Tectonophysics 663 (2015) 339–353

Contents lists available at ScienceDirect

Tectonophysics

journal homepage: www.elsevier.com/locate/tecto

Crustal structure of an intraplate thrust belt: The Iberian Chain revealed by wide-angle seismic, magnetotelluric soundings and gravity data

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A R T I C L E I N F O

Article history:
Received 30 January 2015
Received in revised form 10 August 2015
Accepted 20 August 2015
Available online 2 September 2015

Keywords:
Magnetotellurics
3D MT inversion
Seismic refraction/wide-angle reflection profile
2D seismic velocity–depth model
2D forward gravity modeling
Iberian Chain

A B S T R A C T

The Iberian Chain is a Cenozoic intraplate thrust belt located within the Iberian plate. Unlike other belts in the Iberia Peninsula, the scarcity of geophysical studies in this area results in a number of unknowns about its crustal structure. The Iberian Chain crust was investigated by means of a NE-SW refraction/wide-angle reflection seismic transect and two magnetotelluric profiles across the chain, oriented along the same direction. The seismic profile was designed to sample the crust by means of three shots designed to obtain a reversed profile. The resulting velocity–depth model shows a moderate thickening of the crust toward the central part of the profile, where crustal thickness reaches values above 40 km, thinning toward de SW Tajo and NE Ebro foreland basins. The crustal thickening is concentrated in the upper crust. The seismic results are in overall agreement with regional trends of Bouguer gravity anomaly and the main features of the seismic model were reproduced by gravity modeling. The magnetotelluric data consist of 39 sites grouped into two profiles, with periods ranging from 0.01 s to 1000 s. Dimensionality analyses show significant 3D effects in the resistivity structure and therefore we carried out a joint 3D inversion of the full impedance tensor and magnetic transfer functions. The Mesozoic and Cenozoic basins along the Chain are well characterized by shallow high conductive zones and low velocities. Elongated conductors reaching mid-crustal depths evidence the presence of major faults dominating the crustal structure. The results from the interpretation of these complementary geophysical data sets provided the first images of the crustal structure of the Iberian Chain. They are consistent with a Cenozoic shortening responsible of the upper crust thickening as well as of the uplift of the Iberian Chain and the generation of its present day topography.

1. Introduction

The Iberian Peninsula is constituted by a continental crust formed mostly during the Variscan Orogeny. While the center and western parts the Central Variscan Massif has remained tectonically stable for the last 300 Ma, the eastern part of Iberia is mostly formed by thick Mesozoic sedimentary basins inverted during the Alpine orogeny as the result of the convergence between the Euroasiatic and African plates. This has resulted in the development of the Pyrenees and the Betic Ranges at its northern and southern margins, but also in the formation of intraplate thrust belts. The Iberian Chain, the major of those belts, developed during the Cenozoic because of the contractive inversion of the Iberian Mesozoic rift basins (Salas et al., 2001).

The Iberian Peninsula has been extensively explored using seismic data since the late 1970s to determine its crustal structure. The crustal imbrication beneath the Pyrenees, reaching thicknesses of 45–50 km, has been documented from wide-angle (Daignières et al., 1981; Gallart et al., 1981) and deep multichannel seismic profiles (Choukroune and Ecors-Pyrenees Team, 1989; E.C.O.R.S. Pyrenean Team, 1988) and confirmed later on by Pedreira et al. (2003). The seismic exploration of the Valencia Trough using marine multichannel profiles and wide-angle profiles (Dañobeitia et al., 1992; Gallart et al., 1995; Torne et al., 1992; Watts et al., 1990) has revealed the strong variation in crustal thickness as a result of the rifting process that affected the zone, with Moho depths around 35 km in NE Iberia, thinning to 15–18 km beneath the centre of the Valencia Trough and thickening again toward the Balearic promontory. The crustal structure beneath central Iberian Massif was already explored by early profiles (Banda et al., 1981), but the recent

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http://dx.doi.org/10.1016/j.tecto.2015.08.027
0040-1951/

IBERSEIS and ALCUDIA experiments have allowed to define precisely its geometry and velocity structure, characterized by a subhorizontal Moho located close to 32 km (Carbonell et al., 2004; Ehsan et al., 2014, 2015; Simancas et al., 2003). Although scarce seismic information is available for the Iberian Chain, Zeyen et al. (1985) showed an average crustal thickness of 30–32 km, with a local thickening beneath the central northern part of the chain. Díaz and Gallart (2009) compiled the results from deep seismic sounding profiles beneath Iberia and its surrounding waters, providing a crustal thickness map of the area. Recently, Mancilla and Díaz (2015) have presented another crustal thickness map obtained in this case from the analysis of teleseismic receiver functions. Although some differences can be detected between both maps, the results from the two independent data and methods are remarkably consistent, hence confirming the main features of the crustal structure beneath Iberia.

