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Quaternary landscape evolution driven by slab-pull mechanisms in the Granada Basin (Central Betics)

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ABSTRACT

The Granada Basin is one of the largest Neogene-Quaternary intramontane basins of the Betic Cordillera in SE Spain. The landscape evolution in this basin is complex and does not respond to a simple model of headward erosion following river capture of a former endorheic catchment. In the NE border of the basin, the drainage network is highly incised and reveals two different stages of river development since the Pleistocene. The older drainage network presents low incision, being locally controlled by ENE-WSW open folds. The present-day drainage network features deep incised valleys with a well-defined local base-level controlled by NW-SE normal faults. The ENE-WSW open folds were generated by compressional stresses and affect a geomorphic surface that caps the local sedimentary sequence. These folds are thought to reactivate a Pliocene roll-over formed in the hanging wall of ENE-WSW normal faults that bound the Granada Basin to the north and the deepest Pliocene depocenter. On the contrary, Quaternary depocenters are located in the hanging wall of the NW-SE–oriented normal faults that control the present-day drainage network (NW-SE oriented). The activity of these faults also contributes to the erosion of the Pliocene depocenter located to the north, thus suggesting a southwestward migration of the loci of extension to the center of the basin. The broad-scale scenario envisaged to explain the Pliocene–Quaternary evolution of the NE border of the Granada Basin is one dominated by mantle slab-pull coeval with the Africa–Iberia continuous convergence.

1. Introduction

Tectonic geomorphology is one of the fastest-growing disciplines in Earth sciences. This is due to novel methodological advances using Geographic Information Sciences and new available information sources, such as accurate digital elevation models and high-resolution aerial and satellite imagery (e.g., Burbank and Anderson, 2012). Methodological advances together with new available surface and topographic data allow considering new perspectives on the interactions between tectonics and surface processes in active orogens.

Among the entire spectrum of different approaches in tectonic geomorphology, drainage network analysis is one of the most widely and successfully used (e.g., Belisario et al., 1999; Castelltort et al., 2012; Fubelli et al., 2014; Giaconia et al., 2012; Kirby and Whipple, 2012; Pérez-Peña et al., 2009a, 2009b, 2010; Royden and Perron, 2013; Willett et al., 2014). Rivers are continuously adapting their gradients and/or drainage patterns to climatic, lithological and tectonic conditions. Therefore, changes in river parameters reflect changes in these controlling factors (Giaconia et al., 2012; Jackson et al., 1996; Kirby and Whipple, 2012; Pérez-Peña et al., 2009a, 2010).

Extensional and compressional active tectonic processes drive distinctive geomorphic features that can be quantified and compared through landscape analysis. Drainage network analysis in tectonically active areas can provide information not only on tectonic activity, but also on the relative chronology of the different tectonic processes (e.g., Giaconia et al., 2012; Jackson et al., 1996; Keller et al., 1998). Older geomorphic features will be progressively overprinted by present-day active processes, though they can transiently survive at intermediate timescales yielding complex landscapes. Features such as river terraces, abandoned streams, wind-gaps, water-gaps, etc., can be used to establish relative chronologies of recent geomorphic processes related to active tectonics. This approach is especially interesting in areas with low-to-moderate deformation rates and scarce Quaternary fault slip-rate data (Azañón et al., 2012; Pedrera et al., 2009a; Pérez-Peña et al., 2009a).

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In the central Betic cordillera, extensional and compressional structures are coeval and present clear activity in the Quaternary. For some authors, most of the Quaternary active normal faults are subsidiary to the present-day NW-SE Africa–Iberia convergence (Galindo-Zaldívar et al., 1999, 2003; Pedrera et al., 2012). However, other authors have proposed different sub-crustal mechanisms to drive local extension independently from the present-day Africa–Iberia convergence (Booth-Rea et al., 2007; Duggen, 2005; Faccenna et al., 2004; Garcia-Castellanos and Villaseñor, 2011; Gutscher et al., 2012; Martínez-Martínez et al., 2006).

This work focuses on the landscape evolution of the eastern Granada Basin, where different tectonic structures have interacted since the early Pliocene. This basin is located in a very particular position in the central Betics, and different mantle-driven processes have been recently identified right beneath the basin (Bezada et al., 2013; Mancilla et al., 2013; Palomeras et al., 2014). In this work, we analyze the Quaternary landscape evolution of the NE border of the Granada Basin by examining differences in drainage network patterns and river incision. The drainage network analysis reveals two different stages of drainage development during the Pleistocene that respond to the activity of compressional and extensional structures. The differences between drainage patterns and incision rates of both drainage networks suggest that extensional processes dominate over compressional ones in the Granada Basin since the Pliocene. This extension could be related to sub-crustal processes operating under the Granada Basin rather than the present-day Africa–Iberia convergence.

