Geomorphology 206 (2014) 37–57

Contents lists available at ScienceDirect

Geomorphology

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

The influence of surface and tectonic processes on landscape evolution of the Iberian Chain (Spain): Quantitative geomorphological analysis and geochronology

V.N. Scotti [a], P. Molin [a,*], C. Faccenna [a], M. Soligo [a], A. Casas-Sainz [b]

[a] *Dipartimento di Scienze, Università degli Studi Roma Tre, Largo S. L. Murialdo, 1-00146 Rome, Italy*
[b] *Departamento de Ciencias de la Tierra, Universidad de Zaragoza, c/Pedro Cerbuna, 12-50009 Zaragoza, Spain*

ARTICLE INFO

Article history:
Received 18 February 2013
Received in revised form 12 September 2013
Accepted 21 September 2013
Available online 29 September 2013

Keywords:
Landscape evolution
Iberian Chain
Uplift
Topography
Hydrography
Incision rate

ABSTRACT

In tectonically active areas, the landscape response to tectonic forcing is described and possibly quantified by regional topographic and hydrographic features as well as by spatial variation in rates of surface processes. We investigated the recent landscape evolution of the Iberian Chain (NE Spain), an intraplate thrust-belt formed in Cenozoic times and characterized by a dome-shaped topography. In its central sector the landscape is dominated by low relief surfaces, Late Neogene (?) in age, presently standing at an average altitude of 1300 m. A recent regional uplift controlled the organization of the present fluvial network and dissection of the landscape. In this framework we investigated the geomorphic responses to tectonic forcing by the calculation of morphometric parameters, focusing on topography (map of local relief, swath profiles) and hydrography (basin hypsometric curve and integral, basin asymmetry factor, river longitudinal profiles and relative indices), and using SRTM DEM. The results of morphometric analysis have been coupled with radiometric uranium-series dating of calcareous tufas lying on fluvial strath terraces. The obtained ages allow the estimation of incision rate along the High Tajo and Martín rivers. Our results indicate that uplift and rock-type erodibility are the main factors influencing landscape evolution of the study area. The incision rates are very similar throughout the central sector of the range, indicating that, despite subtle local variation, the rivers are responding to a main tectonic input: the regional uplift. In conclusion, the Iberian Chain landscape is in a transient state in response to a recent dome-like uplift. Indeed, the fluvial processes that weakly incised this landscape at a rate of ~0.6 mm/yr are approaching a radial pattern. On the basis of geological and geomorphic constraints, we hypothesize that the uplift started around or after 3 Ma.

1. Introduction

First-order topographic features, drainage system pattern and spatial variation in surface processes rates in tectonically active areas represent proxies with which to quantitatively characterize landscape response to crustal and sub-crustal processes (Harbor, 1997; Burbank and Pinter, 1999; Willett, 1999; Molin et al., 2004; Lock et al., 2006). The competing forces of most of these processes that build-up topography and of erosion that shapes it tend to balance over time (Hack, 1960; Willett et al., 2001). So, if a low relief landscape is uplifted, the steepening of river channels and adjacent hillslopes induces a progressive increase in erosion rates that eventually could counterbalance rock uplift rate (Whipple, 2001). In this case, the landscape changes from a transient state of disequilibrium to a steady state. The response times of landscape to tectonic or climatic perturbation range from 10^4 to 10^6 yr (Whipple, 2001; Wegmann et al., 2007). Generally speaking, the timescale of regional tectonic input is long with respect to landscape response time, whereas the timescale of recent climate changes is shorter. So, the tectonic perturbation influence is more persistent in the landscape than the influence of climatic fluctuations. Among the geomorphic systems' response to external perturbation, fluvial systems are particularly important since they propagate headward the variations in base-level and rule the adjacent hillslope dynamics (Whipple and Tucker, 1999). This makes the study of hydrography and topography fundamental for investigating the role of tectonics and climate in recent landscape evolution. A good example of a transient landscape where topography and hydrography could be an important source of data for reconstructing recent evolution is the Iberian Chain (northeastern Spain), a dome-shaped range characterized by a high-standing low relief landscape. It is an intraplate mountain belt located within the Iberia Plate, between the Pyrenees to the north, the Central System to the west, and the Valencia Trough to the east (Fig. 1). The formation of this belt has been related to the Middle Eocene–Middle Miocene compressive inversion of a Mesozoic extensional basin (e.g. Álvaro et al., 1979). Mounting geomorphological evidence has shown that while the compressive episode vanished in the Neogene, uplift and incision occurred in recent time (Martín-Serrano, 1991; Mather, 1993; Gutiérrez et al., 1996). Therefore, while the origin of the belt is rather well-understood, the formation of the present-day relief is under

