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Large sediment waves over the Gulf of Roses upper continental slope (NW Mediterranean)

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ABSTRACT

Large sediment waves have been observed over the Gulf of Roses (GoR) continental slope (NW Mediterranean), developed between ~200 and ~400 m water depth. Geometric parameters computed from the acquired swath bathymetry revealed mean wave lengths of ~2000 m, and maximum wave heights of ~60 m. Single-channel reflection seismic profiles provided information on the sediment wave internal structure and the Quaternary stratigraphic architecture of the GoR outer shelf and slope. Seven main seismic units could be identified, with continuous development of sediment waves over the outer continental shelf and upper slope, showing differences in wave height and length. The seismic units are differentiated by erosional surfaces that can be followed from the outer shelf down the slope, and which have been correlated with Pleistocene eustatic oscillations. Sediment cores were collected over the sediment wave crests and troughs, and grain size distribution and sediment accumulation rates were analysed. Results show a dominant fraction of fine sediments, allowing classifying the observed bedforms as mud waves. Calculated sediment accumulation rates ranged between 0.08 and 0.18 cm/y, with no clear sedimentation pattern (e.g. differential sediment deposition rates) observed between wave crests and troughs. Nevertheless, the presence of thick surface mixed layers and the increase of the sand fraction in the upper sections of the cores indicate that the surface sediments are affected by bottom trawling activities, since the area is highly impacted by this human activity. The sediment waves observed over the GoR slope are most likely to be formed by bottom currents generated by overflows of dense water originated in the Gulf of Lions shelf, which cascade downslope in an oblique angle with respect the main bathymetric contours. This study offers new insights on the role of dense shelf water cascading processes and associated off-shelf sediment transport reshaping the morphology of the open-slope regions.

1. Introduction

Sediment waves, defined as large-scale depositional bedforms, can display a wide range of morphologies, dimensions and sediment types (i.e., gravel-, sand- and mudwaves). These features have been observed worldwide in a variety of environments and water depths, generated by sediment transport processes on the bottom boundary layer, such as bottom currents (i.e., alongslope-flowing bottom currents) (Mosher and Thomson, 2002; Masson et al., 2002), turbidity currents (i.e., downslope-flowing turbidity currents) (Wynn et al., 2000; Lee et al., 2002), mixed origin (differential sediment depositional over a pre-existing complex seafloor topography, derived from initial sediment deformation) (Faugères et al., 2002; Cattaneo et al., 2004), or the interaction of internal waves with the seabed over the sloping seafloor (Reeder et al., 2011; Delivet et al., 2016; Ribó et al., 2016a, 2016b). Moreover, downslope bottom currents enhanced by dense shelf waters (DSW) have been also reported to be a mechanism for the formation of sediment waves in upper continental slope areas (Verdicchio and Trincardi, 2006; Anderskouv et al., 2010; Foglini et al., 2016).

The formation of DSWs occur in wide and large shelf regions, when the density of the water in the inner shelf increases, due to an increase in salinity (caused by evaporation or ice formation) and/or a decrease in temperature through cooling (Ivanov et al., 2004). These dense waters can be transported across-shelf, cascading down the continental slope to greater depths, as a near bed gravity current with entrained sediments sinking down to its compensation level (Fieux, 1974; Wilson

