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Glacial cold-water coral growth in the Gulf of Cádiz: Implications of increased palaeo-productivity

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ABSTRACT

A set of 40 Uranium-series datings obtained on the reef-forming scleractinian cold-water corals *Lophelia pertusa* and *Madrepora oculata* revealed that during the past 400 kyr their occurrence in the Gulf of Cádiz (GoC) was almost exclusively restricted to glacial periods. This result strengthens the outcomes of former studies that coral growth in the temperate NE Atlantic encompassing the French, Iberian and Moroccan margins dominated during glacial periods, whereas in the higher latitudes (Irish and Norwegian margins) extended coral growth prevailed during interglacial periods. Thus it appears that the biogeographical limits for sustained cold-water coral growth along the NE Atlantic margin are strongly related to climate change. By focussing on the last glacial–interglacial cycle, this study shows that palaeo-productivity was increased during the last glacial. This was likely driven by the fertilisation effect of an increased input of aeolian dust and locally intensified upwelling. After the Younger Dryas cold event, the input of aeolian dust and productivity significantly decreased concurrent with an increase in water temperatures in the GoC. This primarily resulted in reduced food availability and caused a widespread demise of the formerly thriving coral ecosystems. Moreover, these climate induced changes most likely caused a latitudinal shift of areas with optimum coral growth conditions towards the northern NE Atlantic where more suitable environmental conditions established with the onset of the Holocene.

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1. Introduction

Along the NE Atlantic margin cold-water corals occur in a belt that extends from northern Norway (Barents Sea, 70°N; Lindberg et al., 2007) down to NW Africa (off Mauritania, 16°N; Colman et al., 2005). These ecosystems vary strongly with respect to their appearance, structure and coral vitality. Large flourishing *Lophelia*-reefs occur along the Norwegian margin. With a horizontal dimension of several hundred meters to kilometres they developed to the largest known living cold-water coral reefs worldwide (Fosså et al., 2005). Along the Irish margin cold-water corals are associated with coral mounds that vary in height from a few metres up to >380 m being often densely covered by living coral colonies (Wheeler et al., 2007, and refs. therein). Further to the south, cold-water corals mainly occur as isolated colonies or accumulations of fossil corals in the Bay of Biscay (Reveillaud et al., 2008), on seamounts (Duineveld et al., 2004) and within canyons along the Iberian margin (Tyler et al., 2009), and on coral mounds along the NW African margin (Wienberg et al., 2009).

Along with the geographic distribution, a distinct stratigraphic pattern regarding the development of cold-water coral ecosystems along the NE Atlantic margin has been observed during the last glacial–interglacial cycle. Reefs of Holocene age on the Norwegian shelf started to develop after the retreat of glaciers at the termination of the last glacial (Freiwald et al., 2004). The Irish coral mounds seem to be restricted to interglacials with a very few exceptions (Dorschel et al., 2005; Eisele et al., 2008) and the latest re-establishment of cold-water coral ecosystems appears to have been started after the Younger Dryas (YD) cold reversal (Frank et al., 2009). To the south along the French, Iberian and Moroccan margins, corals are suggested to have been widely distributed during the last glacial (Schröder-Ritzrau et al., 2005; Wienberg et al., 2009). In actual fact, although the Gulf of Cádiz (GoC) was recently identified to be an important cold-water coral site in the temperate NE Atlantic, this area is at present mainly characterised by so-called 'coral graveyards' with only very few living corals (Foubert et al., 2008; Wienberg et al., 2009). Such current depauperation of live coral ecosystems might be explained by the recent warm and oligotrophic

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conditions in the GoC forcing reduced food availability (Wienberg et al., 2009). In addition, tidal currents and internal waves that have been identified to be important hydrodynamic processes for supplying food particles to and through the coral thickets (White et al., 2005, 2007) nowadays do not seem to play a major role in the GoC (Wienberg et al., 2009). However, the widespread occurrence of fossil corals suggests more favourable oceanographic conditions in the past. Indeed, initial datings revealed that cold-water corals have been common in the GoC during the last glacial (Wienberg et al., 2009).

The present study aims to refine and extend this observed stratigraphic pattern of coral occurrence along the NE Atlantic margin by 40 Uranium-series datings of reef-forming scleractinian cold-water corals from sediment cores retrieved in various areas of the GoC. Moreover, it is intended to relate the prosperity and/or demise of cold-water corals in the GoC to a distinct environmental and oceanographic setting that altered along with climate change. Thus, we aim to identify the main forcing factors triggering the development of cold-water coral ecosystems in the GoC.

2. Regional setting

The GoC is situated west of the Strait of Gibraltar, and thus connects the open North Atlantic Ocean and the Mediterranean Sea (Fig. 1). It is bordered by the Iberian Peninsula and the NW African coasts and extends from Cape St. Vincent at the southwestern tip of Portugal down to the Moroccan Atlantic margin at 33°N (Mauritzen et al., 2001). The Iberian continental shelf widens from ~15 km west of Faro to ~50 km further to the east (Garcia-Lafuente and Ruiz, 2007), which is similar to the width of the Moroccan shelf (<60 km; Mittelstaedt, 1991).