---

[*] Corresponding author. Tel.: +39 657338026.
E-mail address: paola.molin@uniroma3.it (P. Molin).

0169-555X/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.geomorph.2013.09.017

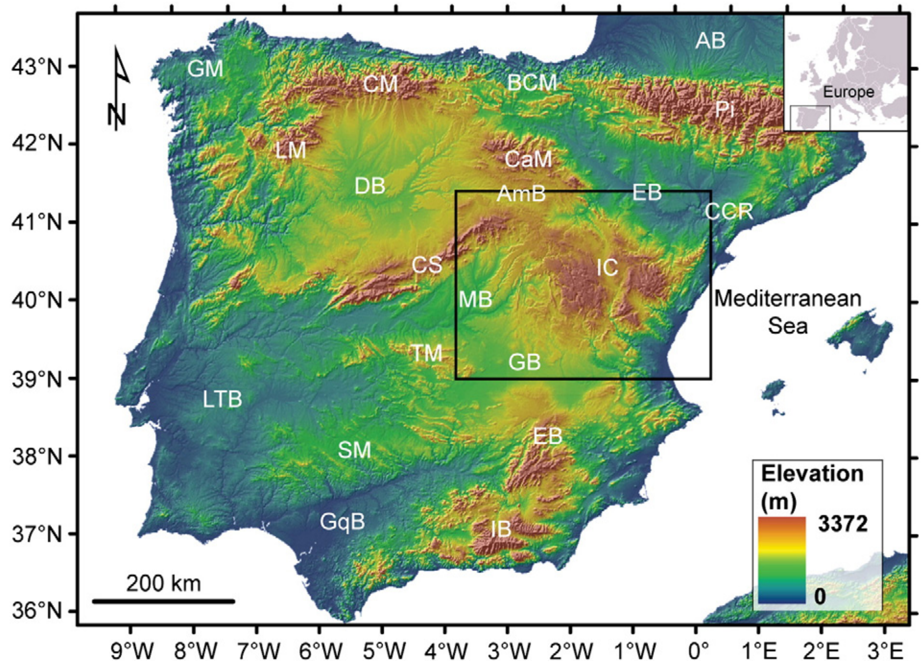

Fig. 1. Topography of the Iberian Peninsula (SRTM DEM database). The black box delimits the studied area. Mountain ranges: Galician Massif (GM), Cantabrian Mts (CM), Basque–Cantabrian Mts (BCM), Pyrenees (Pi), Leon Mts (LM), Cameros Massif (CaM), Central System (CS), Iberian Chain (IC), Catalan Coastal Range (CCR), Toledo Mts (TM), Sierra Morena (SM), External Betics (EB), Internal Betics (IB). Basins: Aquitaine B. (AB), Duero B. (DB), Almazán B. (AmB), Ebro B. (EB), Madrid (High Tajo) B. (MB), Low Tajo B. (LTB), Guadiana-La Mancha B. (GB), Guadalquivir B. (GqB).

debate. Some models proposed that the uplift is generated by large-scale lithospheric folding (Cloetingh et al., 2002; De Vicente et al., 2007), by late stage compressive episode or erosional unloading (Casas-Sainz and De Vicente, 2009), or by the possible action of a mantle upwelling (Boschi et al., 2010; Faccenna and Becker, 2010).

