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Hydrodynamic conditions in a cold-water coral mound area on the Renard Ridge, southern Gulf of Cadiz

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ABSTRACT

Near-bed hydrodynamic conditions obtained by bottom landers on the Renard Ridge are presented complemented with a data set from repeated CTD casts. On the Renard Ridge cold-water coral mounds were discovered in the last 10 years. Unlike cold-water coral habitats known from the Norwegian and Irish margins, these mounds are not covered with living corals. Mounds are located near the boundary between North Atlantic Central Water and Antarctic Intermediate Water. Mediterranean Water was present at greater depth, but was not observed in the vicinity of the Renard Ridge. Near-bed temperature and current speed reflect a baroclinic semi-diurnal tidal motion, causing vertical watermass movements up to 100 m and temperature fluctuations up to 1.2 °C. Average current speed was 8.8 cm s^{-1}, while occasionally peak current speeds up to 30 cm s^{-1} occurred on top of the Renard Ridge. Tidal currents force the formation of up to 300 m thick bottom nepheloid layers. Near-bed hydrodynamic conditions around the mounds fit in the range for cold-water coral occurrences as described in literature. However, at present coral growth seems restricted by the low near-bed current speeds, the low surface productivity in a well stratified water column and the high near-bed load of fine sediment particles.

1. Introduction

Over the past decades it has been demonstrated that cold-water coral ecosystems are widely distributed along the margins of the Northeast Atlantic Ocean (e.g. Freiwald and Roberts, 2005; Roberts et al., 2006). Here cold-water corals either occur as single colonies, patches or as kilometre-long reef and mound structures. On the Norwegian margin mainly reef-like structures are found (Freiwald et al., 1997; Lindberg and Mienert, 2005), kilometre-long and wide mound structures are present on the Rockall Trough margins and in the Porcupine Seabight (De Mol et al., 2002; Van Weering et al., 2003b), while in the Mediterranean Sea mainly isolated coral patches have been observed (Taviani et al., 2005). Cold-water coral mound occurrences are also reported from subtropical latitudes off the coast of NW Africa, on the Mauritanian (Colman et al., 2005; Eisele et al., 2011) and Angolan margins (Le Guilloux et al., 2009).

The Gulf of Cadiz likely links coral occurrences as reported from the southern part of the NE Atlantic Ocean with coral occurrences on the Northern European margins (Frank et al., 2011; Schröder-Ritzrau et al., 2003). In the Gulf of Cadiz cold-water corals were found along the Spanish as well as the Moroccan margins on the flanks of mud volcanoes (Diaz-del-Rio et al., 2003; Pinheiro et al., 2003), encrusting carbonate chimneys or growing on top of authigenic carbonate slabs (hardgrounds), on diapiric ridges, fault escarpments and mound structures (Diaz-del-Rio et al., 2003; Wienberg et al., 2009). Reef forming cold-water corals in the Gulf of Cadiz mainly occur between 500 and 1000 m water depths. Mound structures with an average height of 15 m above the surrounding seabed have been discovered on the Renard Ridge, a topographic elevation bounded by the Pen Duick Escarpment (Foubert et al., 2008; Van Rooij et al., 2011; Wienberg et al., 2009), which forms part of the El Arraiche mud volcano field on the Moroccan continental margin (Van Rensbergen et al., 2005b) (Fig. 1). Unlike cold-water coral mounds on the margins of the Rockall Trough and in the Porcupine Seabight (Huvenne et al., 2005; Mienis et al., 2006; Van Weering et al., 2003a), mounds in the southern Gulf of Cadiz are at present not covered with a dense live coral cover (Foubert et al., 2008; Wienberg et al., 2009). However, bottom samples showed that during glacial periods a thriving living coral cover was present (Wienberg et al., 2010).

Studies on the hydrodynamic controls in thriving cold-water coral habitats have established that cold-water corals and associated species mainly occur in environments with strong currents often related to internal waves, which prevents living corals from smothering by sediment, but also increase the (food) particle supply (Dorschel et al., 2007; Duineveld et al., 2007; Mienis et al., 2007; White et al., 2005). On elevated structures like ridges and mud volcanoes in the

