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Seismic stratigraphy of upper Quaternary shallow-water contourite drifts in the Gulf of Taranto (Ionian Sea, southern Italy)

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A R T I C L E I N F O

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A B S T R A C T

The occurrence of articulated seafloor morphology over continental shelf-upper slope environments, may result in a significant change in the patterns and intensity of basin-scale thermohaline circulation during eustatic sea-level fluctuations. These changes may cause, in turn, erosion, deposition and/or transport of sediments at the seafloor, to form shallow-water contourite drifts. Here we investigate this process in the NW sector of the Gulf of Taranto (Ionian Sea) during and following the Last Glacial Maximum (LGM), by integrating multibeam bathymetric data, ultra-high resolution seismic-reflection data and gravity core data. Sea level fall caused subaerial exposure of the summit of the Amendolara Bank, forming a short-lived island off the eastern coast of Calabria, and also creating a narrow passageway between the island and the northern Calabria mainland. Integrated seismic-stratigraphic data show that Upper Quaternary shallow-water contourite drifts and associated erosional features locally formed both around the flanks of the Amendolara Bank (AMBK), and the continental shelf and upper slope off the Amendolara village. Contourite drifts are bounded at the bottom and at the top by two major unconformities, indicating that the formation of the sediments drifts occurred between the onset of the LGM and the GS-1/Younger Dryas event. The stratal architecture suggests the occurrence of various types of contourite deposits, mostly represented by: a) Axial and lateral channel-patch drifts, and channel-related drifts along the incision to the NE of the AMBK; b) Sheeted drifts along the northeastern slope of the AMBK; c) Elongated drifts along the continental shelf and upper slope off the coast of Amendolara village. Erosional features also developed on the south-eastern flank of the AMBK, where the Levantine Intermediate Water flows from the central Ionian Sea towards the Gulf of Taranto, until the present-day. Both processes and timing responsible for erosion of the seafloor and the formation of sediment drifts in the Gulf of Taranto may be similar to that occurred in the Tyrrhenian margins during the Late Quaternary.

1. Introduction

Contourites are sediments deposited or substantially reworked by the action of bottom currents (Stow et al., 2002). In water depth < 300 m, these deposits may reflect not only basin-scale thermohaline circulation but also local factors/processes implying rapid changes in the intensity and direction of currents (e.g. Stow et al., 2002). Changes in the hydrodynamics of bottom currents may be related to a number of mechanisms, including a) occurrence of narrow gateways that constrict and accelerate bottom-water flows (e.g. Marani et al., 1993), b) upwelling slope currents (e.g. Rodriguez et al., 2004), c) up- and down-canyon flow of water masses (e.g. Okada and Ohta, 1993), and d) off-shelf-cascading dense waters (e.g. Trincardi et al., 2007; Verdicchio and Trincardi, 2008).

Analysis of sedimentary features genetically related to bottom currents is important to derive information on past contour currents circulation form the geological record, and thus plays an increasingly critical role in palaeoceanographic studies. In the Mediterranean Sea, contourite drifts have been documented, so far, in the following areas: a) Sicily channel (Marani et al., 1993; Nelson et al., 1993; Verdicchio and Trincardi, 2008; Martorelli et al., 2011); b) Corsica Channel (Roveri, 2002; Cattaneo et al., 2014; Miramontes et al., 2014); c) Capo Vaticano slope (southern Tyrrhenian Sea) (Amelio and Martorelli, 2008; Martorelli et al., 2016); d) south-western Adriatic margin

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(Verdicchio et al., 2007; Pellegrini et al., 2016); e) Alboran Sea (Hernández-Molina et al., 2002; Ercilla et al., 2016); f) Mediterranean Gibraltar gateway (Rebesco et al., 2014); g) Mallorca south-western outer shelf (Vandorpe et al., 2011). Martorelli et al. (2010) also analyzed the relationships between bottom currents flowing around promontories along in the southern Tyrrhenian and western Adriatic margins, and associated contourite deposits, by using tank- and numerical simulation of contour-following flows.

It is well know that the paths of ocean bottom currents are affected by the seafloor morphology. For instance, in the case of ridge-and-valley morphologies, water masses are typically steered around bathymetric reliefs, and tend to flow along valleys. In shallow-water settings, during sea-level fall and lowstand periods, the role of continental shelf morphology in controlling seafloor hydrodynamics becomes more evident as ephemeral islands and narrow gateways may form at the top and along the flanks of major bathymetric highs. Change in the patterns and intensity of basin-scale thermohaline circulation as consequence of the interplay between eustatic sea-level fluctuations and the shallow seafloor morphology may cause erosion, deposition and/or transport of sediments at the seafloor, to form shallow-water contourite drifts.

In this paper, we investigate the interplay between basin-scale thermohaline circulation, seafloor-bathymetry and eustatic sea-level changes that influence the patterns and the intensity of near-bottom current circulation on the continental shelf and the upper slope, during and following the last glacial period. The research work relies on the recognition of shallow-water (100–250 m below present sea level) contourite drifts that formed in the Gulf of Taranto, around the flanks of the Amendolara Bank (AMBK) and along the northern Calabria shelf-upper slope, between Amendolara and Rossano villages, during the Late Quaternary (Fig. 1a).

The integration of the geophysical and the geological data we present also supported evidence for a change in the near-bottom currents system of the Gulf of Taranto, during a distinct period of climatic cooling at the turnaround of the Last Glacial Maximum (LGM).

