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Displacement transfer from borders to interior of a plate: A crustal transect of Iberia

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ABSTRACT

A N-S crustal transect of the whole Iberian Plate is presented. The displacement transfer during the Alpine deformation from the border ranges (Cantabrian and Betic chains) toward the interior ones was analyzed by means of balanced crustal sections. Inconsistencies in shortening values between upper and middle-lower crust in the Cantabrian Mountains (Basque–Cantabrian Zone) imply a mid-crustal detachment transferring orogenic shortening southward toward the Spanish Central System. Depending on the shortening value attributed to the Central System, this mid-crustal detachment could involve the entire Iberian Plate, connecting the Cantabrian Mountains and the Betic Chain. The very small crustal root in the Central System can be explained as a result of the tectonic load caused by the upper crustal shortening that was transferred from the border ranges. We conclude that a simple shear model, rather than a pure shear with lithospheric folding, better explains the whole Iberia deformation. Finally, the total Alpine shortening of the Iberian Plate is estimated between 267 and 292 km.

1. Introduction

Intraplate compressional structures play an important role in the tectonic framework of many orogenic forelands. However, processes governing transmission of stresses over great distances and the development of intraplate compressional structures are poorly understood (Ziegler et al., 1995; Zoback, 1992). Although a number of geodynamic processes contribute to the building-up of intraplate horizontal stresses, forces related to collisional plate interaction appear to be responsible for the most important intraplate compressional deformations (Ziegler et al., 1995, 1998). These deformations are accompanied by a commensurate amount of crustal shortening.

The intraplate structures developed in the foreland of orogens have been commonly explained by two models: (1) simple shear detachment within or at the base of crust or (2) local compensation by ductile thickening of the lithospheric mantle and lower crust (pure shear) and/or folding of the whole lithosphere (Stephenson and Cloetingh, 1991). The crustal detachment model has been applied, for instance, to explain the Laramide uplifts of the Central Rocky Mountains (Egan and Urquhart, 1993; Erslev, 1991; Sharry et al., 1986; Ziegler et al., 1995) and the imbrication of the external massifs of the Western and Central Alps (Mugnier et al., 1990; Pfiffner, 1992; Roure et al., 1990; Ziegler et al., 1995). In both cases, the evidences come from deep reflection seismic data. In contrast, the crustal configuration of the Danish–Polish Trough, Donets–Donbass Trough, and the Midcontinent Rift (Cannon, 1992; Chekunov et al., 1992; Stephenson and The EUROPROBE Intra-Plate Tectonics and Basin Dynamics Dniepr-Donets and Polish Trough Working Group, 1993) suggest that the crust could be significantly thickened mechanically as a result of 'pure shear' crustal shortening (Ziegler et al., 1995). Finally, deep reflection and refraction seismic data from the Western Baltic Sea show that inversion of the Mesozoic Ronne Graben involved shortening of the brittle upper crust by reverse faulting and thickening of the lower crust by distributed ductile shear, resulting in depression of the Moho (Makris and Wang, 1994; Thomas and Deeks, 1994; Thybo et al., 1994; Ziegler et al., 1995).

This work analyses the deformation transfer from the borders toward the interior of the Iberian Plate in order to decipher the processes involved. The Iberian Plate is a suitable zone to study intraplate deformation because of its small size and its extensive geological and geophysical knowledge. This microplate is located in the westernmost part of the Alpine-Mediterranean orogen, between the large Eurasian and African plates, and it is bounded by two collisional Cenozoic (Alpine) orogens: the Cantabrian–Pyrenean Mountains to the north and the Betic–Rif Chain to the south (Fig. 1). Currently, the Iberian Plate is part of Eurasia, but in the Early Cretaceous, Iberia behaved as an independent plate separated from Eurasia by the Bay of Biscay–Valais Ocean and from Africa by the Piedmont–Ligurian Ocean (e.g., Srivastava et al., 1990; Stampfli and Hochard, 2009) (Fig. 2a). In the Late Cretaceous, the onset of drift to the north of the African Plate resulted in the squeezing of the Iberian Plate between Africa and Eurasia, and the development of the above-mentioned mountain ranges on its borders (Fig. 2b–d). The deformation related to this convergence was not located only on the borders of the Iberian Plate. The collisional coupling with

