iberian margin onto the European margin along the deep ramp of the North-Pyrenean Frontal thrust, which defines the suture. Subsequent full collision and strong relief generation from the late-Mid or Late Eocene to the Early Miocene were associated with thrust accretion of the Iberian plate, underlain by wedging and northward subduction of the decoupled Iberian lower crust.

1. Introduction

The tectonic knowledge of the Pyrenees benefited greatly more than 20 years ago from the acquisition of the ECORS deep seismic reflection profiles (Choukroune et al., 1989; Daignières et al., 1994). Subsequent crustal-scale models for the Pyrenean orogeny included restored sections to the pre-orogenic state that depicted a Mesozoic rift basin floored by a thinned continental crust (Beaumont et al., 2000; Muñoz, 1992; Roure et al., 1989; Teixell, 1998). In recent years, a revisit of the significance of the Pyrenean lherzolites and the application of concepts from passive continental margins led to new understandings of the pre-orogenic reconstruction, invoking extreme crustal attenuation and mantle exhumation during Mid-Cretaceous times (Clerc and Lagabrielle, 2014; Jammes et al., 2009; Lagabrielle and Bodinier, 2008; Lagabrielle et al., 2010; Masini et al., 2014; Tugend et al., 2014). In parallel, new paleothermometrical data have shown a generalized state of high heat flow during the mid- and late Cretaceous, beyond the well-known areas of North-Pyrenean HT metamorphism (Clerc et al., 2015). This heat flow may account for the isostatic equilibrium between extreme crustal thinning and moderate synrift sedimentary thickness and paleobathymetry in the Cretaceous basin (Winnock, 1974), as the hot nature of the Cretaceous

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margins and exhumed mantle domain counteracted the expected subsidence.

New models for the evolution of the late Cretaceous to Cenozoic Pyrenean orogeny can be now developed on the account of these pre-orogenic reconstructions. These models must now take into account feedbacks between the mid-Cretaceous hyperextension and the Pyrenean inversion as well as detailed geological and geophysical observations. The purpose of this paper is to revisit the orogenic evolution of the west-central Pyrenees based on the sequential reconstruction of a new crustal transect (Fig. 1), which, together with tectonics-sedimentation and thermochronological constraints, allows us to address specific points including the identification of the ancient margins and suture, the fit between the upper and lower crustal structure, the role of decoupling at different scales, and the timing and magnitude of orogenic shortening.

2. Section of the west-central Pyrenees: identification of ancient continental margins and suture

A new crustal section of the west–central Pyrenees is presented in Fig. 2. It benefits from our current investigations of the northern Pyrenees in the frame of the ANR Pyramid project. The section runs across the Jaca basin, the western Axial Zone and the Chaînons Béarnais, 10–15 km to the east of the Ansó–Arzacq transect of Teixell (1998) (Fig. 1). Descriptions of the surface geology can be found in the works by Labaume et al. (1985), Teixell and García-Sansegundo (1995), Teixell (1996), Biteau et al. (2006), and Lagabrielle et al. (2010).

A remarkable feature of this transect is that almost the entire profile in the near-surface is characterized by south-verging thrusts and folds, with the exception of the North-Pyrenean Frontal thrust zone. In the southern part, the Ebro and Jaca basins are Cenozoic foreland basins separated by the complex thrust front of the External Sierras. The External Sierras and the Jaca basin are detached in upper Triassic evaporites and shales (Keuper facies). The overlying Mesozoic succession is thin (a few hundred meters of shallow water and terrestrial deposits), whereas the synorogenic Tertiary succession is several thousand meters thick, including flysch and molasse. Under the northern Jaca basin and Axial Zone, thick-skinned basement thrusts uplift the basin floor (e.g., the Guarga and Gavarnie thrusts), with a structural relief of ca. 9.5 km with respect to the regional elevation of the Ebro basin basement. The Axial Zone corresponds to the hanging wall anticline of the Gavarnie thrust (Fig. 1).

North of the Axial Zone is the Lakora thrust with a large displacement (ca. 17 km), carrying a thin thrust sheet composed of the Iguntze–Mendibelza basement massifs and their cover of Albian conglomerates (Teixell, 1993). A lower thrust branch, the Larra thrust, propagated in the Axial Zone cover up to the Middle Eocene strata of the Jaca basin with ca. 5 km of displacement. The Iguntze–Mendibelza massifs have been eroded in the transect line, but are preserved 3 km to the west. They overlie an intermediate thrust unit of upper Triassic rocks (the Bedous unit) and are bound to the north by a Cretaceous normal fault, the Licq fault. North of the Licq fault, the Chaînons Béarnais belt (CBB) is a system of Jurassic to Lower Cretaceous carbonate anticlinal ridges separated by synclines with thick Albian flysch, passing to Upper Cretaceous flysch in the north. The CBB is detached in the Upper Triassic, folding resulting from the rising and squeezing of diapiric salt walls initiated during the Jurassic–Early Cretaceous extension (Canérot, 1988; Labaume and Teixell, 2014). The basement under the CBB can be inferred to plunge northwards, until it attains the regional elevation of the Aquitaine basin. A system of south-verging basement thrusts involving Upper Paleozoic rocks under the Bedous unit and CBB, not exposed in the study transect, is schematically projected from observations in the

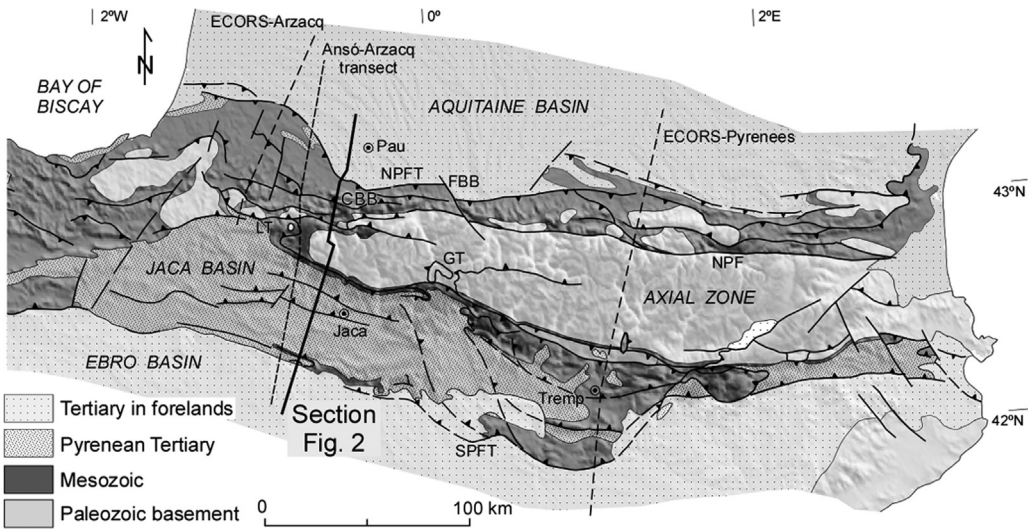

Fig. 1. Geologic sketch map of the Pyrenees showing the location of the study section (Fig. 2) and other seismic or geologic transects discussed in the text. CBB: Chaînons Béarnais belt; FBB: transfer fault at Bagnères-de-Bigorre; GT: Gavarnie thrust; LT: Lakora thrust; NPF: North-Pyrenean fault; NPFT: North-Pyrenean Frontal thrust; SPFT: South-Pyrenean Frontal thrust.