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Structural record of Lower Miocene westward motion of the Alboran Domain in the Western Betics, Spain

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ABSTRACT

In the framework of the Africa–Europe convergence, the Mediterranean system presents a complex interaction between subduction rollback and upper-plate deformation during the Tertiary. The western end of the system shows a narrow arcuate geometry across the Gibraltar arc, the Betic–Rif belt, in which the relationship between slab dynamics and surface tectonics is not well understood. The present study focuses on the Western Betics, which is characterized by two major thrusts: 1) the Internal/External Zone Boundary limits the metamorphic domain (Alboran Domain) from the fold-and-thrust belts in the External Zone; 2) the Ronda Peridotites Thrust allows the juxtaposition of a strongly attenuated lithosphere section with large bodies of sub-continental mantle rocks on top of upper crustal rocks. New structural data show that two major E-W strike-slip corridors played a major role in the deformation pattern of the Alboran Domain, in which E-W dextral strike-slip faults, N60° thrusts and N140° normal faults developed simultaneously during dextral strike-slip simple shear. Olistostromic sediments of Lower Miocene age were deposited and deformed in this tectonic context and hence provide an age estimate for the inferred continuous westward translation of the Alboran Domain that is accommodated by an E-W lateral (strike-slip) ramp and a N60° frontal thrust. The crustal emplacement of large bodies of sub-continental mantle may occur at the onset of this westward thrusting in the Western Alboran domain. At lithosphere-scale, we interpret the observed deformation pattern as the subduction upper-plate expression of a lateral slab tear and its westward propagation since the Lower Miocene.

1. Introduction

In the Mediterranean, the correlation between P-wave tomographic models that reveal the present-day 3D complexity of slab geometry and surface geology has permitted to reconstruct the subduction upper-plate deformation during slab rollback. The trench curvature that progressively increased during trench retreat (Faccenna et al., 2004; Rosenbaum and Lister, 2004) is laterally accommodated by slab tearing along northern Africa, in Central Mediterranean (Wortel and Spakman, 2000), and along western Anatolia, in the Aegean (Brun and Sokoutis, 2010; Jolivet et al., 2013), explaining the progressive formation of the Calabrian and Hellenic arcs, respectively.

The western termination of the Mediterranean realm in the Alboran–Gibraltar arc domain is far less understood. The diffuse plate boundary between Africa and Eurasia is an arcuate system defined by two Alpine belts, the Betics in Spain and the Rif in Morocco (Chalouan et al., 2008; Crespo-Blanc and Frizon de Lamotte, 2006; Platt et al., 2013) that developed during the convergence between Africa and Eurasia plates (Dewey et al., 1989; Mazzoli and Helman, 1994; Rosenbaum et al., 2002; Schettino and Turco, 2011; Vissers and Meijer, 2012). The formation of the Gibraltar arc is viewed as extensional collapse of a previous existing belt (e.g. Platt and Vissers, 1989), driven by i) continental lithospheric delamination, with different direction (Docherty and Banda, 1995; García-Dueñas et al., 1992; Seber et al., 1996), and/or ii) slab rollback (Faccenna et al., 2004; Frizon de Lamotte et al., 2009; Lonergan and White, 1997; Rosenbaum and Lister, 2004; Royden, 1993), with also possible lateral accommodation by continental lithosphere delamination in Morocco (Fadil et al., 2006; Pérouse et al., 2010).

The earlier tomographic images (e.g. Blanco and Spackman, 1993) have lead to various contrasted interpretations (e.g. comment to Gutscher et al. (2002), by Platt et al. (2003c)). The most recent tomographic models (Bezada et al., 2013; Bonnin et al., 2014; Palomeras et al., 2014; Thurner et al., 2014) display a very localized, subvertical, well-resolved high Vp anomaly below the Gibraltar arc, which further suggests subduction rollback as the geodynamical process responsible for the arcuate belt along the plate boundary. However, interpretations that significantly differ in terms of timing, direction of displacement and amount of slab rollback have been proposed (Faccenna et al., 2004;

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Gueguen et al., 1998; Gutscher et al., 2012; Spakman and Wortel, 2004; Vergés and Fernández, 2012).

