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Unravelling hinterland and offshore palaeogeography from pre-to-syn-orogenic clastic sequences of the Betic Cordillera (Sierra Espuña), Spain

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ABSTRACT

The Malaguide Complex (Betic Cordillera) occurs in the Sierra Espuña area (SE Spain) providing a favorable setting to study a sedimentary successions from continental and shallow-marine to deep-marine environments using structural and stratigraphic relations, and petrological and geochemical signatures. The aim of this work is to outline the sedimentary evolution of the Malaguide Complex and the El Niño Fm. This succession is arranged into pre-orogenic (Paleocene-Early Oligocene) and syn-orogenic (Late Oligocene-Early Miocene) stages. The detrital modes of sandstones of the overall succession are heterogeneous and indicate a multi-source area, marked by exhumation till an unknown Malaguide basement and probably lower units of the Internal Betic Zone (e.g. Alpujarride Complex) in the case of the El Niño Fm. Pre-orogenic deposits are mainly carbonate with abundant skeletons of intrabasinal to extra-basinal larger foraminifera, calcareous lithic fragments and quartz grains, and metamorphic lithic fragments. Minor metamorphic lithic fragments occur in the Eocene deposits (i.e. Espuña Fm). Calcareous lithic fragments and extra-basinal fossils (lithoclastic bioclasts) are mostly present in the Early Oligocene pre-orogenic formations (i.e. As Fm) and were derived from the Paleocene-Eocene sedimentary successions of the Malaguide Complex. Syn-orogenic sandstones are quartzolithic with abundant metamorphic and sedimentary lithic fragments (slate, phyllite, fine-grained schist, ooidal grainstone, mudrock and quartz-rich siltstone fragments). Sedimentary lithic fragments were derived from the Mesozoic successions of the Malaguide Complex while metamorphic detritus is related to the Malaguide basement (probably also Alpujarride from Burdigalian on) that was exhumed starting from the Late Oligocene. Mudrocks of the syn-orogenic clastics, record an increase of phyllosilicate, quartz and feldspars and an abrupt decrease in calcite and dolomite. The abundance of calcite and dolomite, and traces of hematite occur dominantly in the pre-orogenic mudrocks. The geochemical signatures suggest a provenance mostly derived from felsic source rocks with a minor supply from mafic metavolcanic rocks in some samples of the syn-orogenic stage. The syn-orogenic formations (i.e. Rio Pliego Fm and El Niño Fm) are characterized by higher Cr/V values than the pre-orogenic formations suggesting a mafic supply for the syn-orogenic samples. In particular, the contents of Cr (average = 85 ppm) and Ni (average = 48 ppm) for the samples of the Rio Pliego and El Niño Formations are higher than those samples (Cr average = 20 ppm; Ni average = 14 ppm) of the pre-orogenic formations. Palaeoweathering indices suggest low to moderate weathering conditions for the source area(s). The Cenozoic studied succession played a key role in the geodynamic evolution of the Betic Cordillera, representing the key tectonic element of the western Mesomediterranean domains.

1. Introduction

The Sierra Espuña area is located to the west of the Murcia province in SE Spain (Fig. 1C), belonging to the Internal Betic Zone (IBZ). The IBZ is mainly made of a tectonic nappe stack formed, from bottom to top, by the Nevado-Filabride, Alpujarride and Malaguide Complexes (Fig. 1B). Both, the Nevado-Filabride and the Alpujarride Complexes are affected by Alpine (and pre-Alpine) metamorphism, whereas the Malaguide is slightly (the older basement) or not at all affected (Martín-Algarra, 1987; Sánchez-Navas et al., 2012, Sánchez-Navas et al., 2014).

