

# The north Pyrenean Front and related foreland basin along the Bay of Biscay: constraints from the MARCONI deep seismic reflection survey

## *Estructura del frente pirenaico y la cuenca de antepaís asociada a lo largo del Golfo de Vizcaya: contribución de la campaña de sismica de reflexión profunda MARCONI*

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**Abstract:** Profile interpretation of MARCONI seismic profiles show that two domains exist in the Bay of Biscay with a different Pyrenean and north-foreland structure: the eastern, Basque-Parentis and the western, Cantabrian domains. In the eastern one, the North Pyrenean front is located close to the Spanish coast and the northern foreland of the Pyrenees is constituted by a continental crust thinned by Early Cretaceous extensional structures. In the western, Cantabrian domain, the North Pyrenean front is shifted to the north and belongs to a thrust imbricated stack deforming a foreland basin which lies on the top of the Lower Cretaceous oceanic or transitional crust that floors the Bay of Biscay abyssal plain. The coincidence of the transition between these two domains with the eastern border of this abyssal plain denotes that differences along strike of the Pyrenean structure are related to a dramatic change in the nature of the subducted crust from continental to the east, to oceanic or transitional westwards. Thus, the rift system developed between Iberia and Eurasia during the Early Cretaceous appears as a major factor controlling not only the location and features of most of the Pyrenean thrust sheets but also the overall structure of the chain.

**Key words:** Pyrenees, Bay of Biscay, subduction, inversion tectonics, Cenozoic.

**Resumen:** Los perfiles sísmicos de la campaña MARCONI permiten distinguir dos dominios en el Golfo de Vizcaya en los que la estructura del frente nord-pirenaico y del antepaís es diferente: el dominio oriental Vasco-Parentis y el dominio occidental Cantábrico. En el primero, el frente nord-pirenaico está adosado a la costa española y el antepaís norte está constituido por una corteza continental adelgazada por estructuras extensivas cretácicas inferiores. En el segundo, dominio Cantábrico, el frente nord-pirenaico está desplazado hacia el norte y corresponde a un sistema imbricado de cabalgamientos que deforma una cuenca de antepaís desarrollada sobre una corteza oceánica a transicional de edad cretácica inferior. La coincidencia de la transición entre estos dos dominios con el límite oriental de la llanura abisal que se extiende sobre esta última corteza, denota que las diferencias longitudinales de la estructura nord-pirenaica están relacionadas con un cambio dramático en la naturaleza de la corteza que subduce bajo Iberia. En consecuencia, el sistema de rift que se formó entre Iberia y Eurasia durante el Cretácico Inferior aparece como un factor esencial que controló no tan solo la localización y características de la mayoría de cabalgamientos pirenaicos sino también la estructura global de la cadena.

**Palabras clave:** Pirineos, Golfo de Vizcaya, subducción, inversión tectónica, Cenozoico.

## INTRODUCTION

The Pyrenees form a doubly vergent mountain belt which resulted from Late Cretaceous-Cenozoic convergence between Iberian and Eurasian plates. They developed over a previous intra-continental thinned lithosphere in the east, and, more to the west, over the passive continental margin fringing to the south the Bay of Biscay oceanic to transitional crust. As a result of this significant change in the pre-orogenic lithospheric configuration, the Pyrenees display different characteristics along strike (Muñoz, 2002). Between France and Spain, the Pyrenees s.s. form a continental

collisional orogen with limited subduction of the continental Iberian lithospheric mantle and lower crust underneath the Eurasian plate (Muñoz, 1992). More to the west, in the Cantabrian Pyrenees, they constitute a weakly deformed upper crustal wedge of continental rocks bounded by a very limited south-directed subduction of the Bay of Biscay oceanic lithosphere and to the south by the north-directed continental subduction of Iberia mainland (Fernández-Viejo *et al.*, 2000).

Accordingly, in the Pyrenees s.s., the North Pyrenean front is made up by basement involved north-directed thrusts formed from the inversion of the faults

bounding to the north the main intracontinental basins inherited from the opening of the Bay of Biscay (Muñoz, 1992). In contrast, in the Cantabrian Pyrenees, the North Pyrenean front is an accretionary prism located in the front of the Cantabrian continental slope that deforms the sediments overlying the Bay of Biscay oceanic to transitional crust (Ayarza *et al.*, 2004).