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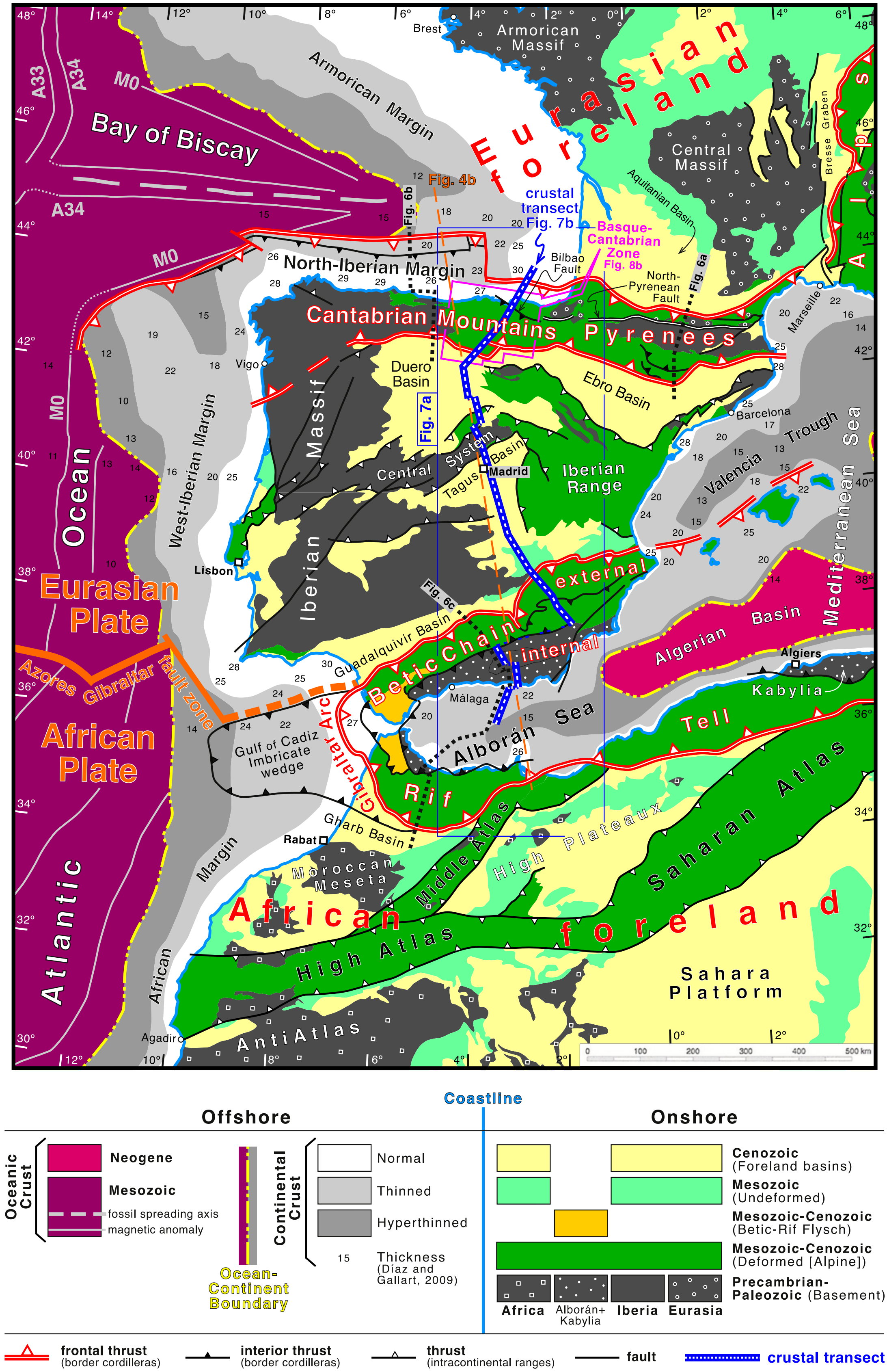

Fig. 1. Geological map of the Iberian Plate and its boundaries with the Eurasian and African plates. Location in Fig. 2d. The Mesozoic–Cenozoic (Alpine) contractional orogens, the continental (Alborán) and oceanic (Algerian) Neogene extensional basins, and the Mesozoic oceanic crust of the Atlantic–Bay of Biscay are represented. The geology is synthetized from Asch (2007). The trace of the Iberian crustal transect of Fig. 7b and of the velocity–depth distribution transect of Fig. 4b are indicated. The isolines of the offshore continental crust around Iberia are built using the crustal thickness values from Díaz and Gallart (2009). Some of these number values are represented. The isolines of the Armorican Margin are from Tugend et al. (2014) and of the African Margin are speculative. The geology of the Bay of Biscay and of the West-Iberian Margin (oceanic and continental crust) are based on Sibuet et al. (2004), Tugend et al. (2014) and Vissers and Meijer (2012a and b).