The tectonic stacking and the alpine metamorphism of the IBZ is the response to a continental collision (Guerrera and Martín-Martín, 2014) of the Mesomediterranean Microplate (MM: responsible of the Alpujarride and Malaguide Complexes) against the South Iberian Margin (External Betic Zone - EBZ - subdivided in the Subbetic and Prebetic

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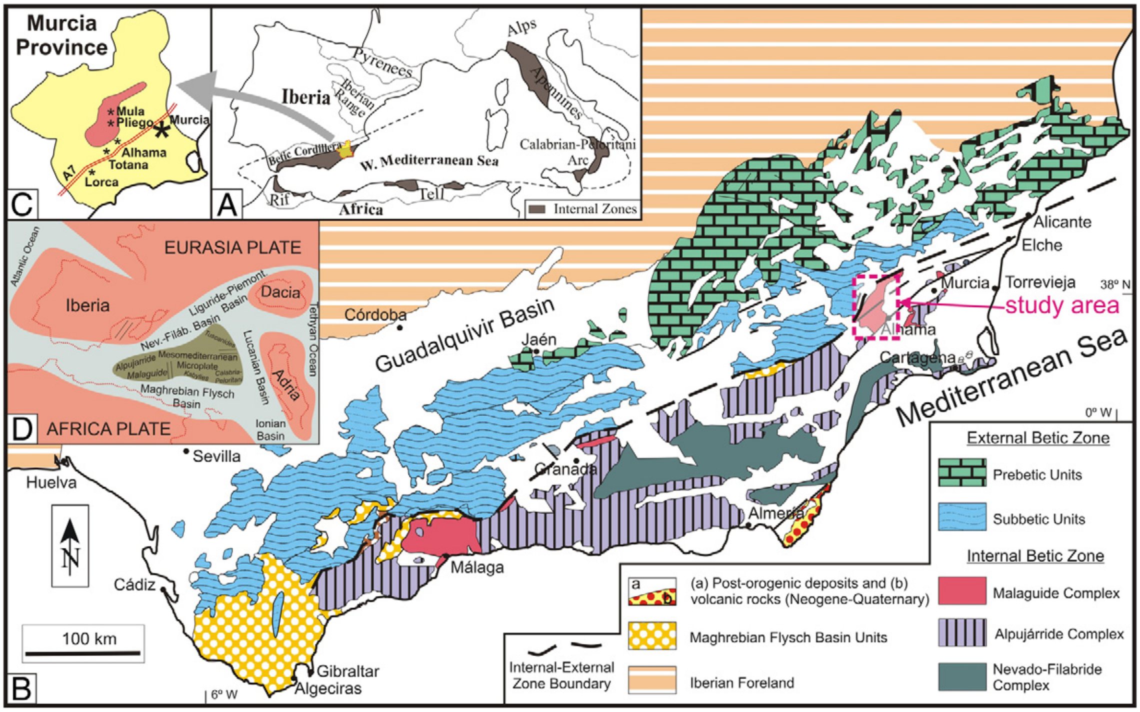

Fig. 1. A) The Internal Zones of others alpine chains of the Circum-Mediterranean belts (i.e. Rif, Tell, Calabria-Peloritani and Apennine chains). B) Geological sketch map of the Betic Cordillera. C) The Murcia province in SE Spain. D) Paleogeographic reconstruction of the central-western Mediterranean area showing the position of the Mesomediterranean Microplate. Modified from Martín-Algarra (1987), Guerrera et al. (1993, 2005), Perrone et al. (2006), Critelli et al. (2008), Perri et al. (2013).

units) involving the Nevado-Filabride oceanic branch (subducted below the MM) (*e.g.*, Perrone et al., 2006; Critelli et al., 2008; Perri, 2014; Perri et al., 2013, 2016b) (Fig. 1D). The Malaguide Complex was related to the Kabylian and Calabrian Internal units, and all of them constituted the southern part of the MM (Martín-Martín et al., 2006a) to the N of the Maghrebian Flysch Basin (*e.g.*, Boullin, 1986; Guerrera et al., 2005; El Talibi et al., 2014 and references therein). This basin separated the MM from Africa during the Mesozoic and part of the Cenozoic (Fig. 1D).