In order to improve the structural and the tectonic knowledge of the area comprised between these two well-differentiated Pyrenean domains, in September 2003, a deep seismic reflection survey was carried out in the eastern part of the Bay of Biscay aboard the Spanish R.V. Hesperides (Gallart *et al.*, 2004; Fig. 1). This survey, called MARCONI (North-Iberian CONTinental MARGin), included the acquisition of 11 multichannel deep seismic reflection profiles and the record of signal in a network of 24 OBS/OBH instruments and 36 land stations (Ruiz, 2007). These data, together with the pre-existing deep and industrial seismic profiles, constitute an excellent dataset to characterize the crustal structure of the segment of the Pyrenean front comprised between the Pyrenees s.s. and the Cantabrian Pyrenees.

The present work aims at illustrating the main features of the North Pyrenean front and related foreland basin along this segment from the description

and interpretation of MARCONI seismic profiles. The main purpose of this description is to highlight the role played by the pre-existing Mesozoic structures in the change in the structural style of North Pyrenean front, and thus, to better understand the processes that governed the evolution of the Pyrenees.

#### PYRENEAN AND NORTH-FORELAND STRUCTURE IN THE EASTERN PART OF THE BAY OF BISCAY

From seismic interpretation of MARCONI profiles, two domains with a different Pyrenean and north-foreland structure have been recognized in the eastern part of the Bay of Biscay: the eastern, Basque-Parentis sector and the western, Cantabrian sector.

In the eastern domain, the North Pyrenean front is located close to the coast at the bottom of the Basque continental slope. It corresponds to an E-W a basement-involving complex thrust wedge developed along the northern margin of the Basque-Cantabrian Basin. This thrust wedge deforms the uppermost Cretaceous to Lower Miocene successions of a North Pyrenean foreland basin which extended northwards upon a thinned continental crust with a major Mesozoic basin to the north, the Parentis Basin, and a coeval structural high to the south, the Landes High.

