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Morphology of turbidite systems within an active continental margin (the Palomares Margin, western Mediterranean)

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ABSTRACT

The Palomares Margin, an NNE–SSW segment of the South Iberian Margin located between the Alboran and the Algerian–Balearic basins, is dissected by two major submarine canyon systems: the Gata (in the South) and the Alías–Almanzora (in the North). New swath bathymetry, side-scan sonar images, accompanied by 5 kHz and TOPAS subbottom profiles, allow us to recognize these canyons as Mediterranean examples of medium-sized turbidite systems developed in a tectonically active margin.

The Gata Turbidite System is confined between residual basement seamounts and exhibits incised braided channels that feed a discrete deep-sea fan, which points to a dominantly coarse-grained turbiditic system. The Alías–Almanzora Turbidite System, larger and less confined, is a good example of nested turbiditic system within the canyon. Concentric sediment waves characterize the Alías–Almanzora deep-sea fan, and the size and acoustic character of these bedforms suggest a fine-grained turbidite system. Both canyons are deeply entrenched on a narrow continental shelf and terminate at the base of the continental slope as channels that feed deep sea fans. While the Alías–Almanzora Turbidite System is the offshore continuation of seasonal rivers, the Gata Turbidite System is exclusively formed by headward erosion along the continental slope. In both cases, left-lateral transpressive deformation influences their location, longitudinal profiles, incision at the upper sections, and canyon bending associated with specific fault segments.

1. Introduction

Submarine canyons are common incisions on continental margins acting as conduits for the transfer of sediment and organic matters toward the deep basin, frequently forming part of turbidite systems (e.g., Shepard and Dill, 1966). Canyons incept either at the continental shelf by rivers extending across the shelf, or at the continental slope with headward erosion by retrogressive failures (e.g., Twichell and Roberts, 1982; Farre et al., 1983; Pratson and Coakley, 1996; Covault and Graham, 2010). Sometimes both processes may be active through time in relation with sea-level variations (e.g. Baztan et al., 2005). In all cases, they represent key geomorphologic features that are especially sensitive to tectonic activity and sea level changes, which control incision pattern, slope instability processes, and the architecture of the turbidite bodies (e.g., Malinverno et al., 1988; Lewis and Barnes, 1999; Baztan et al., 2005; Sultan et al., 2007; Covault and Graham, 2010; Henrich et al., 2010; Davies et al., 2012).

Submarine canyons occurring in the western Mediterranean Sea have been extensively studied during the last decades (Alonso and Ercilla, 2003; Canals et al., 2004, 2006, 2009; García et al., 2006; Palanques et al., 2006, 2009). Large canyons (>100 km long), with tributaries of different magnitude, feed ample deep-sea fans at the base of the continental slope along passive margins, as the Gulf of Lion Margin (e.g., Canals et al., 2004; Droz et al., 2006; Palanques et al., 2006). In contrast, short (few tens of km long) isolated canyons can also incise the continental slope, with no or few tributaries, leading to small turbidite systems seawards. These small canyons occur both along passive and active margins (e.g., Alonso and Ercilla, 2003; Canals et al., 2004). The tectonically active northern Alboran and Algero–Balearic margins host small to medium sized canyons that increase in size from west to east (Comas and Soto, 2006). The canyons from the northern Alboran Margin have been studied in detail and, among them, the Almería canyon (Fig. 1a) west of Cabo de Gata with 55 km long is the most prominent (e.g., Estrada et al., 1997; Alonso and Ercilla, 2003; García et al., 2006).

Here, we focus our study on the geomorphologic analysis of two major submarine canyon systems in the Palomares Margin, which are located immediately east of the Almería Margin (Fig. 1): The Gata (in the south) and Alías–Almanzora (in the north).