Here, we investigate the geomorphology and the recent landscape evolution of the Iberian Chain. Geomorphic responses to tectonic forcing have been analyzed by the calculation of morphometric parameters, focusing on the first order features of the present topography (map of local relief, swath profiles, frequency plots of slope and local relief values and their relationships with elevation) and hydrography (basin hypsometric curve and integral, basin asymmetry factor, river longitudinal profiles and relative indices) using the SRTM DEM as the main data source (Snyder et al., 2000; Molin et al., 2004; Wobus et al., 2006; Molin et al., 2012). Morphometric analysis has been also combined with radiometric uranium-series dating of calcareous tufas lying on fluvial strath terraces in order to estimate incision rates.

Our goal is to investigate the landscape evolution of an intraplate orogen where crustal or sub-crustal processes have driven a regional dome-like uplift. The dominance of this upheaval in geomorphic evolution is just partially disturbed by local scale changes in rock-type or tectonic features. The results are consistent with a poorly incised landscape where erosion rates are far from counterbalancing the uplift rate. We used these results to develop a conceptual model for the long-term evolution of the Iberian Chain landscape.

2. Geological setting

The *Iberian Chain* is an intraplate double vergent thrust belt, formed as consequence of the convergence between Africa and Iberia (Late Cretaceous–Middle Miocene). The range itself results from the positive inversion of faults originated during the Mesozoic extension of the Iberian Basin (Álvaro et al., 1979; Guimerà et al., 2004), accommodating Cenozoic intraplate shortening (Casas-Sainz and Faccenna, 2001). Estimates of shortening range up to 22% (30 km) along the Demanda–Cameros Unit (northwestern sector of the chain, Casas-Sainz, 1993; Guimerà et al., 1995; Casas-Sainz et al., 2000) decreasing to ~17% in the Montalbán–Utrillas Thrust (Casas-Sainz et al., 2000; Simón and Liesa, 2011) and to ~10% in the Maestrazgo Unit (De Vicente, 2004; De Vicente and Vegas, 2009) (Fig. 2A). The Castilian (Rodríguez-Pascua and De Vicente, 1998) and Aragonese (Ferreiro et al., 1991; Calvo Hernández, 1993; Cortés Gracia and Casas-Sainz, 1996; Casas-Sainz et al., 1998) branches, conversely, show a strike-slip component along NW–SE structures with basement-induced positive flower structures (Wilcox et al., 1973) (Fig. 2B). Finally, the Altomira Unit, located in the westernmost sector (Fig. 2A), is a north–south trending fold-and-thrust belt, affecting a thin Cretaceous cover, with a westward direction of tectonic transport (Muñoz-Martín and De Vicente, 1998; De Vicente, 2004).

The Iberian Chain ends westward against the Central System (Fig. 2A). The linkage between these ranges is characterized by several NW–SE dextral strike-slip faults. The Central-System is also a NE–SW, double-vergence intraplate belt in central Iberia, resulting from thick-skinned Tertiary compression involving metamorphic–granitic Variscan basement (De Vicente et al., 2007).

Tertiary endorheic compressional basins border the thrust belts (e.g. Calvo et al., 1993; Villena et al., 1996; Alonso-Zarza, 2008): the Duero Basin to the NW, the Ebro Basin to the N, the La Mancha Plain Basin to the S, and the Alto Tajo Basin to the SW. The latter is divided into two parts separated by the Altomira Unit: the Madrid Basin towards the W and the Loranca piggy-back basin to the E (Fig. 2A). Conversely, the Teruel and Calatayud-Montalbán basins, filled with Upper Oligocene–Pliocene (4.5–3 Ma) continental sequences deposited in internally drained basins (López-Martínez et al., 1987; Anadón et al., 1990; Anadón and Moissenet, 1996; Alcalá et al., 2000; van Dam and Sanz Rubio, 2003), interrupt the general dome-shaped topography of the Iberian Chain. These basins remained isolated from each other and from the surrounding basins until the Late Miocene, when a widespread deposition of coarse to fine fluvial sediments along the basin margins and lacustrine carbonates located along the depoaxis of each basin (Páramo Fm.) overlapped the entire system (Armenteros et al., 1989; Alonso-Zarza and Calvo, 2000). The origin of these basins is