The present study aims at providing geological and structural constraints on the timing and direction of displacement of the Alboran Domain in the Western Betics. In this paper, we first describe the geological setting of the Betic–Rif belt and more specifically the northern branch of the Gibraltar arc, the Western Betics, which is characterized by the presence of the Ronda Peridotites, the largest sub-continental mantle body in the world. New structural and kinematic data are presented that document the coeval development of E-W dextral strike-slip corridors and N60° trending thrust faults. We propose that the northern part of the Gibraltar arc has been formed, mainly during the Lower Miocene, by the westward motion of the Alboran Domain, accommodated by simultaneous E-W trending lateral ramps and N60° frontal thrust. The E-W strike-slip deformation zones, acting as lateral ramps of the moving and extending hinterland, more likely correspond to an upper-plate expression of slab tearing at depth.

2. Geological setting

2.1. Overview of the Betic–Rif arc

Fig. 1 presents a simplified tectonic map of the Betic–Rif system. A major tectonic contact, hereafter called the Internal–External Zone Boundary (IEZB; Platt et al., 2013) divides the tectonic system in two zones: 1) the Internal Zone, also called the Alboran Domain (red, dark green, blue and gray in Fig. 1), characterized by metamorphic rocks with variable metamorphic grades and ages; and 2) the External Zone, composed of two main tectonic domain: the Subbetics (in Spain)/Intra- and Meso-Rif (in Morocco) that consist in a non-metamorphosed Mesozoic and Tertiary sedimentary cover on top of the Iberian/Maghrebian basement (pale green in Fig. 1) and the Flysch Trough Complex (Cretaceous to Miocene sediments, orange together with Miocene deposits of the Western Betics in Fig. 1).

The Internal Zone, or *Alboran Domain*, is structurally made of a nappe pile of three tectonic units, which are, from bottom to top: the Nevado-Filabride, the Alpujarride and the Malaguide (see Didon et al. (1973); Egeler and Simon (1969); Torres-Roldán (1979)).

The *Nevado-Filabride* is cropping out only in the central and eastern part of the Betics and is mainly composed of Paleozoic orthogneisses and graphitic schists with a thin Permo-Triassic cover (light brown in Fig. 1, Bakker et al., 1989; García-Dueñas et al., 1988; Martínez-Martínez et al., 2010; Platt et al., 1984). Late Jurassic metamorphosed mafic (Hebeda et al., 1980; Puga et al., 2011) and ultramafic (Padrón-Navarta et al., 2008; Puga et al., 1999) rocks occur locally and are interpreted as Tethysian oceanic remnants affected by a Tertiary (Monié et al., 1991; Platt et al., 2006) high-pressure metamorphic event. Note that the Nevado-Filabride has no equivalent in the Rif.

The *Alpujarride*, Sebtide in the Rif, mainly consists of Paleozoic/Early Mesozoic crustal rocks (several tectonic units with different tectonic evolution, e.g. Booth-Rea et al., 2005) that contain large bodies of sub-continental peridotites (Ronda and Beni Bousera Peridotites, Obata, 1980). The Alpine metamorphic grade generally increases westward (Tubía et al., 1992), from high-pressure/low-temperature south of