The aim of this paper is to provide new results about modern sedimentary dynamics of submarine canyons in the Palomares Margin from analysing morphological features of the Gata and Alías–Almanzora canyons, which finally define the Gata and Alías–Almanzora turbidite systems (Fig. 1). We show the results of the interpretation of novel geophysical data from the Gata and Alías–Almanzora canyons, adding new

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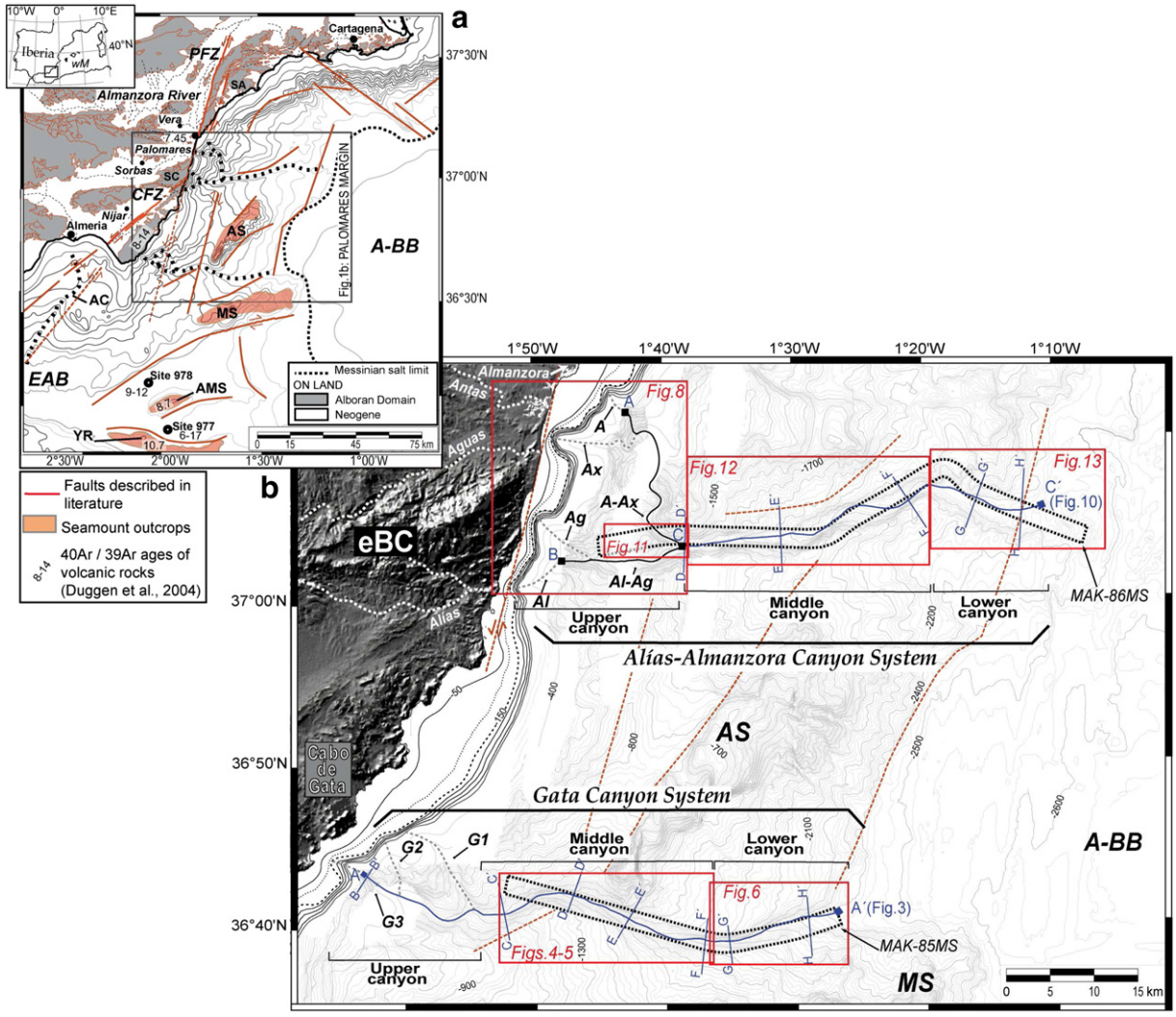

