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Sedimentation patterns on a cold-water coral mound off Mauritania

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ABSTRACT

An unconformity-bound glacial sequence (135 cm thick) of a coral-bearing sediment core collected from the flank of a cold-water coral mound in the Banda Mound Province off Mauritania was analysed. In order to study the relation between coral framework growth and its filling by hemipelagic sediments, U-series dates obtained from the cold-water coral species *Lophelia pertusa* were compared to ^{14}C dates of planktonic foraminifera of the surrounding matrix sediments. The coral ages, ranging from 45.1 to 32.3 ka BP, exhibit no clear depositional trend, while on the other hand the ^{14}C dates of the matrix sediment provide ages within a much narrower time window of <3000 yrs (34.6–31.8 cal ka BP), corresponding to the latest phase of the coral growth period. In addition, high-resolution computer tomography data revealed a subdivision of the investigated sediment package into three distinct parts, defined by the portion and fragmentation of corals and associated macrofauna as well as in the density of the matrix sediments. Grain size spectra obtained on the matrix sediments show a homogeneous pattern throughout the core sediment package, with minor variations. These features are interpreted as indicators of redeposition. Based on the observed structures and the dating results, the sediments were interpreted as deposits of a mass wasting event, namely a debris flow. During this event, the sediment unit must have been entirely mixed; resulting in averaging of the foraminifera ages from the whole unit and giving randomly distributed coral ages. In this context, for the first time mass wasting is proposed to be a substantial process of mound progradation by exporting material from the mound top to the flanks. Hence, it may not only be an erosional feature but also widening the base of the mound, thus allowing further vertical mound growth.

1. Introduction

Large seabed structures build up and stabilised by cold-water corals are known from all over the Atlantic Ocean margins (Freiwald et al., 2004; Roberts et al., 2009). The most prominent representatives in the NE-Atlantic are the large reefs bodies of e.g. the Røst Reef off Norway with a lateral extension of 35 km (Fosså et al., 2005) or the giant cold-water coral mounds (in the following referred to as coral mounds) off Ireland, reaching several 100 m in height and several kilometres of lateral extension (Mienis et al., 2007). In the warm-temperate NE-Atlantic large coral mounds have been reported from the Mauritanian slope (Colman et al., 2005; Eisele et al., 2011).

Coral mounds are composed of loosely arranged coral fragments, embedded in a fine sediment matrix of hemipelagic origin and bioerosional detritus of corals and associated benthic fauna (De Mol et al., 2002; Mienis et al., 2009; Titschack et al., 2009). A well-balanced interplay of the growth of a coral framework and the sedimentation of a fine-grained matrix, stabilising each other enables the coral structure to outpace sedimentation on the adjacent seafloor, resulting in the formation of a mound structure (Foubert et al., 2011; Huvenne et al., 2009). The growth of a coral thicket requires a hard substrate, certain physical and chemical boundary conditions (Davies et al., 2010; Dullo et al., 2008; Roberts et al., 2003), sufficient food supply and strong currents (Frederiksen et al., 1992; Messing et al., 1990; White, 2007). Matrix sedimentation in turn needs sufficient sediment supply, both from the water column and from the coral ecosystem, and a weak

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current regime allowing the sediment particles to settle from the water column (Huvenne et al., 2009). The contrasting current regimes for coral growth and matrix sedimentation are induced by the mound structure, itself. Coral mounds act as an obstacle on the seafloor and thus cause enhanced current speeds around the mound structure (De Mol et al., 2005), whereas inside the coral framework a rather low energetic microenvironment prevails (Dorschel et al., 2005), which allows the deposition of significantly finer sediments compared to the "normal" background sedimentation (Mullins et al., 1981). However, the temporal relation of coral growth and matrix sedimentation (i.e. contemporaneous vs. sedimentation following coral growth with some temporal offset) is still poorly constrained (e.g. Dorschel et al., 2005).

Former studies focusing on the glacial-interglacial development of coral mounds imply that late Pleistocene to Holocene mound formation has been discontinuous, albeit temporally shifted and underlying different environmental controls. The Irish coral mounds in the cold-temperate NE-Atlantic are predominately growing during interglacials (Dorschel et al., 2005; Eisele et al., 2008; Frank et al., 2009, 2011; Rüggeberg et al., 2007) most likely favoured by a vigorous current regime that is delivering sufficient food to the corals (Frederiksen et al., 1992; Messing et al., 1990; White, 2007). Coral growth in the warm-temperate NE Atlantic off Morocco and Mauritania is restricted to glacials, when primary productivity was strongly enhanced, increasing the availability of food (Eisele et al., 2011; Frank et al., 2011; Wienberg et al., 2010). Regardless of the main controlling factors, mound formation is closely coupled to the presence of a coral framework.

