Deep-Sea Research II 99 (2014) 227–236

Contents lists available at ScienceDirect

Deep-Sea Research II

journal homepage: www.elsevier.com/locate/dsr2

Environmental boundary conditions of cold-water coral mound growth over the last 3 million years in the Porcupine Seabight, Northeast Atlantic

Jacek Raddatz [a,*], Andres Rüggeberg [a,b,c], Volker Liebetrau [a], Anneleen Foubert [a,c,d], Ed C. Hathorne [a], Jan Fietzke [a], Anton Eisenhauer [a], Wolf-Christian Dullo [a]

[a] GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel, Wischhofstr. 1-3, 24148 Kiel, Germany
[b] Renard Centre of Marine Geology, Department of Geology and Soil Sciences, Ghent University, Krijgslaan 281, S8, B-9000 Gent, Belgium
[c] Department of Geosciences, University of Fribourg, Chemin du Musée 6, CH-1700 Fribourg, Switzerland
[d] Department of Earth and Environmental Sciences, KU Leuven, Celestijnenlaan 200 E, B-3001 Leuven, Belgium

ARTICLE INFO

Available online 24 June 2013

Keywords:
Cold-water corals
Challenger Mound
IODP Site 1317
Lophelia pertusa
Mg/Li
Ba/Ca
Mediterranean Outflow Water

ABSTRACT

IODP Expedition 307 made it for the first time possible to investigate the entire body of a cold-water coral carbonate mound. Here we provide new insights into the long-term history of Challenger Mound on the European continental margin off Ireland. This study is based on age determinations (^{230}Th/U, ^{87}Sr/^{86}Sr) and geochemical signals (Mg/Li and Ba/Ca) measured in the scleractinian cold-water coral *Lophelia pertusa* from IODP Site 1317 in the Porcupine Seabight. The paleoceanographic reconstructions reveal that coral growth in the Porcupine Seabight was restricted to specific oceanographic conditions such as enhanced export of primary production and Bottom-Water Temperatures (BWT) between ~8 and 10 °C, related to the water mass stratification of the Mediterranean Outflow Water (MOW) and Eastern North Atlantic Water (ENAW). The geochemical signals from the coral skeletons can be explained by the close interaction between cold-water coral growth, sea-surface productivity and the surrounding water masses – the boundary layer between MOW and ENAW. Enhanced sea-surface productivity and the build-up of a stable water mass stratification between ENAW and MOW caused enhanced nutrient supply at intermediate water depths and facilitated a steady mound growth between ~3.0 and 2.1 Ma. With the decrease in sea-surface productivity and related reduced export productivity the food supply was insufficient for rapid coral mound growth between ~1.7 and 1 Ma. During the late Pleistocene (over the last ~0.5 Myr) mound growth was restricted to interglacial periods. During glacials the water mass boundary between ENAW/MOW probably was below the mound summit and hence food supply was not sufficient for corals to grow.

1. Introduction

1.1. Background

Cold-water coral carbonate mounds are common features in certain parts of the worlds oceans (Roberts et al., 2006). Over the last 20 years these unique ecosystems have attracted increasing interest in their origin, growth and demise. The environmental boundary conditions necessary for their initiation are still debated. The continental slopes along the European margins contain large provinces of cold-water coral mounds and reefs (Freiwald et al., 2004; Roberts et al., 2006). Here mounds are mainly built by the scleractinian cold-water corals *Madrepora oculata* and *Lophelia pertusa*. The appearance and distribution of these heterotrophic and filter-feeding corals is controlled by several parameters. Settlement of coral larvae only occurs on hard substrata preferentially on continental slopes, seamounts or oceanic ridges. These areas are often associated with high sea-surface productivity and enhanced current strength (e.g. Guinotte et al., 2006; White et al., 2005). In particular, *L. pertusa* tolerates a wide range of temperatures (4°–14 °C) and salinities of 32–39, but mostly occurs in salinities between 35 and 37. It appears that the seawater density plays an important role in the distribution of living *Lophelia*-reefs and mounds on the European continental margin. The study of Dullo et al. (2008) highlighted that vivid *Lophelia*-reefs along the SW Irish and Norwegian margin tend to occur within a narrow density envelope between sigma theta (σ_θ)=27.35–27.65 (Dullo et al., 2008). However, this finding appears not to be valid for each

* Corresponding author.
E-mail address: jraddatz@geomar.de (J. Raddatz).

0967-0645/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.dsr2.2013.06.009

Lophelia – reef as exceptions can be found for example in submarine canyons in the Bay of Biscay and in the Mediterranean Sea (e.g Freiwald et al., 2009; Huvenne et al., 2011). Living and fossil reefs occur from northern Norway in the Barents Sea (70°N, Lindberg et al., 2007) to NW Africa off Mauritania (16°N, Colman et al., 2005). On the Norwegian margin large flourishing reefs developed after the retreat of the glaciers at the end of the last glacial, forming the largest known living cold-water coral reefs in the worlds oceans (Freiwald et al., 2004; Fosså et al., 2005). The margin southwest of Ireland represents a major region of abundant cold-water coral carbonate mounds that tend to cluster in provinces (De Mol et al., 2007; Freiwald et al., 2004) and vary in height from a few metres up to > 380 m (Wheeler et al., 2007). Especially, the Porcupine Seabight is characterised by different mound provinces some of which contain over 1000 buried and exposed mounds (Huvenne et al., 2007). The Belgica Mound province is one of five mound provinces (De Mol et al., 2002; Foubert et al., 2005; Wheeler et al., 2011) and the Challenger Mound is one of 66 mounds in the Belgica Mound Province. Here, the coral mounds are elongated, subconical structures and occur at depths between 600 and 1000 m, corresponding to the transition zone of Eastern North Atlantic Water (ENAW) and the underlying Mediterranean Outflow Water (MOW) with temperatures of ~9.5 °C (White, 2007; Fig. 1). Due to the large differences in density between the ambient intermediate water masses a pycnocline forms at around ~800 m (Dickson and McCave, 1986; Dullo et al., 2008; White and Dorschel, 2010). Here, corals benefit from organic matter that settles from the sea surface through vertical migration. The resuspension of organic matter by internal waves might be one reason for a general steady supply of nutrients into the Porcupine Seabight mound regions (White, 2007; Kiriakoulakis et al., 2007). Purser et al. (2010) demonstrated that *L. pertusa* polyps capture more efficiently zooplankton under low flow velocities of about 5 cm s^{-1}. These specific hydrodynamic conditions facilitate dense cold-water coral growth and mound build up SW of Ireland (De Mol et al., 2002; Kano et al., 2007).

