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Jurassic extension and Cenozoic inversion tectonics in the Asturian Basin, NW Iberian Peninsula: 3D structural model and kinematic evolution

Hodei Uzkeda [a,*], Mayte Bulnes [a], Josep Poblet [a], José Carlos García-Ramos [b], Laura Piñuela [b]

[a] Departamento de Geología, Universidad de Oviedo, C/Jesús Arias de Velasco s/n, 33005 Oviedo, Spain
[b] Museo del Jurásico de Asturias (MUJA), Rasa de San Telmo s/n, 33328 Colunga, Spain

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ABSTRACT

We constructed a geological map, a 3D model and cross-sections, carried out a structural analysis, determined the stress fields and tectonic transport vectors, restored a cross section and performed a subsidence analysis to unravel the kinematic evolution of the NE emerged portion of the Asturian Basin (NW Iberian Peninsula), where Jurassic rocks crop out. The major folds run NW-SE, normal faults exhibit three dominant orientations: NW-SE, NE-SW and E-W, and thrusts display E-W strikes. After Upper Triassic-Lower Jurassic thermal subsidence, Middle Jurassic doming occurred, accompanied by normal faulting, high heat flow and basin uplift, followed by Upper Jurassic high-rate basin subsidence. Another extensional event, possibly during Late Jurassic-Early Cretaceous, caused an increment in the normal faults displacement. A contractional event, probably of Cenozoic age, led to selective and irregularly distributed buttressing and fault reactivation as reverse or strike-slip faults, and folding and/or offset of some previous faults by new generation folds and thrusts. The Middle Jurassic event could be a precursor of the Bay of Biscay and North Atlantic opening that occurred from Late Jurassic to Early Cretaceous, whereas the Cenozoic event would be responsible for the Pyrenean and Cantabrian ranges and the partial closure of the Bay of Biscay.

1. Introduction

The Asturian Basin is a Permian-Mesozoic extensional basin, located in the NW portion of the Iberian Peninsula, partially inverted during the Cenozoic as a result of an Alpine age contractional event that caused the elevation of the Cantabrian Mountains, the formation of the Pyrenean chain to the E and the partial closure of the Bay of Biscay to the N (Fig. 1). The main features of this basin have been previously described, however, there is still a lack of understanding of the relevance as well as the precise age of the extensional and contractional structures that define the current framework of the basin, especially of its eastern sector (e.g., Beroiz et al., 1972a, 1972b; Pignatelli et al., 1972; Suárez Rodríguez, 1988; Lepvrier and Martínez-García, 1990; Riaza Molina, 1996; Alonso et al., 2009; Cadenas, 2013; Martín et al., 2013; Uzkeda, 2013; Uzkeda et al., 2013).

In order to characterize the different structures and the modes of inversion, relating them to the influence exerted by old extensional faults as well as the behaviour of inherited structures, we constructed a geological map, a 3D model and several cross sections, and performed a structural analysis of the study area, that is, the NE emerged portion of the Asturian Basin where Jurassic rocks crop out (Fig. 1). In addition, we attempted to gain insight regarding the evolution of the Asturian Basin by carrying out a comprehensive analysis of the study area which includes determining the tectono-thermal regime, the stress field, the tectonic transport vectors and the amounts of extension and contraction during the different events.

Apart from the purely scientific perspective, the Jurassic rocks exposed in the study area are also interesting from the points of view of hydrogeology (Menéndez Casares et al., 2004), engineering geology (Gutiérrez Claverol et al., 2008), hydrocarbon source rocks

* Corresponding author.
E-mail addresses: hodei@geol.uniovi.es (H. Uzkeda), maite@geol.uniovi.es (M. Bulnes), jpoblet@geol.uniovi.es (J. Poblet), jcgramos.muja@gmail.com (J.C. García-Ramos), lpinuela.muja@gmail.com (L. Piñuela).