According to De Mol et al. (2005), coral mounds form when scattered coral patches merge to larger structures. Once the mound structure reaches a certain elevation above the seafloor, it acts as an obstacle enhancing and redirecting currents. This setting leads to a positive feedback as the enhanced current speeds increase the food supply, and thus stimulate further coral growth. In addition, the currents deliver enhanced sediment loads which are actively baffled by the coral framework, and thus, support further mound aggradation (Dorschel et al., 2005). Consequently, the shape of a mound is directly coupled to the modifications it exerts on the current system. Moats are being formed around the mound bases and the mound structures themselves are stretched or arranged in elongated clusters as the corals grow along the main direction of the currents and fine grained material is preferentially deposited on the lee-side of the mounds (Van Rooij et al., 2003; van Weering et al., 2003; Wheeler et al., 2005).

During the past two decades, several models of mound formation have been introduced, particularly concentrating on vertical mound aggradation (e.g. de Haas et al., 2009; De Mol et al., 2005; Dorschel et al., 2005; Eisele et al., 2008; Henriet et al., 2002). A first generalised model of coral mound formation introduced by Henriet et al. (2002) hypothesised initial mound formation to be linked to hydrocarbon seepage. However, sediments from the base of an Irish coral mound (Challenger Mound) drilled during IODP leg 307, did not reveal evidence for such a linkage, but showed that the mound base is situated on an erosional unconformity (Expedition Scientists, 2005). Subsequent models suggest external forcing (i.e. currents, food supply) to favour mound formation (de Haas et al., 2009; De Mol et al., 2005; Dorschel et al., 2005; Huvenne et al., 2009). Frequently observed hiatuses in mound records only have been considered in terms of (negatively) affecting vertical mound growth without any discussion about the fate of the removed sediment (e.g., de Haas et al., 2009; Dorschel et al., 2005; Eisele et al., 2008). Thus, all the mound formation models focus on vertical coral mound growth – the mound aggradation – while the lateral expansion of mounds – the mound progradation – is so far largely disregarded.

The present study aims for the first time to examine the export of material from the mounds summit to its flanks as process of coral mound progradation. Furthermore, small-scale mound aggradation processes are addressed by reconstructing the chronological order of coral growth and matrix sedimentation within the coral framework. This study will contribute to the understanding of both the small-scale interplay of the accumulation of coral framework and the deposition of matrix sediments, and the mound-wide sedimentation dynamics.

2. Regional setting

The Banda Mound Province is situated on the continental slope off southern Mauritania between 450 and 550 m water depth. Multibeam and ROV surveys showed that the Banda Mound Province is part of a 200 km long, slope-parallel chain of coral mounds (Colman et al., 2005). The mounds grow from north of the Timiris Canyon System (Krastel et al., 2004) along the undisturbed central Mauritanian slope and on the uppermost edge of the Mauritania Slide Complex (Wien et al., 2007) in the south (Fig. 1). Standing alone, arranged in (elongated) clusters or merged to highly complex composite structures, they reach heights of up to 100 m with a diameter of ~500 m at the foot of the mounds (Fig. 1).

At present, bottom currents appear to be low in the mound province. Current speeds measured in off-mound sites varied between 8.2 and 10 cm s^{-1} and video surveys did not show any current induced bedforms (Colman et al., 2005). Solely the slope-parallel elongated shapes of some mounds and mound clusters indicate that currents may have been stronger in the past.

3. Materials and methods

3.1. Sample material

All analyses presented in this study were conducted on a coral-bearing sediment core (GeoB 11569-2) which was collected during R/V Poseidon cruise POS346 from a coral mound along the southern Mauritanian margin (Fig. 1; Westphal et al., 2007). The coral mound belongs to the Banda Mound Province and has a NW-SE-elongated shape with two spurs directed downslope (SW). The mound has a height of ~100 m ranging from 430 to 520–530 m water depth (see Fig. 1). Sediment core GeoB 11569-2 was retrieved from the mound's northern flank (17°40′N, 16°40.3′W) at a water depth of ~470 m (see Fig. 1), and has a total recovery of 509 cm. The core is composed of a sediment matrix of dark grey fine sand interspersed with fragments of the scleractinian cold-water coral species *Lophelia pertusa* and shells of associated fauna.

This core was already subject of two earlier studies dealing with U-series ages obtained on *Lophelia* fragments collected at various core depths (Table 1; Douville et al., 2010; Eisele et al., 2011). The coral ages of this core display three distinct periods of sustained coral growth during the last glacial, which coincide with periods of increased productivity in the region (Eisele et al., 2011). This study focuses on a 135-cm-thick sediment unit of this core, which is delimited by two erosive interfaces marking major hiatuses at 35 and 170 cm core depth (Fig. 2). Eight *Lophelia* fragments from this unit have been dated revealing U-Th ages ranging from 45.1 to 32.3 ka BP (Eisele et al., 2011; Table 2).

3.2. ^{14}C dating

Nine multi-species samples of planktonic foraminifera were sampled for ^{14}C dating from the matrix sediments (Table 2). AMS ^{14}C analyses were conducted at LMC14/CEA-CNRS in Gif-sur-Yvette/France and at NOSAMS in Woods Hole/Massachusetts, with the results from both institutions showing good coherence. Each age was calibrated with the Calib 6.0 software