1.2. Paleoceanographic reconstruction with scleractinian cold-water corals

Deep-sea or cold-water corals thrive in dark, cold and nutrient rich waters. Similar to their tropical counterparts their skeleton is composed of aragonite and hence can be used as an archive for paleoceanographic reconstructions (e.g. Adkins et al., 1998). Recent developments highlighted the use of Mg/Li (Li/Mg) and Li/Ca ratios in scleractinian corals as a proxy for temperature (Case et al., 2010; Hathorne et al. 2013). In this study we use the Mg/Li

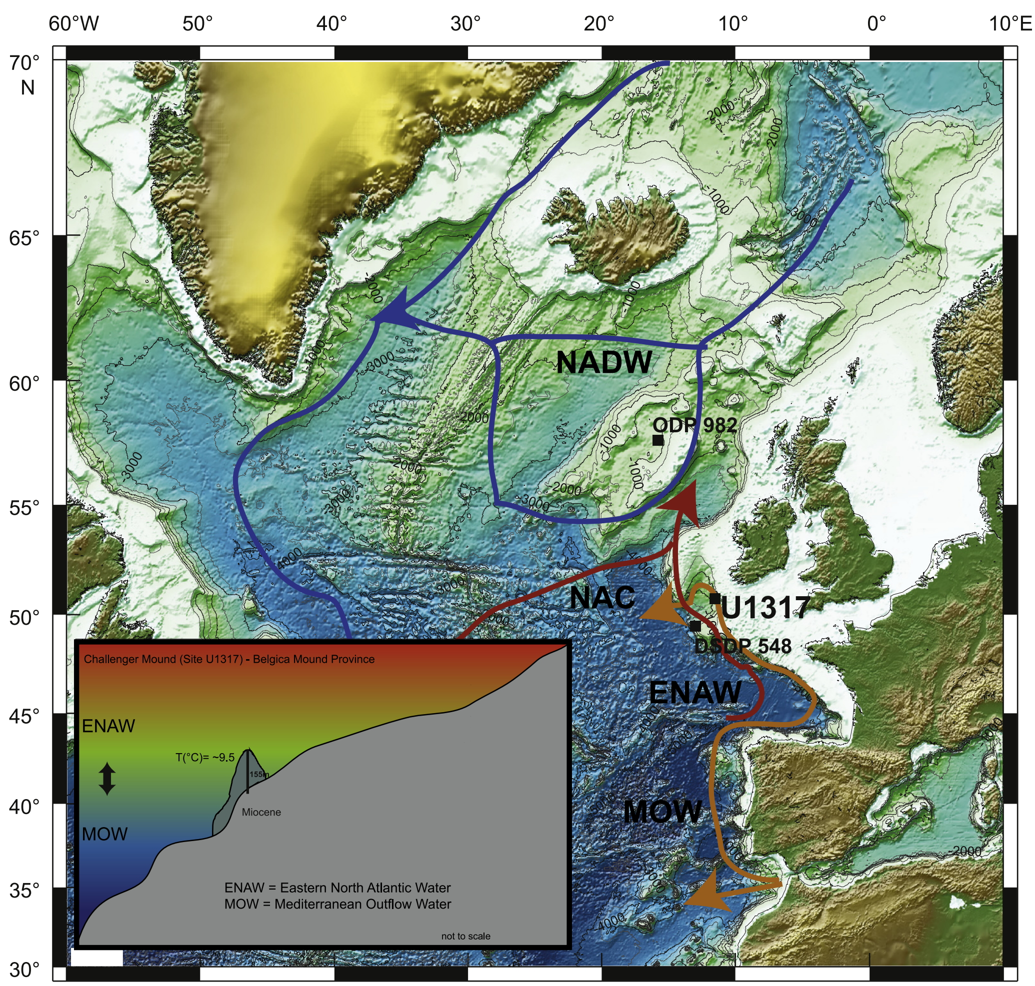

Fig. 1. Map showing the North Atlantic with the core location IODP Site 1317 in the Porcupine Seabight. Also shown are the Sites DSDP 548 and ODP 982. The orange arrow indicates the flow of the Mediterranean Outflow Water (MOW), the red arrow of the Eastern North Atlantic Water (ENAW) and the North Atlantic Current (NAC) and the blue arrow the North Atlantic Deep Water (NADW). The small figure shows a schematic sketch of the seismic profile of the Challenger Mound on the slope of the Porcupine Seabight and the corresponding intermediate water masses (MOW and ENAW) with the modern annual mean Bottom-Water-Temperature of 9.5 °C (White, 2007). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)