2. Geologic and tectonic setting

2.1. General tectonic setting

The Betics and Rif form the western termination of the peri-Mediterranean Alpine orogen (Fig. 1). The northern and southern branches of this mountain belt resulted from the continental collision between a westward migrating continental block, namely, the Alboran domain (Internal zone), and the south-Iberian and Maghrebian Mesozoic to Tertiary palaeomargins (External zones), within the context of the N-S to NW-SE Africa–Iberia convergence (DeMets et al., 2010; Koulali et al., 2011; Platt et al., 2013). This collision developed during the Miocene, generating a fold-and-thrust belt with westwards vergence (Crespo-Blanc and Campos, 2001; Platt et al., 1995, 2003a), while the hinterland (Alboran Sea and Internal zones) was simultaneously extended (Booth-Rea et al., 2007; García-Dueñas et al., 1992; Platt and Vissers, 1989; Platt et al., 2013).

Several models for upper mantle mechanisms beneath the Betic–Rif cordillera have been proposed to explain widespread extension within a convergent setting; (i) detachment of subcontinental lithosphere either by delamination (Calvert et al., 2000; García-Dueñas et al., 1992) or by convective removal of lithospheric mantle (Platt and Vissers, 1989; Platt et al., 2003b); (ii) slab roll-back of an east-dipping subducting oceanic lithosphere (Faccenna et al., 2004; Gutscher et al., 2002; Lonergan and White, 1997; Royden, 1993; Spackman and Wortel, 2004); (iii) slab break-off (e.g., Blanco and Spakman, 1993) and (iv) combination of slab roll-back beneath the Alboran sea and delamination of

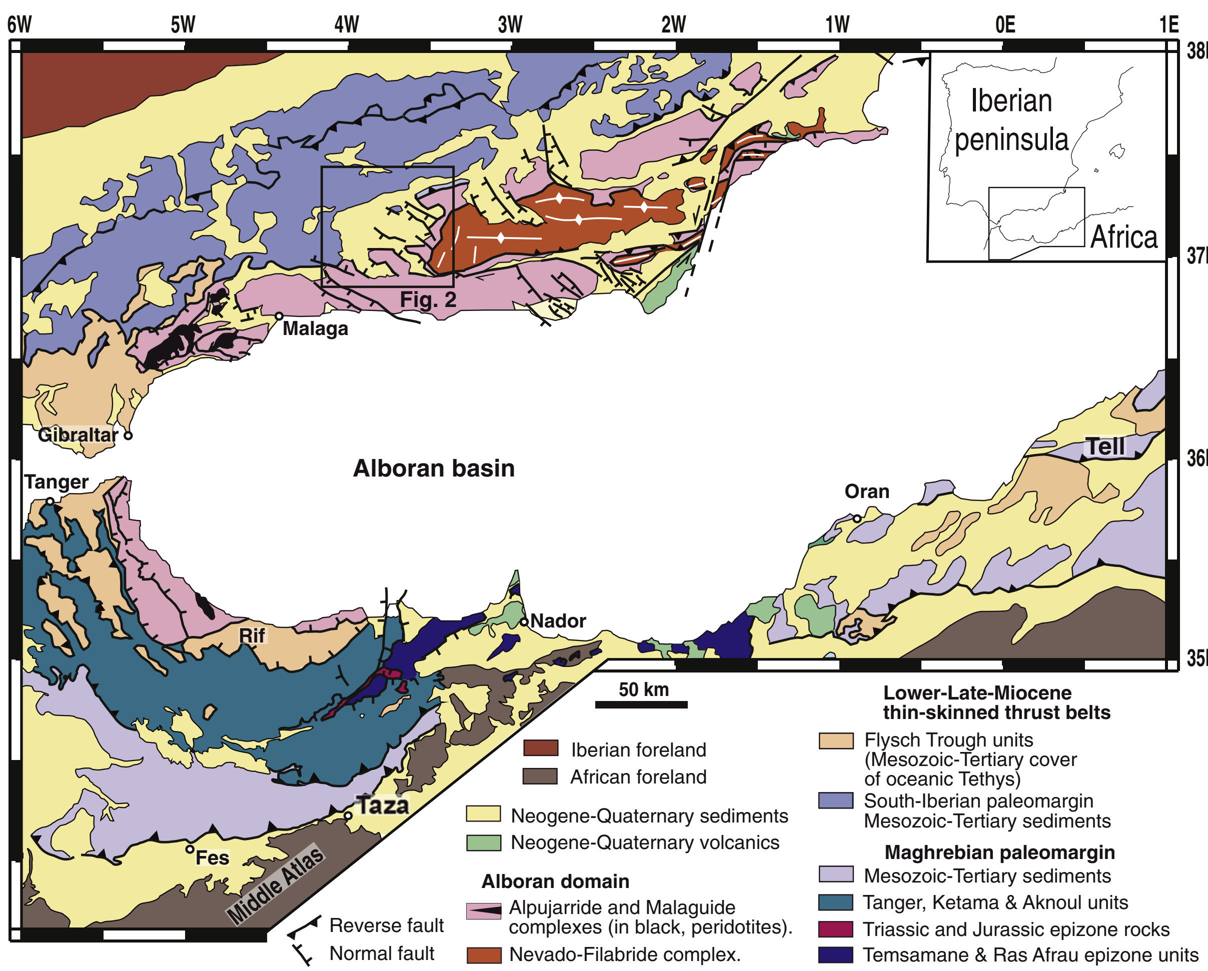

Fig. 1. Simplified geological map showing the tectonic domains of the Betic–Rif Cordillera. The location of the study area (Fig. 2) is indicated.