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Erosive sub-circular depressions on the Guadalquivir Bank (Gulf of Cadiz): Interaction between bottom current, mass-wasting and tectonic processes

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ABSTRACT

Morphological features (escarpments, depressions and valleys) identified on the Guadalquivir Bank, within the middle slope of the Gulf of Cadiz, have been investigated based on high- and mid-resolution geophysical datasets. The morphological and seismic stratigraphic analyses allowed their interpretation as the result of the interaction between oceanographic, mass-wasting and tectonic processes. A phase of enhanced tectonic activity occurred during the Mid-Pleistocene related to the activity of diapiric structures, the front of the allochthonous units, and/or basement uplift or adjustments. This event seems crucial for the origin of widespread mass-wasting events along middle slope sheeted drift plateaus that have been further reworked by the Mediterranean Outflow Water. This resulted in the erosion of a marginal valley to the north of the Guadalquivir Bank, while fluid escape processes also have a minor role in the creation of crescent-shaped depressions. The Diego Cao channel is the result of a complex evolution, from a contourite moat associated to a separated drift to a multi-crested drift and moat system during the Pliocene and Early Quaternary. During the Mid-Pleistocene, the mass-wasting phase produced a prominent erosive surface that opened a deep gateway into the Guadalquivir Bank uplifted basement, allowing the onset of the Mediterranean Intermediate Branch to flow towards the N-NW. The system evolved into a contourite system composed of the present-day channel and an associated deposit on its western side (Bartolomeu Dias sheeted drift plateau) that forms a particularly complex separated drift. This drift displays a series of circular depressions that are similar in morphology to collapse features or pockmarks, but are in contrast, the result of the interaction between the bottom current and the irregular mass-wasting-related scars.

1. Introduction

Morphological, sedimentological and seismic stratigraphy analyses have revealed the prominent scientific and economic interest of contourite depositional systems (Pickering et al., 1989; Rebesco, 2005; Viana and Rebesco, 2007; Viana, 2008; Hernández-Molina et al., 2010). Their study has focused the attention of geologists, geophysicists and oceanographers, as demonstrated by the increasing amount of publications, including this special issue, devoted to contourites, and highlights their enormous importance to investigate the past and present sedimentary and oceanographic processes (Rebesco et al., 2014). Research on contourites is also providing important clues on the geodynamic evolutions of continental margins and basins, such as the opening and modification of deep sea gateways that have affected the deep-water circulation (Maldonado et al., 2003, 2005; Hernández-Molina et al., 2006; Hernández-Molina et al., 2014a,b). Several models and classifications of contourites have been proposed, but as depositional features are being widely investigated, the origin and development of the associated erosional features is far from being understood (Rebesco and Camerlenghi, 2008; Hernández-Molina et al., 2008a; Rebesco et al., 2014). This is the case of the so-called "sub-circular depression structures", "sub-circular-to-oval scour hollows", "elongate-to-irregular erosional scours", and "arcuate to circular slide scars",

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which are commonly recognized in different deep marine settings adjacent to sea-floor irregularities by different authors, although their origin is still controversial (e.g. Maldonado et al., 2003; Hernández-Molina et al., 2008b; Stow et al., 2009; Van Rooij et al., 2010; Rebesco et al., 2014).

The middle slope of the Gulf of Cadiz (500–1200 m water depth) is under the influence of the Mediterranean Outflow Water (MOW) that after exiting the Strait of Gibraltar generates one of the best studied examples of contourite depositional systems. The structural, sedimentary and oceanographic setting in this area is being further investigated after the IODP 339 Expedition (Stow et al., 2013; Hernández-Molina et al., 2014b). The first attempts of characterizing and classifying contourite erosive features were carried out in the Gulf of Cadiz by García (2002) and García et al. (2009). In this classification, contourite moats and channels, marginal valleys and furrows were analyzed in terms of the interaction between the MOW and structural reliefs on the seafloor. More recent works have also dealt with morphological depressions in this region. Sub-circular depression structures have been identified in the Gulf of Cadiz. For example, crescent-shaped depressions located on the lower slope of the Gulf of Cadiz have been related to the tectonic/diapiric activity and the further reworking by turbidite currents (Duarte et al., 2010) while some sub-circular depressions on the middle slope have been attributed to fluid escape processes and the bottom currents reworking (León et al., 2010). In the present work, new high- and mid-resolution geophysical datasets from the Guadalquivir Bank in the Gulf of Cadiz middle slope are analyzed with the aim of a) characterizing sub-circular depressions and other erosive features as amphitheatre-shaped escarpments and valley-shaped features, based on bathymetric and seismic data; b) providing new interpretations on their origin; and c) determining their implications to the regional stratigraphic and palaeoceanographic models, which can be further applied to future research on contourite depositional systems.

