

## Contourite processes associated with the Mediterranean Outflow Water after its exit from the Gibraltar Strait: Global and conceptual implications

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**Abstract:** *Herein we characterize the eastern Gulf of Cadiz, proximal to the Strait of Gibraltar, using a multidisciplinary approach that combines oceanographic, morphosedimentary and stratigraphic studies. Two terraces (upper and lower) were identified along the middle slope. They comprise of several associated morphologic elements, including two large erosive channels, which determine a new and more detailed understanding of the Mediterranean Outflow Water (MOW) pathway and its deceleration upon exiting the Strait of Gibraltar. There is evidence for along-slope circulation, and an additional secondary circulation oblique to the main flow. The present upper core of the MOW flows along the upper terrace and the present lower core along the lower terrace. However, the lower terrace shows larger and better-defined erosive features on the seafloor than does the upper terrace, which we attribute to a denser, deeper and faster MOW circulation that prevailed during past cold-climate times. Development of the present features was not established until the Late Pliocene-Early Quaternary, when the MOW enhanced, coeval with global cooling, a sea-level fall and an increase in Thermohaline Circulation (THC).*

**Key words:** *Contourites, Gulf of Cadiz, Strait of Gibraltar, Mediterranean Outflow Water*

### INTRODUCTION

Our understanding of the role of deep ocean circulation in the sedimentary evolution of continental margins is rapidly improving. However, gaining knowledge on the processes involved requires that connections be made between contourite features, their spatial and temporal evolution, and the near-bottom flows that form them. In this work we present a multidisciplinary approach recently published by Hernández-Molina et al. (2014) to evaluate the present and ancient processes related to the Mediterranean Outflow Water (MOW) and its evolution in the Gulf of Cadiz after it is funnelled through the Strait of Gibraltar (SG). Morphosedimentary features are identified using swath bathymetry and seismic profiles, and their oceanographic and geologic implications are discussed. Oceanographic analysis was performed using acoustic Doppler Current Profiler (ADCP) and Conductivity, Temperature and Depth (CTD) datasets, integrated with acoustic analysis and numerical simulations. Seismic data and sediment samples collected by dredges, cores and borehole MPC-1 provided details on sedimentology, stratigraphy, evolution and age constraints. Oceanographic data are not included here but can be seen in Hernández-Molina et al. (2014).

### CONTOURITE FEATURES

Erosional and depositional contourite features were identified west of the Strait of Gibraltar (Fig. 1). Two zones (eastern and western) are separated by a region of basement highs (BHs), and are coincident with a marked change in margin trend from WSW to NW, as well as the development of a distinct middle slope to the west. Erosional features dominate in the *eastern zone*, comprising a large (3–4 km wide), WSW trending channel (hereafter *Southern Channel*, SC) located along the southern part of the Strait. A smaller northern channel (hereafter *Northern Channel*, NC) also was identified. In the *western zone*, two terraces (*Lower* and *Upper*) are present, each comprising (from landward to seaward): a basinward dipping *erosional surface*, a *channel*, a *smooth mounded drift* adjacent to the channel, and numerous small *furrows* oblique to the channel.

The *upper terrace* is shallower in the east (500 m) and deepens north-westwards (~730 m). It is 13.5–23 km wide and slopes seaward ~0.34° in the east and ~0.18° in the west. The erosional surface is a marked erosive scarp incised into the upper slope with a clear truncation surface. The NC is filled with coarse sandy sediments and becomes more distinctive toward the

northwest, where it feeds into the Cadiz and Guadalquivir Contourite Channels (Fig. 1). Its axis slopes from 500 m in the east to 780 m in the NW, and it is bounded on its seaward flank by a drift. The crest of this drift also slopes, from 530 m in the east to 650 m in the west. It is constructed by erosional and depositional phases having a complex internal structure composed of sandy deposits. A series of furrows deviates from the Northern Channel by 30–45°. The *lower terrace* has larger and better-defined features than does the upper terrace (Fig. 1). It also deepens north-westwards from 585 m in the SE to 750 m in the NW. Approximately 9 km wide, it slopes seawards an average of 0.45° in the eastern sector and 0.18° in the western sector. The large and incised SC is ~6 km wide and is characterized by coarse-very coarse sand deposits. It has a broadly sinusoidal shape, WSW to NW trend, and feeds into the Cadiz Contourite Channel in the central sector. The channel axis slopes from 715 m in the east to 780 m in the NW. Seaward of the SC, an associated drift is characterized by irregular morphology and muddy deposits. The drift has a crest deepening westward from 600 to ~830 m. Numerous furrows are evident across the drift, trending at 40–45° from the channel orientation, but they evolve downslope to SW-orientated furrows due to the changing gradient of the lower slope. The onset and evolution of these contourite features is related to a significant regional change in both seismic facies and depositional style occurred during the late Pliocene/early Quaternary, observed in a hiatus from 3.2 to <2.58 Ma (the base of the Quaternary discontinuity, BQD).

