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Carbonate mounds of the Moroccan Mediterranean margin: Facies and environmental controls

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A B S T R A C T

Sedimentological and geochemical studies of boxcores from the Brittlestar Ridge I and Cabliers carbonate mounds, along the Moroccan Mediterranean margin, show that sediments are composed of cold water scleratian corals and micritic mud, muddy micrite or muddy allochem limestone matrix, outlining seven different facies that can be attributed to "cluster reefs". The mixed siliciclastic/carbonate sediments have been derived from both extra- and intrabasinal sources. Extra-basinal sources may be the geological formations outcropping in the Moroccan hinterland and Sahara, the latter including corals and associated bioclasts. Sediments were transported by wind and rivers and redistributed by bottom currents and local upwelling. Our results confirm the role of tectonics in the genesis of these carbonate mounds and reveal that their developments during the Holocene (10.34–0.91 ka BP) was controlled by climatic fluctuations (e.g. Holocene Climate Optimum and Little Ice Age), eustatic sea level change, and hydrodynamic regime.

1. Introduction

The discovery of cold-water carbonate mounds at the European Atlantic margins over the past decades has increased the interest of the scientific community in these ecosystems (Freiwald, 2002). However, some questions are still open concerning the factors controlling their genesis, development and evolution. Along the Moroccan Mediterranean margin, cold-water carbonate mounds were reported in east of Mellila by Comas and Pinheiro (2007), who named this field "Melilla Carbonate Mound Field" and west of Mellila Lo Iacono et al. (2014). These two fields were named by Hebbeln et al. (2015) as "East and West Melilla Cold water coral Province", respectively (Fig. 1). Studies on the eastern Melilla Province mostly focused on descriptions and age determinations of corals and their associated fauna (Fink et al., 2013; Stalder et al., 2015). A geochemical study carried out by Fink et al. (2013) revealed that cold-water corals (CWC) were prolific during the last glacial–interglacial transition (13.5–12.8 ka BP), early Holocene (11.3–9.8 ka BP) and the mid-Holocene (5.4 ka BP) and that their development was controlled by marine productivity and circulation patterns. Fink et al. (2013) also highlighted arid conditions between 16 and 9.6 ka BP with high input of aeolian dust followed by humid conditions between 9.8 and 8 ka with enhanced fluvial input. Furthermore, a sedimentological study by

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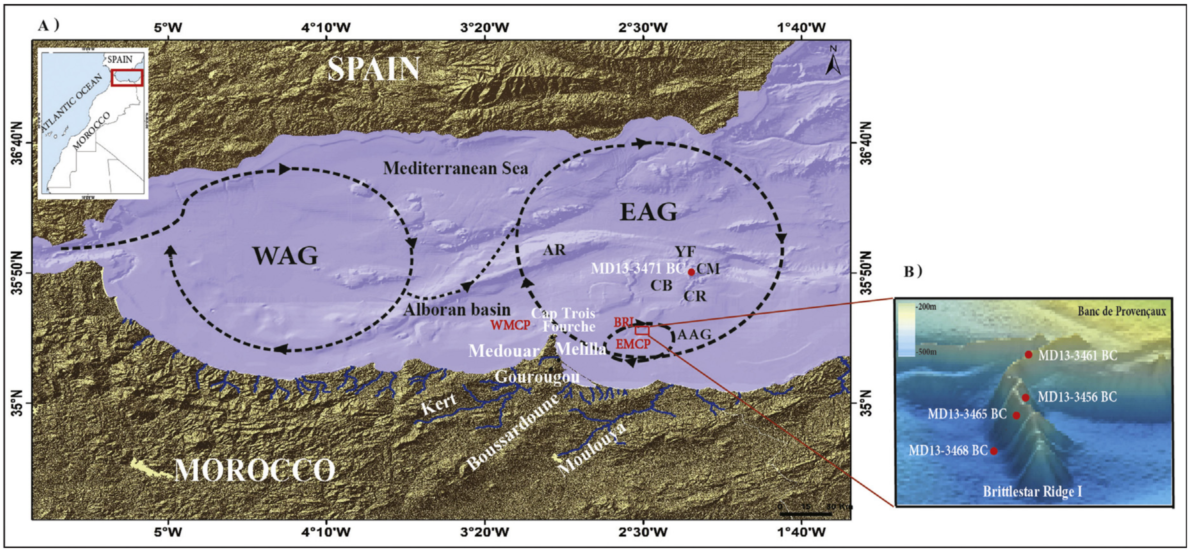