The deeper basin of the GoC is characterised by a widespread occurrence of diapiric ridges and mud volcanoes (Somoza et al., 2003). Many of these mud volcanoes were identified to be covered by fossil cold-water corals (Somoza et al., 2003; Wienberg et al., 2009). Further conspicuous topographic features in the GoC are hundreds of coral mounds that are 20–30 m in height, and 50–200 m in length, and that are covered by fossil corals. They are restricted to the Moroccan

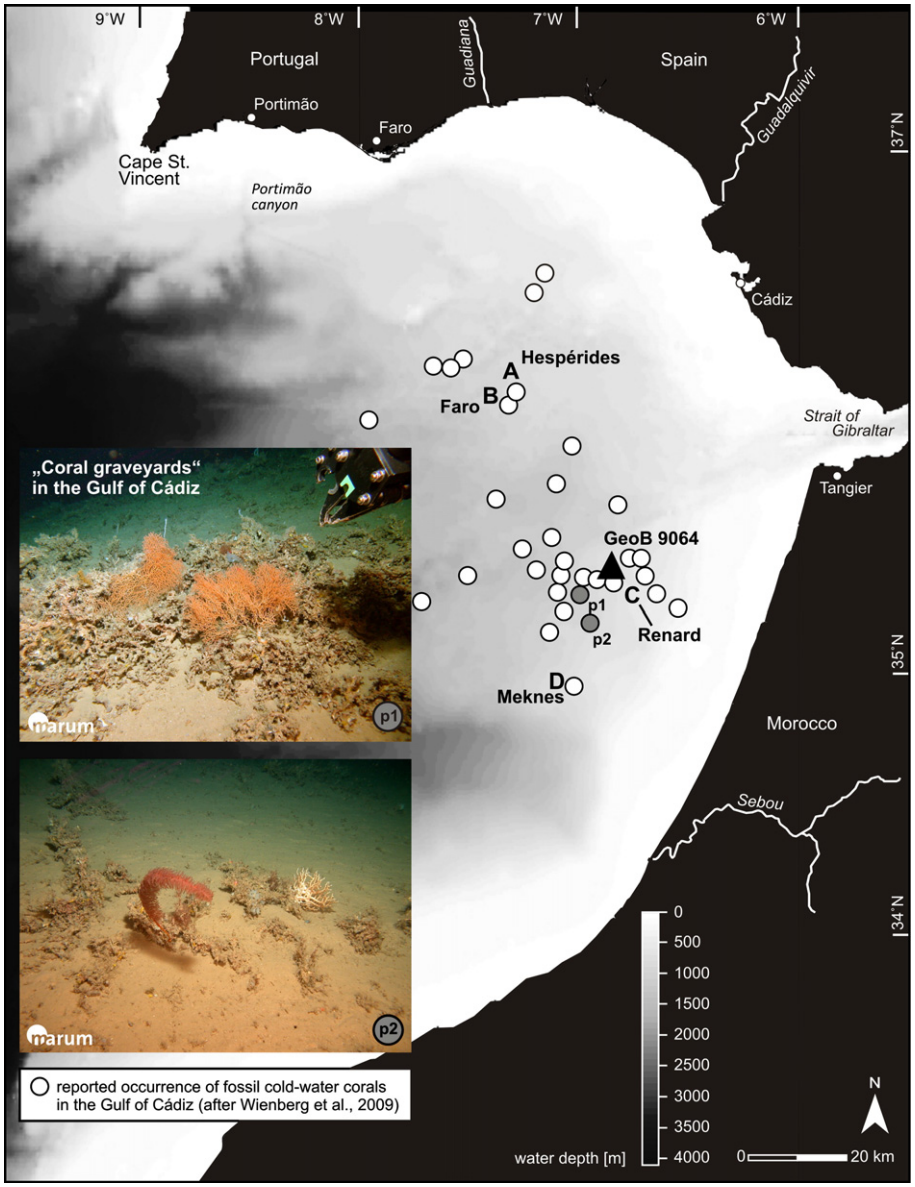

Fig. 1. Map of the Gulf of Cádiz (GoC) showing the coring sites (bathymetric data source: GEBCO). Reference sediment core GeoB 9064 (black triangle) and coral-bearing sediment cores (A–D). A: Hespérides mud volcano (GeoB 9018), B: Faro mud volcano (GeoB 9031, GeoB 9032), C: Renard Ridge (GeoB 9070, GeoB 12101, GeoB 12102, GeoB 12103, GeoB 12104, M2004-02), D: north of Meknes mud volcano (GeoB 12106). Indicated are the reported occurrences of fossil cold-water corals (after Wienberg et al., 2009). Lower left: photographs showing characteristic 'coral graveyards' in the southern GoC, Moroccan margin (position is indicated on the map as p1, p2) (images ©MARUM, Bremen).

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