## CONCLUSIONS

The new morphosedimentary map and the oceanographic, geological and geophysical data that we

have presented here have enabled the first-ever detailed mapping of the interaction between the MOW and the seafloor west from the Gibraltar gateway, in the Gulf of Cadiz. MOW circulation combines a main along-slope flow direction with oblique secondary circulation filaments. The present-day flow of the MOW is mainly as the upper core along the upper slope and the proximal part of the middle slope. A denser, deeper and enhanced circulation of the MOW as the lower core is inferred during climatically cold intervals. The vertical displacement of the MOW due to climatic variations explains the formation of the largest erosional features west of the Gibraltar gateway. The presence of extensive sand-rich deposits over contourite terraces has important conceptual implications, both in establishing a facies model for sandy contourites, as well as in assessing their potential for deep-water hydrocarbon exploration.

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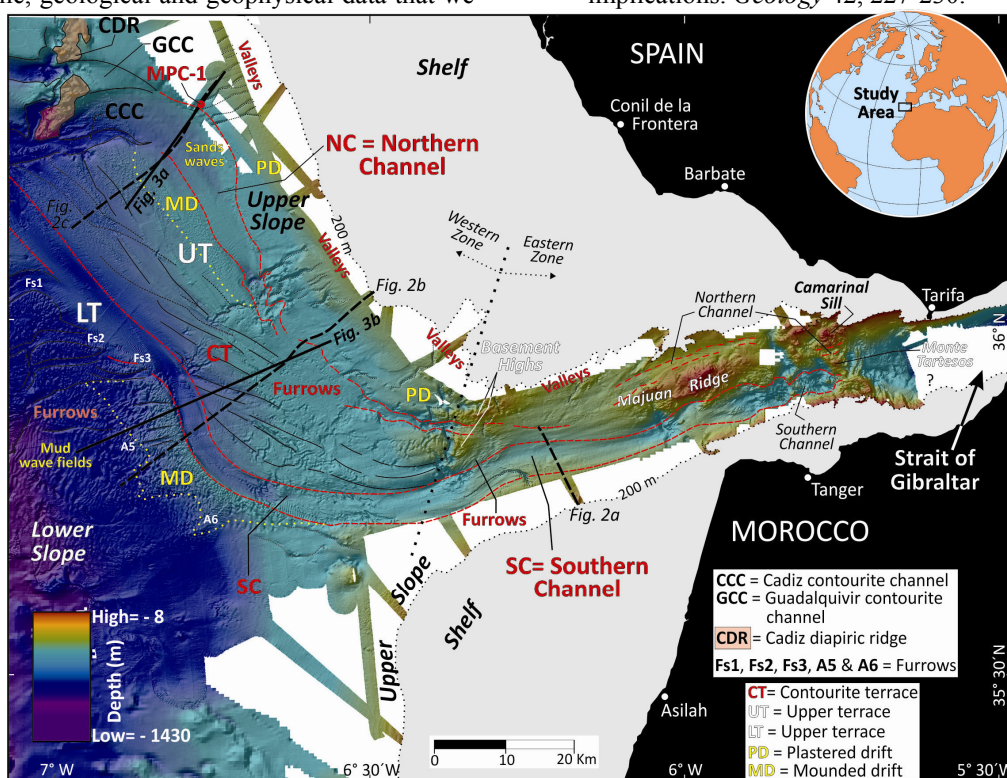


FIGURE 1. Swath bathymetry at the exit of the Strait of Gibraltar. Main depositional and erosive features are shown.