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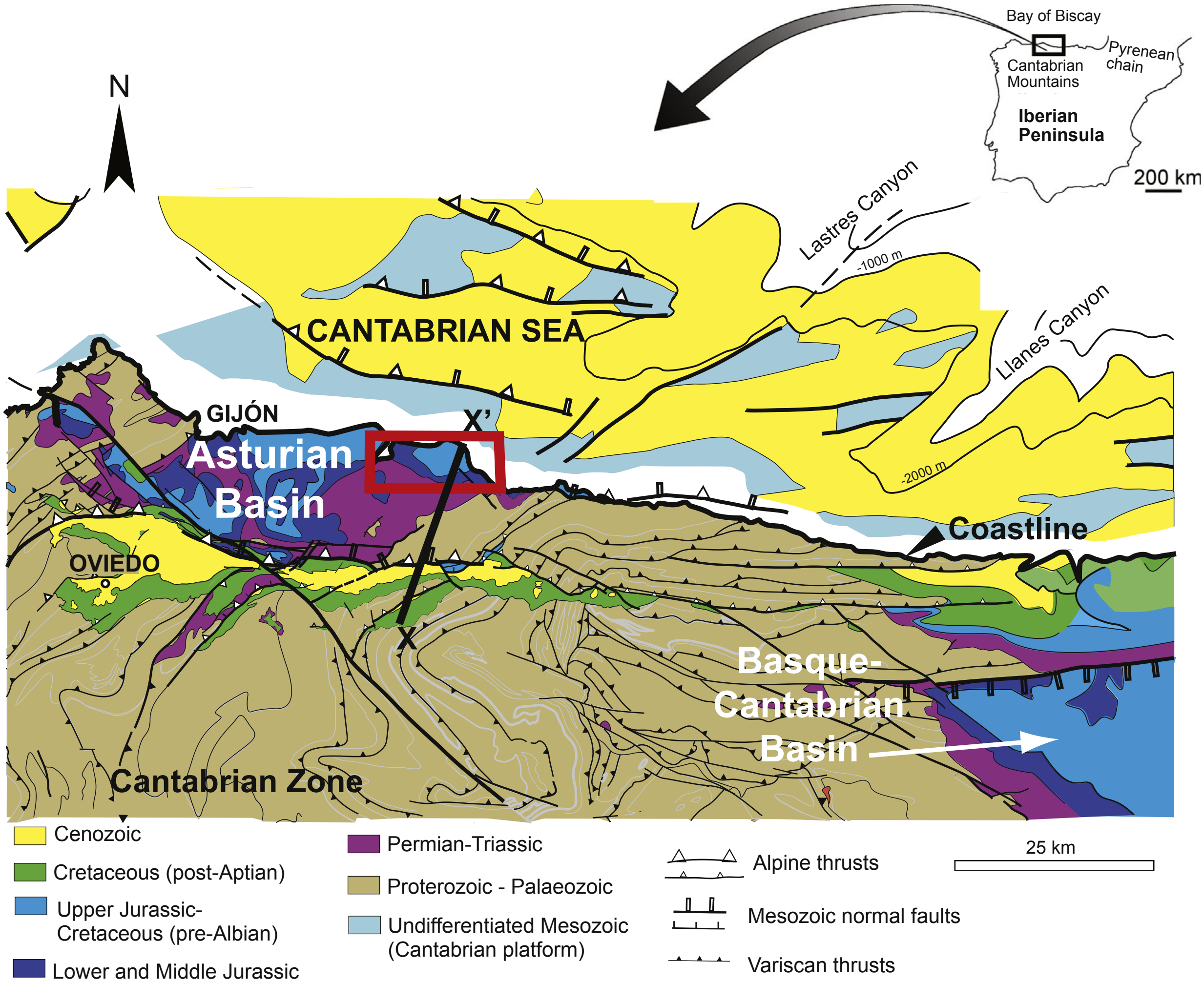

Fig. 1. Structural sketch of the Asturian Basin and surrounding areas (modified from Alonso et al., 2009) showing the position of the study area (red rectangle) and the cross section X-X′ in Fig. 16b.

with type II kerogen (Soler et al., 1981; Valenzuela et al., 1986; Valenzuela, 1988; Suárez-Ruiz, 1989; García-Ramos and Gutiérrez Claverol, 1995; Suárez-Ruiz and Prado, 1995; Riaza Molina, 1996; Borrego et al., 1997; García-Ramos et al., 2006, 2008; Bádenas et al., 2013), jet jewellery (e.g., Campón et al., 1978; Suárez-Ruiz et al., 2006; García-Ramos et al., 2008), vertebrate dinosaur palaeontology (Ruiz-Omeñaca et al., 2006; Lockley et al., 2007) and heritage protection and conservation (Carcavilla et al., 2010; García-Ramos, 2013). Unravelling the structure of these rocks is also important because a hydrocarbon investigation permit has been requested by an oil company to explore the subsurface beneath the study area, which, in turn, belongs to a Spanish State reserve acreage for CO_2 storage.

2. Geological setting

The studied area is situated in the NE part of the emerged portion of the Asturian Basin (Fig. 1), located in the N continental margin of Iberia. This basin has an infilling of Permian-Mesozoic materials unconformably overlying a Palaeozoic basement of Cambrian to Carboniferous age. These basement rocks are involved into a fold-and-thrust belt located in the foreland of the Variscan Orogen of W Iberia, known as Cantabrian Zone, generated mainly during the Carboniferous. The Cantabrian Zone, as well as hinterland portions of the orogen, displays an orocline geometry around an approximately E-W axis called Asturian or Ibero-Armorican Arch and the Asturian Basin sits on top of the N branch of the arch. The basement, as well as the Permian and part of the Mesozoic deposits, have undergone diverse extensional episodes related to a Permian-Triassic continental rifting (e.g., Suárez Rodríguez, 1988; Lepvrier and Martínez-García, 1990; Riaza Molina, 1996; García-Ramos, 1997) and to the Late Jurassic-Early Cretaceous opening of the Bay of Biscay and North Atlantic (e.g. Lepvrier and Martínez-García, 1990; Riaza Molina, 1996; Aurell et al., 2002, 2003; Uzkeda et al., 2013). These rocks, in conjunction with the remaining Mesozoic and Cenozoic deposits, were deformed during the Alpine contraction resulting from the convergence of the Iberian and Eurasian plates that, in this region, took place during the Cenozoic (Alonso et al., 1996; Riaza Molina, 1996). It caused uplift and partial inversion of the Asturian Basin through reactivation of previous structures (e.g., Julivert et al., 1971; Lepvrier and Martínez-García, 1990; Alonso et al., 1996; Riaza Molina, 1996; Pulgar et al., 1999; Uzkeda et al., 2013). The evolution of the area continued with the episodic uplift of marine abrasion platforms (Flor, 1983; Mary, 1983; Álvarez-Marrón et al., 2008 amongst others) and neotectonic activity such as occasional outcrop-scale faulting (Gutiérrez Claverol et al., 2006) and small magnitude earthquakes (López-Fernández et al., 2004).