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The contourite depositional system of the Gulf of Cádiz: A sedimentary model related to the bottom current activity of the Mediterranean outflow water and its interaction with the continental margin

F.J. Hernández-Molina[a,*], E. Llave[b], D.A.V. Stow[c], M. García[d], L. Somoza[b], J.T. Vázquez[e], F.J. Lobo[f], A. Maestro[b], V. Díaz del Río[g], R. León[b], T. Medialdea[b], J. Gardner[h]

[a]*Dpto.de Geosciencias Marinas, Facultad de Ciencias del Mar, Universidad de Vigo, 36200 Vigo (Pontevedra), Spain*
[b]*Instituto Geológico y Minero de España, Ríos Rosas 23, 28003 Madrid, Spain*
[c]*Southampton Oceanography Centre (SOC), Waterfront Campus, Southampton SO14 3ZH, UK*
[d]*Instituto de Ciencias del Mar, CSIC, Paseo Marítimo de la Barceloneta 37-49, 08003 Barcelona, Spain*
[e]*Facultad de Ciencias del Mar, Univ. de Cádiz, 11510 Puerto Real, Cádiz, Spain*
[f]*Instituto Andaluz de Ciencias de la Tierra, CSIC, Campus de Fuentenueva, s/n, 18002 Granada, Spain*
[g]*Instituto Español de Oceanografía, C/ Puerto Pesquero s/n, 29640 Fuengirola, Spain*
[h]*Naval Research Laboratory, Code 7420, 4555 Overlook Avenue SW, Washington, DC 20375, USA*

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Abstract

The present paper is mostly a synthesis of work conducted on the continental margin of the Gulf of Cádiz using a broad database collected by several cruises and projects supported by the Spanish Research Council and the NRL and Naval Oceanographic Office (USA), including: bathymetry, sidescan sonar imagery, seismic profiles, sediment cores, submarine photographs and physical oceanographic data. These data have enabled us to establish a detailed understanding of the morphologic development of the margin, its Pliocene and Quaternary stratigraphy, and a full characterization of the contourite depositional system (CDS) generated by the Mediterranean outflow water (MOW). The northern margin of the Gulf of Cádiz shows the following distinct features: (a) an active compressive framework where the "*Cádiz Allocthonous Unit*" provides an unstable substratum for Late Miocene, Pliocene and Quaternary sedimentation; (b) a relative lack of submarine canyons, except in the western area of the Algarve margin; (c) a very broad continental slope that lacks a marked continental rise; (d) a middle slope dominated by *along-slope* processes driven by the MOW, which has generated a complex CDS during the Pliocene and Quaternary; and (e) an irregular lower slope and abyssal plain region dominated by *down-slope* processes that is partly detached from an upper slope source region. The CDS is composed of both depositional and erosive features. The main depositional features are characterised by *sedimentary wave fields*, *sedimentary lobes*, *mixed drifts*, *plastered drifts*, *elongated mounded, and separated drifts* and *sheeted drifts*. The main erosive features are *contourite channels*, *furrows*, *marginal valleys* and *moats*. These various depositional and erosive features have a specific location along the margin, and their detailed distribution is essential to understand the present (and past) interaction of the MOW

*Corresponding author. Tel.: +34 986 814017; fax: +34 986 812614.
E-mail address: fjhernan@uvigo.es (F.J. Hernández-Molina).

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with the middle slope. Based on this distribution, five morphosedimentary sectors have been identified within the CDS, which from east to west are: (1) proximal scour and sand ribbons; (2) overflow sedimentary lobe; (3) channels and ridges; (4) active contourite drifts; and (5) submarine canyons. The development of the CDS has been controlled in general by the Pliocene and Quaternary environmental and paleoceanographic changes and by the morphology of the margin, but in detail the development of each of these sectors is related to systematic deceleration of the MOW as it flows westwards, to the interaction with the margin bathymetry, and to the effects of Coriolis force. Our comprehensive sedimentary model for the CDS defines the Gulf of Cádiz margin as a mixed *contourite-turbidite* system with a *detached combined drift-fan* morphology. This is different from many other contourite influenced margins, where the contourite processes are dominant on the middle slope, and separated from the down-slope processes, which are characteristic on the lower slope and abyssal plains.

Keywords: Gulf of Cádiz; Continental margin; Morphology; Seismic stratigraphy; Sedimentary processes; Contourites

1. Introduction

Many continental margins are built up by the combined action of *down-slope* and *along-slope* sedimentary processes (Faugères et al., 1999; Weaver et al., 2000; Stow et al., 2002a). Where *down-slope* processes dominate they generate turbidite, debrite or mixed mass-gravity depositional systems (Stow, 1986, 1994; Einsele, 2000; Weaver et al., 2000). Where *along-slope* processes dominate, they generate a Contourite Depositional System (CDS) (Stow et al., 2002a; Hernández-Molina et al., 2003; Rebesco, 2005). There are many examples of continental margins built up by a combination of submarine slides, debris flows, and turbidity currents, such as the polar margins in the northern and southern Hemispheres (Larter et al., 1997; Weaver et al., 2000; Mienert and Weaver, 2003; Laberg et al., 2005) or predominantly by turbidity currents, such as many other glacially-influenced and fluvial-dominated margins (Tucholke and Mountain, 1986; Locker and Laine, 1992; Weaver et al., 2000; Benetti, 2006, among many others). In other cases, contourite deposits (*drifts*) are a common part of continental margins swept by strong bottom currents, typically in association with varied downslope deposits (Rebesco et al., 1997, 2002; Stow and Faugères, 1998; Faugères et al., 1999; Rebesco and Stow, 2001; Lu et al., 2003). Indeed, marine geological studies conducted over the past four decades have confirmed the essential role of bottom current processes in marine environments, and show that they can generate large sedimentary bodies hundreds of km long, tens of km wide, and between 200 and 2000 m thick, similar in dimensions to large-scale turbidite bodies (Stow et al., 1986, 2002b; Zhenzhong et al., 1998; Faugères et al., 1999; Maldonado et al., 2003a, 2005). Several classification systems have been proposed for contourite bodies, based mainly on morphological, sedimentological and seismic characteristics (McCave and Tucholke, 1986; Faugères and Stow, 1993; Faugères et al., 1993, 1999; Rebesco and Stow, 2001; Stow et al., 2002a; Rebesco, 2005). All drifts are related to a combination of regional oceanographic conditions and the physiographic domains in which they develop. Thus, it is possible to deduce, from their morphologic, stratigraphic and sedimentary characteristics, the temporal and spatial variations of the water mass responsible for their development.

Over a long period of geological time, continental margins are built up by sedimentary processes driven by plate tectonic evolution and environmental changes (Einsele, 2000). Both controls may result, at different periods, in continental margins sedimentation being mainly dominated by either down-slope or along-slope processes (e.g., Pickering et al., 1989, 1994; Rebesco et al., 1997, 2002; Stoker et al., 1998; Armishaw et al., 2000; Hernández-Molina et al., 2004a; Laberg et al., 2005). Over a shorter time period (e.g., Late Quaternary), environmental changes in climate, sea-level and oceanographic conditions clearly exert a major control on margin evolution, but are nevertheless modulated by local tectonic effects (Hernández-Molina et al., 2000; Weaver et al., 2000; Llave et al., 2001, 2006a–c; Øvrebø et al., 2006). Once again they condition the predominance of down-slope versus along-slope processes.

Recently, Weaver et al. (2000) and Benetti (2006) have identified the Quaternary sedimentary processes that have controlled the margin evolution in the North Atlantic Basin. Between 41°N and 33°N