2. Background of the study area

2.1. Geodynamic and structural setting

The Guadalquivir Bank area is located in the central Gulf of Cadiz middle slope and consists of a prominent SW–NE-oriented relief related to an uplifted basement high (Fig. 1). Its present-day physiography is the result of a complex geodynamic evolution that started in the Triassic with the opening of the Neo-Tethys and the Central Atlantic (Terrinha et al., 2002; Medialdea et al., 2009). Since then, the evolution of the Gulf of Cadiz has been controlled by the tectonic processes associated to the African–Eurasian plate boundary (Rosenbaum et al., 2002). The Mesozoic extension produced half-graben (Lopes et al., 2006) and horst structures, including the Guadalquivir Bank, which has later subsided during the Neogene (Zitellini et al., 2004). The Guadalquivir Bank is part of the NE–SW trending basement high and is composed of three structural highs delimited by normal faults (Gràcia et al., 2003). The Mesozoic extension also produced the reactivation of the NW-SE-oriented San Marcos–Quarteira Fault Zone as a transtensional fault (Terrinha, 1998a,b). Later compressional events reactivated the extensional structures as dextral strike slip faults (Lopes et al., 2006). The

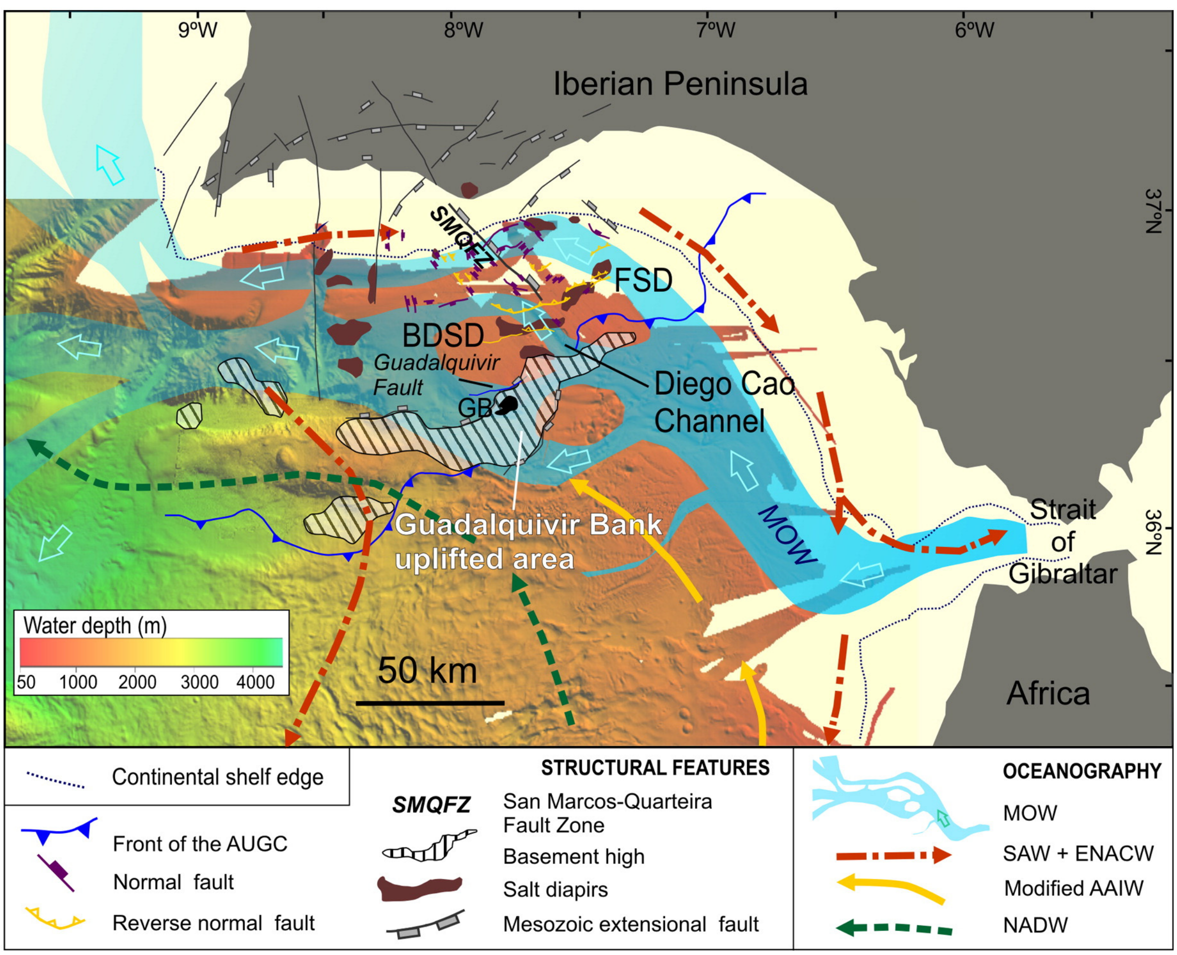

Fig. 1. Location of the Guadalquivir Bank uplifted area, on the middle slope of the Gulf of Cadiz. The map shows the main structural and oceanographical features affecting the study area. AUGC: Allochthonous Unit of the Gulf of Cadiz; GB: Guadalquivir Bank; MOW: Mediterranean Outflow Water; SAW: Surface Atlantic Water; ENACW: Eastern North Atlantic Central Water; AAIW: Modified Antarctic Intermediate Water; NADW: North Atlantic Deep Water.