The Internal Betic Zones together with the alpine chains (Fig. 1A) of the Circum-Mediterranean belts (i.e. Rif, Tell, Calabria-Peloritani and Apennine chains) were formed after the breakoff of the previously deformed MM (which had formed a laterally continuous orogenic belt called AlKaPeCa: Bouillin, 1986; Guerrera et al., 1993), which opened the Western Mediterranean basins during the Miocene (Critelli et al., 2008; Guerrera et al., 2012; Alcalá et al. 2013; Guerrera and Martín-Martín, 2014; Guerrera et al., 2015). Moreover, these Internal Zones had a quite similar Meso-Cenozoic geologic evolution. These facts and the occurrence of a thick, continuous, unmetamorphosed and complete sedimentary Meso-Cenozoic cover over the Malaguide Complex makes the Sierra Espuña area very important for correlations among of them, allowing the increase of knowledge on the Paleogene to Early Miocene paleogeographic and geodynamic evolution of the central-western Mediterranean region. The aim of this paper is to discuss the stratigraphic relations and the compositional signatures of Paleocene to Burdigalian arenites and mudrocks of the stratigraphic cover of the Malaguide Complex that constrain the tectonic history of the Betic Cordillera orogenic accretionary processes and related foreland basin system.

2. Geological settings

The study area includes the Sierra Espuña mountain area and the Mula-Pliego Basin located to the NE of it (Figs. 2 and 3A). The Sierra Espuña mountain area constitutes an antiformal stack of Malaguide and Alpujarride tectonic units, followed, towards the N, by a great synclinorium in the basin, including several smaller folding and thrusting structures forming structural culminations exclusively made of Malaguide Paleogene to Lower Miocene Rocks (Martín-Martín and Martín-Algarra, 2002; Martín-Martín et al., 2006a; Martín-Rojas et al., 2007). The detachment level of the thrusts of the entire area is the Paleozoic-Triassic boundary (Martín-Martín and Martín-Algarra, 2002).

The antiformal stack is constituted, from bottom to top, by one Alpujarride tectonic unit, two intermediate Alpujarride-Malaguide units and three Malaguide units. The two Malaguide upper units (Morrón de Totana and Perona) include a Triassic to Tertiary sedimentary cover.

The Morrón de Totana unit bears at its base a thin Carboniferous basement of slates and graywackes in tectonic contact onto the Mesozoic succession of the La Santa Malaguide tectonic unit, and this is followed by the thickest and most continuous Meso-Cenozoic succession of the Malaguide Complex (Martín-Martín et al., 2006a). The Mesozoic succession is more than 2000 meters thick and is made up of Triassic and Jurassic sediments followed by a thin Cretaceous succession (Martín-Martín et al., 2006a; Caracuel et al., 2006). The Triassic succession (Martín-Martín et al., 2006a; Perrone et al., 2006; Critelli et al., 2008; Perri, 2014; Perri and Ohta, 2014; Perri et al., 2013), unconformable onto the Paleozoic, is made of continental redbeds with carbonatic and conglomeratic intercalations arranged into three main depositional sequences. The Triassic succession has been interpreted as belonging to shallow marine-transitional and continental realms. The Triassic succession gradually changes upwards to the Jurassic succession due to a marine transgression and is made of dolostones, at the base, followed by several limestone facies evolving upward into nodular limestones in the Late Jurassic (Cecca et al., 2002; Caracuel et al., 2006; Martín-Martín et al., 2006b; Critelli et al., 2008). The entire succession is interpreted as the evolution of a marine platform to a slope realm in the upper part. The thin Cretaceous succession (Caracuel et al., 2006) shows Berriasian limestones appearing in continuity over the Late Jurassic succession. After a stratigraphic gap, these are followed by a sandy glauconite-rich level Albian in age followed by Upper Cretaceous marly-limestones and marls (Paquet, 1969). The Mesozoic succession is topped by an unconformity followed by a thick (more than 1000 m) Paleocene to Early