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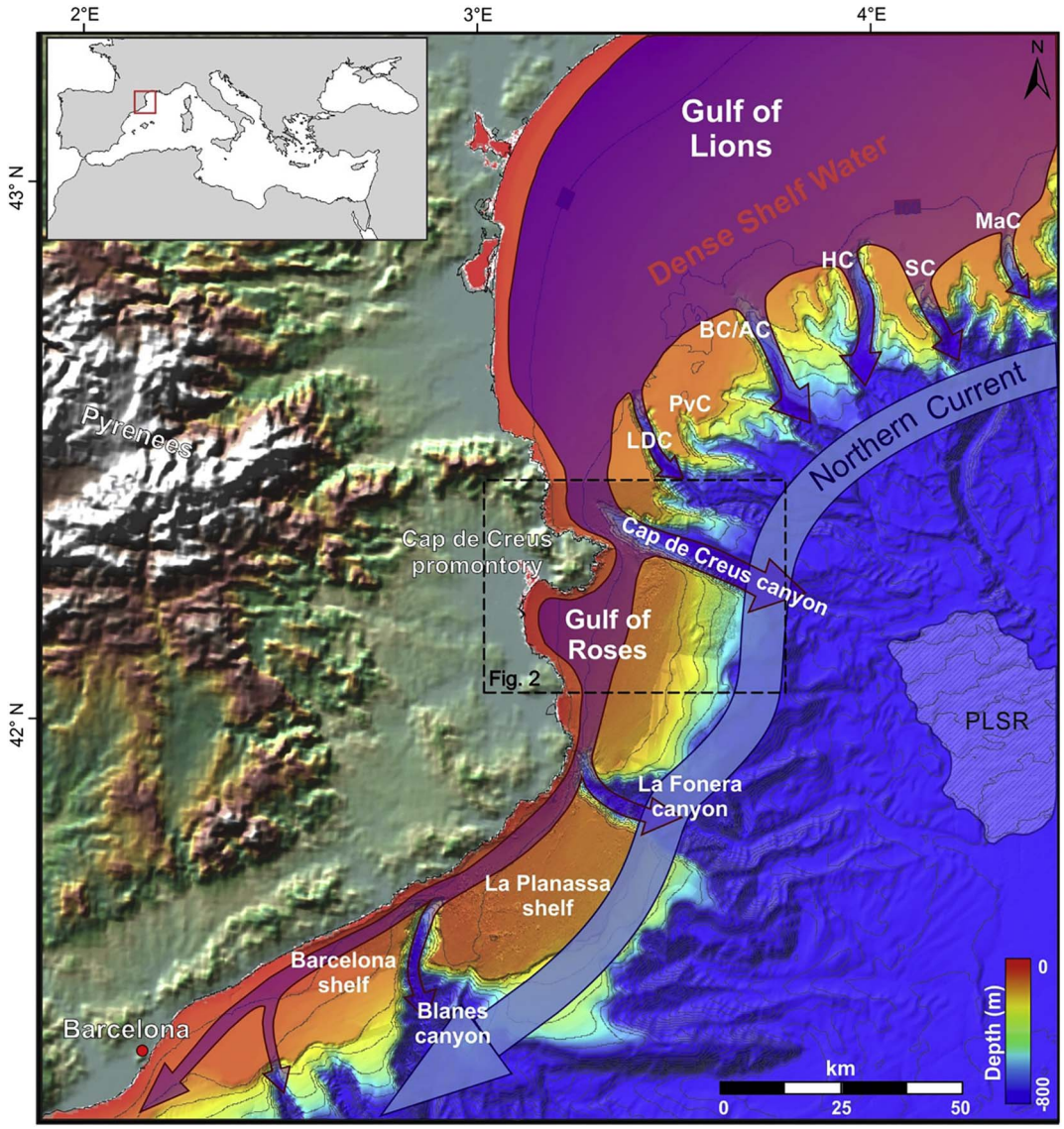

Fig. 1. Location map and bathymetry of the North Catalan margin from the Gulf of Lions (GoL) to the Gulf of Roses (GoR), showing along-slope Northern Current circulation, the major dense shelf water formation and off-shelf export through the submarine canyons, and the location of the Pyreneo-Languedocian Sedimentary Ridge (PLSR). LDC: Lacaze-Duthiers Canyon; PvC: Pruvot Canyon; B/AC:Bourcart or Aude Canyon; HC: Herault Canyon; SC: Séte Canyon; MaC: Marti Canyon. Dashed line box indicates the location of Fig. 2. Multibeam mosaic is a composition of the data from GEBO Digital Atlas (IOC et al., 2003) and the Catalano-Balearic Sea bathymetric chart build from several oceanographic surveys (Farrán, 2005).

and Roberts, 1995; Shapiro et al., 2003; Durrieu de Madron et al., 2005). The dense shelf water cascading (DSWC) events can last for several weeks, with strong currents that can induce erosion and resuspension of sediments in the outer shelf and upper slope (Fohrmann et al., 1998). Sediment transport and seafloor shaping resulting from the bottom currents enhanced by DSWC events on the Gulf of Lions (GoL) and the northern Catalan margin (Fig. 1) have been widely described (Canals et al., 2006; Palanques et al., 2006, 2008; Lastras et al., 2007, 2011; Puig et al., 2008; Durán et al., 2014, among others). However, most of the studies have mainly focussed on the sediment processes within the submarine canyon and/or over shelf areas, whereas their impact on the open slope and basin has received less attention and is still poorly known (Jallet and Giresse, 2005; Palanques et al., 2011, 2012; Puig et al., 2013). New evidences of sediment transfer across the Gulf of Roses (GoR) continental slope are here provided, in agreement with the hydrodynamic DSWC downslope pathways. This study aims to characterize the morphology and internal structure of the GoR upper continental slope, where the occurrence of sediment waves is observed, previously related to slump and creep-like deformation (Ercilla et al., 1994). New detailed bathymetric, seismic and geochronology data allowed a new interpretation of the observed sediment waves and their formation processes. This paper will contribute to a better understanding of the sedimentary evolution of the Northern Catalan margin and how the sediment deposition and accumulation can be disrupted by human activities such as bottom trawling.

1.1. Regional setting

1.1.1. Geological and morphological setting

The GoR extends over an area of ~1000 km^2 south from the Cap de Creus promontory, on the Northern Catalan margin, NW Mediterranean (Fig. 1). The pre-Cenozoic basement structure of this margin is defined by NW-SE to NNW-SSE normal faults, which originated a system of horsts and grabens reflected in the present-day configuration of the coastal plain (Muñoz et al., 1986; Maillard et al., 1992; Tassone et al., 1996; Ercilla et al., 1994; Roca et al., 1999; García et al., 2011). The pre-Messinian sedimentary record in the Catalan margin includes Lower to Upper Oligocene sediments deposited in piggyback basins during the pre-extensional episode; Lower Miocene sediments deposited in the graben troughs during the *syn*-rift episode; and late Langhian to