2. Physical background

2.1. Geological setting

The Amendolara Ridge (AR) stretches ~ N130°E in the south-western sector of the Taranto Gulf (Fig. 1a) and represents a seaward extended structure of the Southern Apennines fold and thrust belt (Fig. 1b). The ridge is constituted by a complex assemblage of Mesozoic-Cenozoic thrust units and upper Miocene syn-orogenic covers mantled by an uneven thickness of Plio-Quaternary marine deposits (Del Ben et al., 2008; Ferranti et al., 2014). The shallow subsurface structure of the AR is represented by broad folds that form the core of three 13–8 km long marine banks topping the ridge. The area was affected by Mid to Late Quaternary transpression that is marked by the development of syn-sedimentary growth faults (Ferranti et al., 2009; Ferranti et al., 2014), and local accumulation of debris flow and slump deposits (Ceramicola et al., 2014).

A number of depositional sequences bounded by unconformities, which developed during individual phases of sea-level change, and/or their correlative conformities, were recognized in the first 200–300 m of the marine succession (Ferranti et al., 2014). The recentmost sequence overlays a major erosional surface that formed during the LGM sea level lowstand. Older strata consist of mid-upper Late Pleistocene prograding parasequences, likely representing the Falling Stage and Lowstand Systems Tracts deposits associated with the last eustatic cycle. On high-resolution seismic profiles, they are expressed by well-stratified, laterally continuous high-amplitude reflectors with thickness of 30–40 m (Ferranti et al., 2014). This stacking pattern is typically observed on the central Mediterranean shelves and upper slopes affected by vertical tectonic movements (Chiocci et al., 1997; Ridente and Trincardi, 2002; Pepe et al., 2010, 2014; Kuhlmann et al., 2015).

2.2. Oceanographic setting

The Mediterranean Sea is a mid-latitude, mostly enclosed marine basin connected to the global ocean circulation through the Strait of Gibraltar with a limited exchange of water with the North Atlantic (Fig. 1c). Oceanographic circulation of the Mediterranean is characterized by three major water masses: a) the Atlantic Water, also known as Modified Atlantic Water (Malanotte-Rizzoli et al., 1999), is a relatively fresh and light water mass entering from the Strait of Gibraltar and flowing eastward; b) the Levantine Intermediate Water (LIW) is a salty and relatively warm water mass forming in the Eastern Mediterranean, moving westward at intermediate depths of 200–800 m below sea level (bsl), and outflowing from the Strait of Gibraltar (Roussenov et al., 1995), and c) the Western Mediterranean Deep Water is confined into deeper western basins (El-Geziry and Bryden, 2010).

The coastal circulation in the Gulf of Taranto is controlled by the Western Adriatic Current (WAC), which flows through a narrow corridor from the northern Adriatic Sea into the Gulf (Poulain, 2001; Bignami et al., 2007; Turchetto et al., 2007, Fig. 1a). The less saline waters of the WAC mix with the salty Ionian Surface Water (ISW) flowing from the central Ionian Sea. The outflow of the WAC from the Adriatic Sea depends on its density anomaly. During mild winters, moderately dense coastal waters are absorbed by mixing with ISW in the Gulf of Taranto and further south. Conversely, during cold winters the WAC is formed by dense water masses, which are released at depth and transformed by intrusion and mixing with ambient water (Sellschopp and Álvarez, 2003).

The surface circulation of the Gulf is subjected to a marked variability both at seasonal (Pinardi et al., 2016), and decadal (Poulain et al., 2012) scales. Particularly, decadal variability has been interpreted as due to the switching of current patterns from cyclonic versus anticyclonic mode in the northern Ionian Sea (Northern Ionian Reversal phenomenon), as a consequence of episodic oscillations of the Atlantic Ionian Stream (AIS). Changes in the wind stress curl (i.e. relaxation of wind stress) may play an important role in determining this phenomenon, which appears to coincide with a stable positive North Atlantic Oscillation-NAO index (Pinardi et al., 2016).

The deep circulation of the Gulf of Taranto is characterized by the Adriatic Deep Water (ADW), a dense water mass resulting from the merging of the northern Adriatic dense Deep Water (NAdDW) with the deep convection active in the southern part of the basin during late winter/early spring, that is also responsible for the formation of the Southern Adriatic dense Deep Water (Artegiani et al., 1997; Vilibić and Orlić, 2002).

In the Mediterranean area, Late Quaternary glacio-eustatic sea-level fluctuations were likely responsible for the modification of water circulation at various scales (Lascaratos et al., 1999; Cacho et al., 2001, 2002; Toucanne et al., 2012). Indeed, most of the northern Adriatic shelf was exposed to the subaerial domain during the LGM, thus hampering the formation of the NAdDW, while the Levantine Intermediate Water (LIW) production in the Western Mediterranean decreased during the subsequent interglacial stage (Myers et al., 1998).

3. Material and methods

This study is based on the integration of a geophysical and geological datasets including: a) multibeam bathymetry, b) ultra-high-resolution (sub-bottom chirp) seismic-reflection data, and c) marine gravity core data (Tea C1-A).

3.1. Multibeam bathymetry

The Morpho-bathymetric survey (~ 1100 km^2) was carried out using a 70–100 kHz Simrad EM710 multibeam equipment