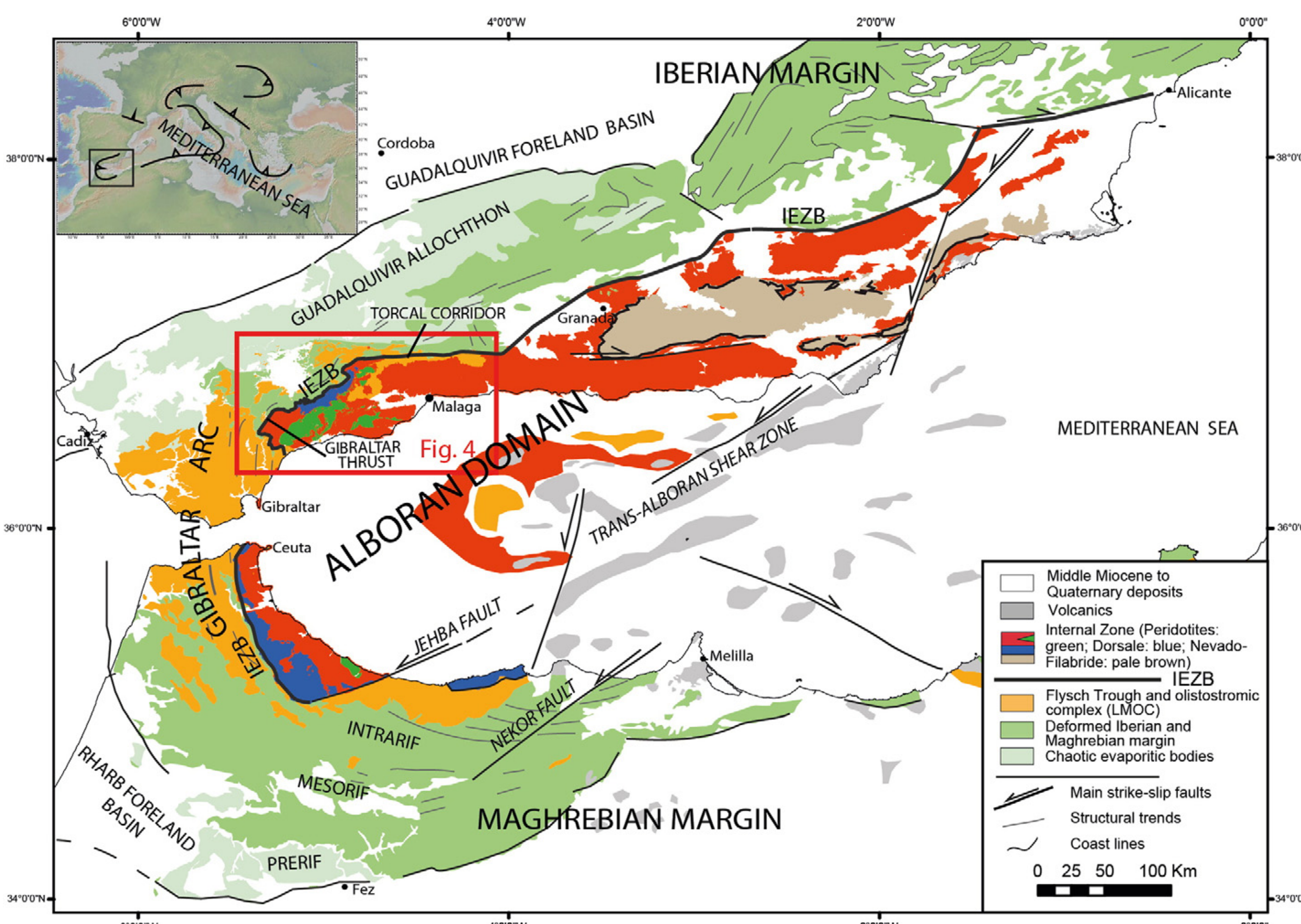

Fig. 1. Simplified tectonic map of the Betic–Rif belt (Redrawn for the Betics after IGME: http://info.igme.es/cartografia/magna50.asp?c=s and Crespo-Blanc and Frizon de Lamotte (2006), for the Rif after Chalouan et al. (2008) and for the Alboran Domain after Martínez-García et al. (2013)). Left-up corner inset: Location in the Mediterranean (from GeoMapApp, http://www.geomapapp.org). Red rectangle: Location of the study area.