Fig. 1. Location map of the Palomares Margin and surrounding areas. a) Structural framework of the Palomares Margin. The major structures are represented onshore and offshore, as well as the radiometric ages of the volcanic provinces, obtained from bibliographic review. Contour lines from GEBCO 2000. Inset map: location within the western Mediterranean (wM). PFZ: Palomares Fault Zone. CFZ: Carboneras Fault Zone. SC: Sierra Cabrera. SA: Sierra Almagrera. AC: Almería Canyon. AS: Abubacer Seamount. MS: Maimonides Seamount. AMS: Al-Mansour Seamount. YR: Yusuf Ridge. EAB: East Alboran Basin. A–BB: Algerian–Balearic Basin. **b)** Multibeam-derived bathymetry contour map of the Palomares Margin with main structures plotted. Contour lines every 25 m. Dotted line at −150 m: medium value of the continental shelf break. Note the positioning of the longitudinal (A–A , A–C, B–C, C–C) and transverse (B–B´ to H–H´) profiles from the Gata and Alías–Almanzora canyons (included in Figs. 3, 8 and 10). The positioning of MAK-85MS and MAK-86MS side-scan sonar sonograph corresponding to Figs. 4–6 and 11–13 are shown. eBC: eastern Betic Cordillera. A–BB: Algerian–Balearic Basin. AS: Abubacer Seamount. MS: Maimonides Seamount. Tributary canyons: A: Almanzora Canyon; Ax: Antas Canyon; Ag: Aguas Canyon; Al: Alías Canyon; A–Ax: Almanzora–Antas Canyon; Al–Ag: Alías–Aguas Canyon; G1: Gata Canyon 1; G2: Gata Canyon 2; G3: Gata Canyon 3.

examples to the knowledge of submarine canyons by the use of multibeam bathymetry, deep-towed side-scan sonar data and TOPAS sub-bottom profiles. We consider canyon systems development in terms of both regional control factors and local processes shaping the seafloor.

2. Regional setting

The Palomares Margin, a segment of the South Iberian Margin off the eastern Alpine Betic Cordillera, is located north-east of the transition between the Alboran Sea and Algerian basins in the western Mediterranean (Fig. 1). This margin is involved in the Miocene to recent geodynamic evolution of the Gibraltar Arc System (GAS), which in turn is related to the NW–SE/NNW–SSE Eurasian and African oblique plate convergence (e.g., Comas et al., 1999 and references therein; Acosta et al., 2013).

Igneous activity accompanied the geodynamic evolution of the GAS. In the nearby Cabo de Gata and eastern Betics, middle to upper Miocene volcanic rocks (radiometric ages between 14–8 Ma) crop-out extensively, and submarine volcanic structures are widespread in the eastern Alboran Sea Basin (e.g. Duggen et al., 2004 and references therein). The Maimonides and Abubacer seamounts (MS and AS in Fig. 1) have been described several times as clear exposure of such volcanism associated with prominent magnetic anomalies (Mauffret et al., 1992). Those seamounts are extended seawards to the Palomares Margin remaining as residual structural-highs till nowadays (e.g., Mauffret et al., 1992; Comas et al., 1999, 2000).

The nature of the basement at the Palomares Margin has not yet been verified by drilling as is also the case in the adjacent Alboran Sea Basin (Comas et al., 1999 and references therein). However, its continuation with the coastal eastern Betics (Sierra Cabrera and Sierra Almagrera onshore) and the Alboran northeastern margin offshore (Almería Margin) (Fig. 1) allow us to infer that the thinned internal metamorphic complexes of the Betic and Rif Cordillera (the so called Alboran Domain) also constitute the basement of the margin (e.g., Mauffret et al., 1992, 2004). Noteworthy, the Palomares upper margin, like the Alboran margin and basins, lacks the Messinian salt units. The Messinian salt appears at the foot of the margin (around