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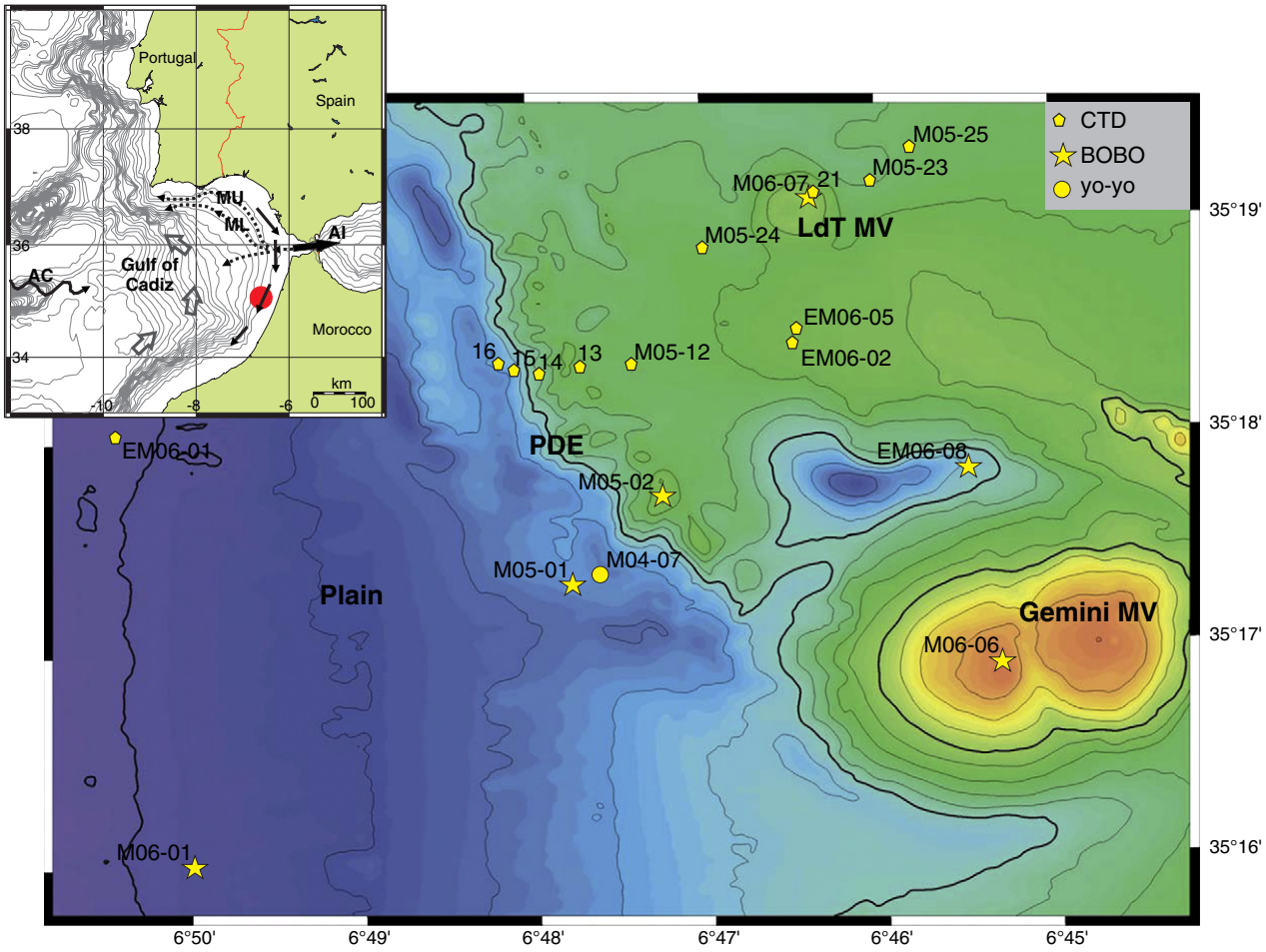

Fig. 1. Multibeam map (contour interval 20 m) of part of the El Arraiche mud volcano field showing the Pen Duick Escarpment, the Lazarillo de Tormes (LdT) and Gemini mud volcano. Mounds covered with fossil cold-water corals are present on the edge of the escarpment and on the edge of the gully of the Gemini mud volcano. BOBO lander positions (stars), CTD casts (polygon) and CTD yo-yo station (circle) are indicated. Inset shows the location of the research area in the Gulf of Cadiz and the general circulation pattern of the Atlantic Inflow (AI), Mediterranean Outflow Water (MU = Mediterranean Upper Water, LW = Mediterranean Lower Water), the Azores Current (AC), NASW/NACW (black arrows) and NADW (block arrows).

Gulf of Cadiz, corals could have benefited from the interaction of the local topography with the hydrography, which accelerates the water flow (Frederiksen et al., 1992; Genin et al., 1986).

Even though the surface water circulation in the southern Gulf of Cadiz forms an important part of the North Atlantic sub-tropical gyre, the region near the Moroccan margin is under-sampled and under-studied with regards to hydrodynamic conditions compared to the northern part of the Gulf of Cadiz. First results on the hydrodynamic conditions have been published by Alves et al. (2011) and Van Rooij et al. (2011). In this study we report results on near-bed hydrodynamic conditions retrieved from benthic landers that were deployed for periods of several days up to a year on the Renard Ridge, on top of the mounds and on the plain below the Pen Duick Escarpment (Fig. 1, Table 1). In addition water column studies were carried out with a CTD to measure the water column structure during cruises with the RV Pelagia in August 2004, May 2005 and October 2006 (Fig. 1). Subsequently, the near bed hydrodynamic conditions on the Moroccan margin are compared with the conditions as found in other mound and reef areas, such as the Irish and Norwegian margin.

1.1. Regional setting

The Gulf of Cadiz is an embayment of the NE Atlantic Ocean, which is bounded to the NE and SE by the coasts of Spain and Morocco, respectively (Fig. 1) (Machín et al., 2006). The Gulf of Cadiz is underlain

Table 1
Overview of BOBO lander deployments.

Station	Location	Latitude	Longitude	Depth	Deployment	Recovery	Days
M04-09	On ridge	35°18.00 ′N	6°47.00 ′W	545	19 Aug. 04	21 Aug. 04	3
M05-01	Plain below PDE	35°17.29 ′N	6°47.79 ′W	641	21 May 05	02 Jun. 05	13
M05-02	On ridge	35°17.69 ′N	6°47.26 ′W	498	21 May 05	01 Jun. 05	12
M05-02	On ridge	35°17.70 ′N	6°47.28 ′W	526	02 Jun. 05	24 Sep. 06	479
M06-01	Plain below PDE	35°16.02 ′N	6°49.99 ′W	685	24 Sep. 06	Drift	4
M06-06	Gemini MV	35°16.89 ′N	6°45.33 ′W	422	06 Oct. 06	24 Oct. 06	18
M06-07	Lazarilo de Tormes MV	35°19.08 ′N	6°46.38 ′W	498	07 Nov. 06	30 Apr. 07	174
EM06-08	Gulley off Gemini	35°18.79 ′N	6°45.50 ′W	608	26 Oct. 06	27 Oct. 06	2
EM06-08	Gulley off Gemini	35°18.79 ′N	6°45.50 ′W	608	28 Oct. 06	05 Nov. 06	8