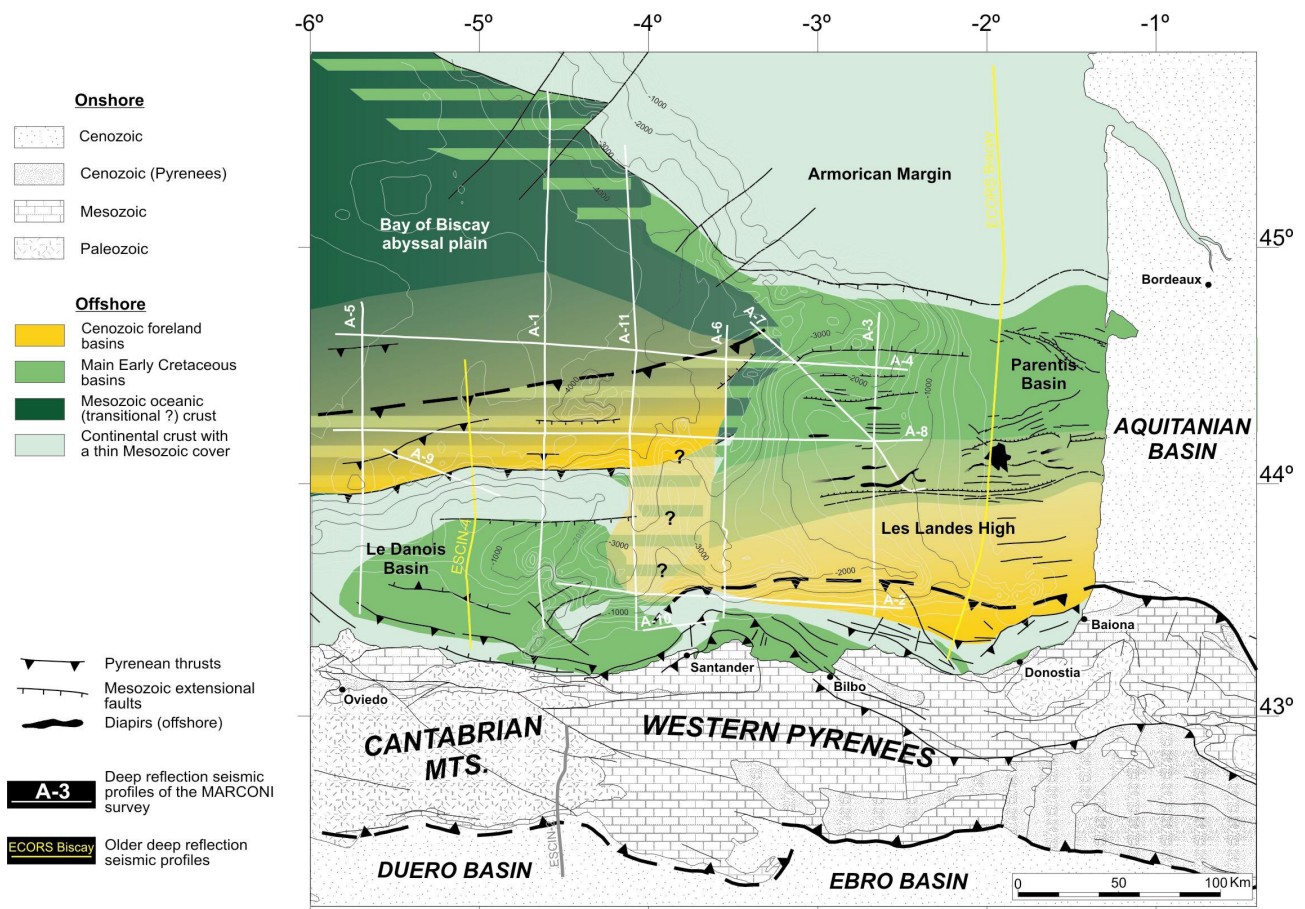


FIGURE 1. Structural map of the eastern part of the Bay of Biscay showing the offshore distribution of: the north-Pyrenean foreland basin, the major faults and the main Early Cretaceous basins formed during the opening of the Bay of Biscay. The boundaries of the Cretaceous oceanic crust have been defined from data provided by Thinin (1999) y Sibuet *et al.* (2004).

The Parentis Basin, striking E-W, appears as bounded southwards by a major north-dipping planar fault with a normal displacement of near 15 km. It is filled up by a thick (up to 10 km) sequence of Jurassic-upper Cretaceous carbonates affected by salt domes and diapirs of Triassic evaporites and mudstones. These salt tectonic structures grew during the Mesozoic opening of the Bay of Biscay and were squeezed during the deposition of the uppermost Cretaceous to lower Miocene synorogenic deposits which are folded upon these structures. Close to the southern boundary of the basin, the MARCONI-3 profile also shows the development of a pop-up affecting the pre-upper Miocene deposits which resulted from the reactivation of the major faults bounding the basin to the south. This indicates that, although minor, some Pyrenean contractional structures developed also in this area.

In the western, Cantabrian, domain, the North Pyrenean front is located 40-70 km north of the toe of the continental slope, and therefore clearly shifted to the north in relation to its position in the Basque-Parentis Domain. Its geometry clearly differs from the eastern sector: it is a northward-directed blind thrust imbricated stack interpreted previously as an accretionary prism (profiles MARCONI-1 and 5 in Fig. 2). This thrust system is buried beneath the upper Miocene-Holocene sediments filling the Bay of Biscay abyssal plain, and deforms a North Pyrenean foreland basin located in front of the Cantabrian continental slope. Also shifted to the north with respect to the Basque-Parentis domain, this foreland basin lies on the top of the crust of the Bay of Biscay abyssal plain which has been interpreted as oceanic or transitional, unlike in the eastern sector (Ruiz, 2007). As observed northwards in front of the Armorican margin (Thinon *et al.*, 2001), this crust appears affected by minor normal faults which were partially inverted during the Pyrenean compression.

The transition between these two well differentiated domains of the north Pyrenean structure corresponds to a soft transfer zone trending NNE-SSW, located north of Santander (Fig. 1). In this 50 km wide zone, the continental crust between the Cantabrian and the Basque north Pyrenean front is affected by major north-dipping NE-SW to E-W Early Cretaceous extensional faults inverted during the Pyrenean deformation. North of this transfer zone, the boundary between the continental and the oceanic to transitional realms of the Bay of Biscay coincides with a NNE-SSW bathymetric scarp that separates the Landes Plateau from the Bay of Biscay abyssal plain. This scarp, located in continuity with the transfer zone, is crossed by the Marconi 4 profile which shows that the boundary between these two domains belongs to a major thrust that places the continental basement of the Landes Plateau over the oceanic to transitional crust of the abyssal plain.