Fig. 1. A. Location of the study area and the boxcore MD13 3471 BC. Topography and bathymetries from the Digital Elevation Models (DEM) and Shuttle Radar Topography Mission (SRTM) of Earth Explorer–USGS source; red square: Brittlestar Ridge I (BRI); WMCP: West Melilla Cold water coral Province; EMCP: East Melilla Cold water coral Province (Comas and Pinheiro, 2007; Hebbeln et al., 2015; Lo Iacono et al., 2014); red point: Cabliers mound (CM) and Boxcores location; AB: Alboran Ridge; CR: Cabliers Ridge; CB: Cabliers Bank; YF: Yusuf Fault; WAG: western Alboran Gyre; EAG: eastern Alboran Gyre; AAG: Atlantic Anticyclonic Gyre (after L'Helguen et al., 2002). B. 3D map of Brittlestar Ridge I, BRI, (Fink et al., 2013) and the location of the studied boxcores.

Titschack et al. (2016) indicates for the upper Unit of the Brittlestar Ridge I (1) that the CWC skeletons represent around 20% of the deposits, (2) that the carbonate content results from organic and detrital sources and (3) that the aggradation rate is between 125 and 241 cm·kyr^{-1}. The aim of this work is to contribute to a better understanding of the formation and evolution of the uppermost part of two carbonate mounds, Brittlestar Ridge I (BRI) and the Cabliers Mound (CM), located along the Moroccan margin, off Melilla (Fig. 1A). In this study, we describe the main sedimentary facies and infer the sediment source and transport mechanisms through grain size, mineralogical and geochemical analyses of the investigated boxcores.

2. Geological and oceanographic settings

2.1. Geological setting

The Moroccan Mediterranean margin consists of a rather narrow continental shelf from 5 to 16 km in width (Tesson and Gensous, 1978). The shelf (Fig. 1) is connected through a steep slope to the southern Alboran basin (1200 m water depth), which presents an irregular topography with ridges, and to the Provençaux and Cabliers Banks (Comas et al., 1999; Fink et al., 2013; Gràcia et al., 2016; Hebbeln et al., 2015). The BRI (Fig. 1) is the steepest and highest of the three existing ridges, it has a sinusoidal shape and reaches 6 km in length and 80 m in elevation from the sea floor (Fink et al., 2013). The CM outcrops in the Cabliers bank, which is bounded by depressions at its eastern and western sides, by a channel, connects to the Yusuf fault at its northern side and is bounded by the Cabliers Ridge to the south (Gràcia et al., 2016). The ridges and most mounds in this region are aligned in deep and large depressions (Comas et al., 1999).

The Moroccan Mediterranean margin is an active margin that develops in a regional compressive context linked to the NW–SE convergence of the Africa and Eurasian plates (Auzende et al., 1975). The Alboran basin originated at the end of the Cretaceous by the thinning of the thick continental crust as a result of the continental collision of the surrounding Betic and Rif Chains (Comas et al., 1999). After the paroxysmal phases of the Alpine orogeny, this hinterland was subjected to compressional and distensional tectonics during the Neogene and Quaternary and was accompanied by a calc-alkaline volcanism (Guillemin and Houzay, 1982; Hernandez, 1983; Louaya and Hamoumi, 2010; Morel, 1989). This tectonic activity is still recorded at present as shown by the numerous earthquakes that affect the region (Vázquez et al., 2014).

2.2. Oceanographic setting

Four water masses have been identified in the Mediterranean Sea (Benzohra and Millot, 1995; Gascard and Richez, 1985; Parilla et al., 1986):

- the Atlantic water, in the upper 150 m of water depth, with a salinity of 36.5 psu increasing up to 38.0 psu while progressing eastward through the Strait of Gibraltar and with a temperature of 16 °C; the characteristics of this water is not regular from west to east;
- the Modified Atlantic Water (MAW), between 150 to 200 m in water depth, with a salinity of 38.3 psu and a temperature ranging from 12.65 to 13.20 °C, flowing through the Strait of Gibraltar into the Algerian basin:
- the Levantine Intermediate Water (LIW), between 200 and 600 m water depth, formed in the eastern Mediterranean and flowing westward to the Atlantic