Magnetotelluric profiles have provided crustal resistivity images of the main orogens and related foreland basins in the Iberian Peninsula. The Alpine orogens are the Pyrenees (e.g., Campanya et al., 2012; Pous et al., 1995), the Cantabrian range (e.g., Pous et al., 2001), and the Betic Mountains (e.g., Pous et al., 1999; Ruiz-Constán et al., 2012), while Monteiro Santos et al. (1999), Almeida et al. (2005), Pous et al. (2004), Muñoz et al. (2008), and Pous et al. (2011) have investigated the Iberian Variscan Massif. As the electrical resistivity is a physical parameter independent of the elastic seismic parameters, a combination of both geophysical methods has contributed to clarify ambiguities in the interpretations (e.g., Carbonell et al., 2004).

Nevertheless, these studies are scarce in the Iberian Chain, and no relevant information on the major crustal structures, in particular the Moho structure, has been obtained so far. The aim of this paper is to present the results of a refraction/wide-angle reflection seismic profile and a magnetotelluric (MT) survey across the central part of the Iberian Chain, in order to gain new insights on its crustal structure. Furthermore, the velocity model is converted to density and the predicted Bouguer anomaly is compared with the new Bouguer anomaly data compiled by Ayala et al. (Submitted for publication) (the map and data can be downloaded from http://geodb.ictja.csic.es/BBDDTopoIberia/)

2. Geological setting

The major geological features of the Iberian Peninsula are the result of the geological events produced during the Phanerozoic. The Variscan basement crops out extensively in the Variscan Iberian Massif (in the western half of the peninsula), but also within the Iberian Chain, which occupies the central and eastern peninsular areas (Fig. 1). The Variscan basement was strongly eroded during the latest Paleozoic, a generalized planation surface being developed over it. This surface was covered by the Lower Triassic red beds (Buntsandstein facies) and

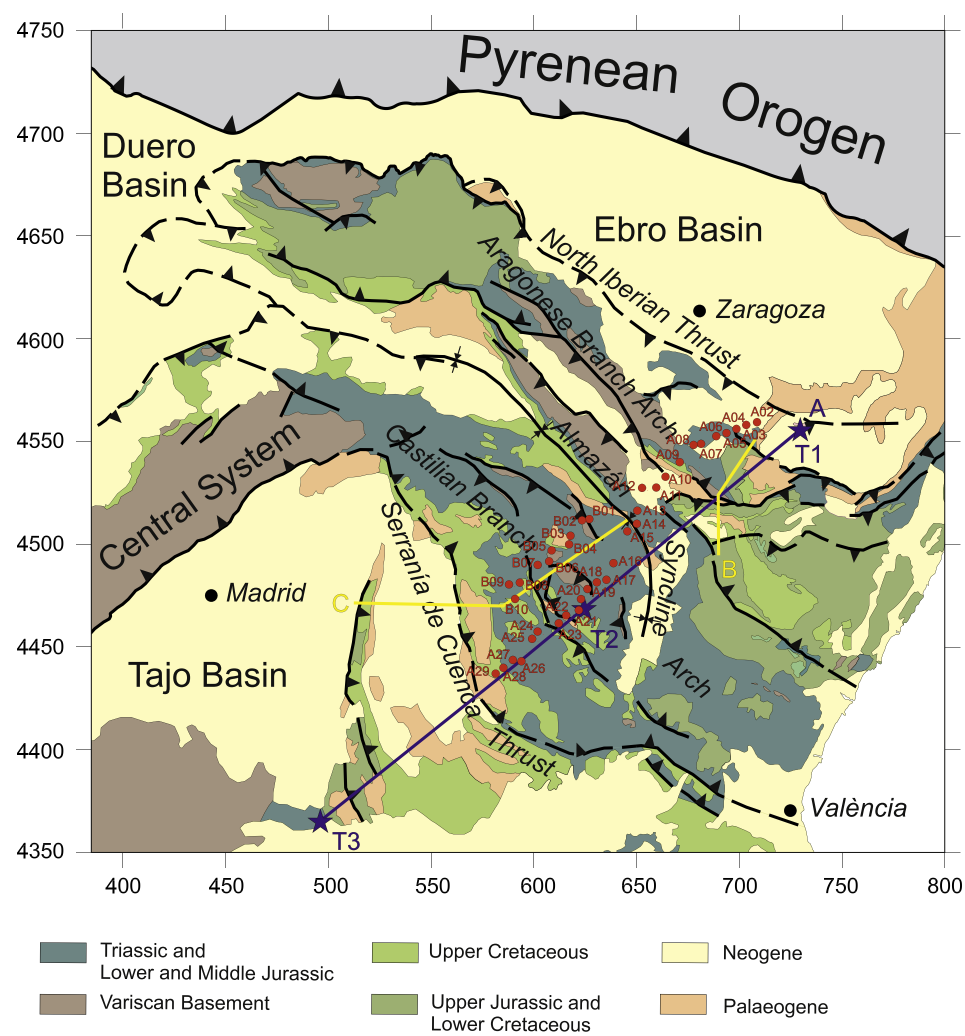

Fig. 1. Simplified geological map of the Iberian Chain and surrounding Tertiary basins (modified after Guimerà, 2004, 2013). A seismic line (Fig. 5); (C and D) Geological cross sections of Fig. 2. magnetotelluric sites (red dots), seismic shots (blue stars), and the major geological units are shown. UTM coordinates (30 T, ED50) are also shown in km.