## DISCUSSION AND CONCLUSIONS

The coincidence of the transfer zone with the eastern border of the Bay of Biscay oceanic to transitional crust

denotes that the different features along strike of the north Pyrenean structure in the Bay of Biscay are related to a dramatic change in the nature of the subducted crust from continental to the east, to oceanic or transitional to the west). Therefore the rift system developed between Iberia and Eurasia during the Early Cretaceous appears as a major factor controlling not only the location and features of most of the Pyrenean thrust sheets but also the overall structure of the chain.

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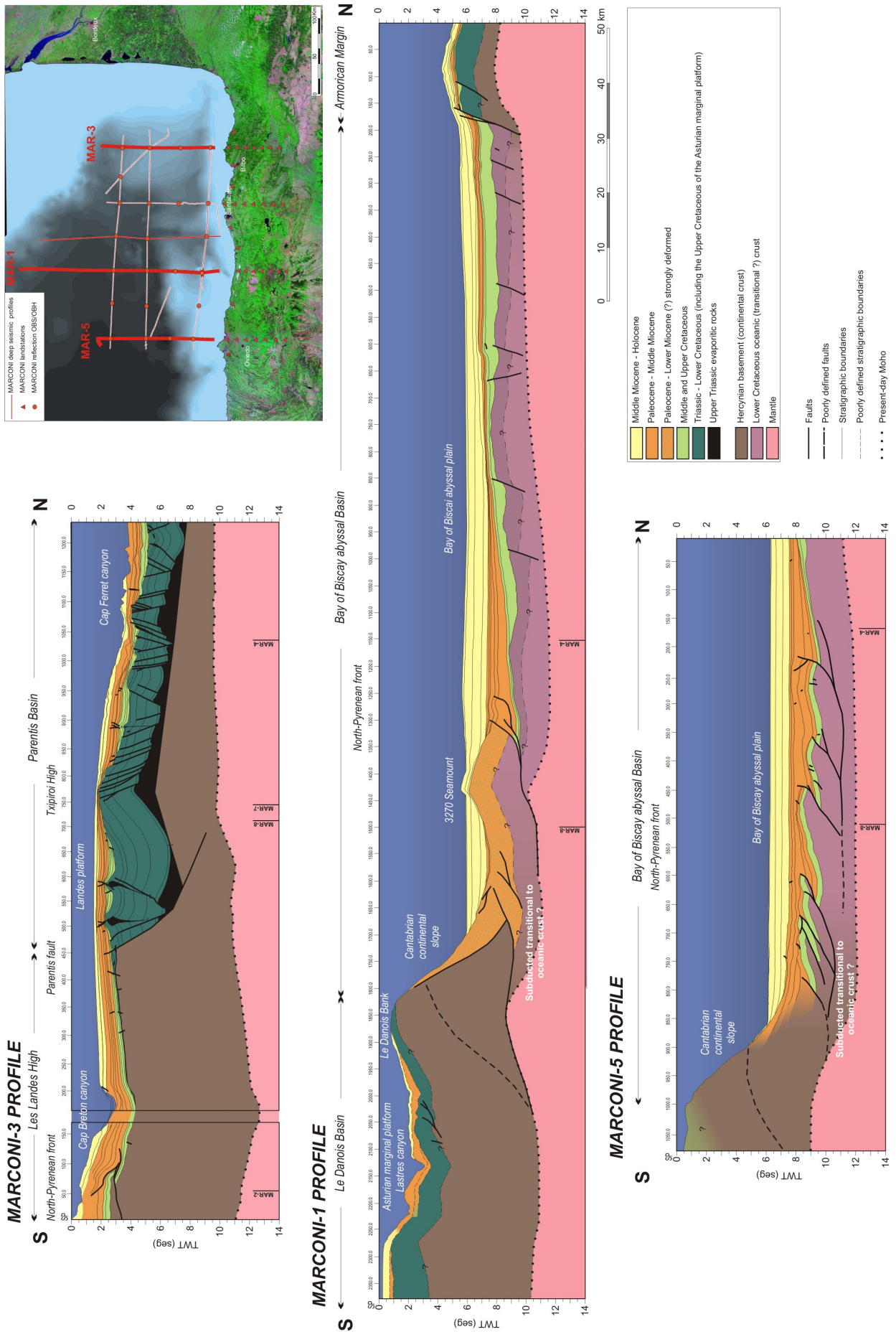


FIGURA 2. Interpretation of the time migrated seismic sections of the MARCONI-1, MARCONI-3 y MARCONI-5 profiles. The Moho geometry is the one defined by Ruiz (2007) from the analysis of wide-angle seismic data obtained in the MARCONI survey.