Marine Geology xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Marine Geology

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

Carbonate mounds in the Santaren Channel, Bahamas: A current-dominated periplatform depositional regime

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ARTICLE INFO

Article history:
Received 21 September 2015
Received in revised form 24 February 2016
Accepted 15 March 2016
Available online xxxx

Keywords:
Carbonate mound
Cold-water corals
Drift sedimentation
Bottom current
Carbonate platform
Great Bahama Bank
Oceanographic setting

ABSTRACT

New hydroacoustic data, high resolution multichannel seismic reflection data, CTD casts and sampling document the dominance of bottom currents and the occurrence of carbonate mounds in the Santaren Channel off Great Bahama Bank and Cay Sal Bank. Based on these data sets, three types of carbonate mounds have been identified in water depths between 285 and 685 m. Their distribution is strongly related to the present current regime. Bank-driven sediments are caught up by the currents and redeposited mainly in the channel center, resulting in the accumulation of giant confined drifts flanked by moats. The moats at the banks toe-of-slope are formed by a southward and northward flowing water mass, respectively, mainly Antarctic Intermediate Water and Subtropical Underwater. The observed carbonate mounds are concentrated in these moats. Mound type 1 has an elongated shape parallel to the prevailing bottom current direction, a gently inclined flank facing the water flow and a steep flank in its current shadow. Its upstream flank is covered by a thin sediment wedge whereas the lee side is marked by a parabolic scour. Type 1 occurs at both bank margins but mainly off Great Bahama Bank, consisting of cold-water coral rubble floating in a sediment matrix and is, thus, interpreted as cold-water coral mound. By contrast, type 2 mounds are restricted to the Cay Sal margin and have a predominately conical outline. Bottom samples including living sessile crinoids show that its surface must be lithified and colonized by macroepibenthos, except corals. The mounds are situated in pockmark-like depressions that are underlain by fluid escape structures like pipes and chimneys. These fluid pathways are generated by a network of fractures. Mound type 2 is probably formed by abiotic carbonate precipitation; however, a chemoherm nature cannot be ruled out. Mound type 3 has a conical to polygonal shape and occurs off Cay Sal Bank and Great Bahama Bank. It is surrounded by a scour which is elongated in downcurrent and crescent in upcurrent direction. A sediment bulge formed at its front. This type is consistent with blocks and boulders colonized by macroepibenthos and related to gravity-controlled mass movements at the steep bank slopes.

Principally, two habitats can be distinguished: the Great Bahama Bank periplatform deep-water province dominated by mound type 1 and the Cay Sal Bank slope to basin province occupied by mound type 2 that is associated with pockmark-like structures. Mound type 3 occurs in both habitats. Physical water mass properties for the existence of cold-water corals are limited to a depth range of ca. 430 to 685 m, with seawater densities (σ-θ) of 26.93 to 27.29 kg/m and temperatures below 13 °C. Their dominance off Great Bahama Bank might be addressed to a more effective food supply induced by local downwelling.

1. Introduction

Carbonate mounds are widely reported throughout the Caribbean, especially for the Straits of Florida (e.g. Neumann and Ball, 1970; Neumann et al., 1977; Reed, 1980; Mullins et al., 1981; Paull et al., 2000; Grasmueck et al., 2006; Reed et al., 2006; Correa et al., 2012b; Hebbeln et al., 2014). They occur in water depths between 260 m and 1300 m and are predominantly built by cold-water corals. Preferably their summits are colonized by living corals. The Straits of Florida is a diverse cold-water coral province because the Florida Current and the benthic counter currents and internal tides provide a variable current regime that delivers food to these deep-water ecosystems (e.g., Neumann and Ball, 1970; Grasmueck et al., 2006; Correa et al., 2012b). As a result, the morphology of the coral mounds varies widely in the Straits of Florida. For example, coral made bioherms situated at the slope below the Miami Terrace form a series of up to 20 m high elongated and asymmetric ridges that have a steeper side towards the prevailing current (Correa et al., 2012a). In contrast, along the western toe-of-slope of Great Bahama Bank (GBB) mound morphology in generally shows no correlation with the prevailing bottom current direction (Correa et al., 2012b). All

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http://dx.doi.org/10.1016/j.margeo.2016.03.013
0025-3227/© 2016 Published by Elsevier B.V.

mounds or mound ridges in common are a framework of coral rubble and unconsolidated sediments (Mullins et al., 1981; Correa et al., 2012a, 2012b). Another type of topographic highs in the Straits of Florida is blocks and boulders that are associated with large slope failures, covered by corals (Correa et al., 2012b; Reed et al., 2006; Principaud et al., 2015). A third type of carbonate mound, named lithoherm, was reported by Neumann et al. (1977); Mullins et al. (1981); Messing et al. (1990); Paull et al. (2000) and Reed (2002) along the slopes of Little Bahama Bank. The lithoherm has a teardrop-shape and is aligned parallel to the Florida Current. It is characterized by lithified carbonate limestone around its summit and poorly cemented flanks. It exhibits a faunal zonation with crinoids populating the flanks and downcurrent crests, whereas corals are found near the upcurrent end and zoanthids on the top. Recently Correa et al. (2012b) reported that many of the lithoherms are not cemented but instead consist of soft sediment trapped between coral frameworks.

The boundary conditions for scleractinian cold-water corals depend on different environmental factors like a suitable settling substrate, higher current speeds, favorable food supply and gradients in sea water density (e.g. Roberts et al., 2006; Flögel et al., 2014; Naumann et al., 2014; and references herein). Additionally, biogeochemical parameters such as e.g. aragonite and dissolved inorganic carbon concentration, total alkalinity and pCO_2 can play an important role (Flögel et al., 2014). In the framework of the Meteor cruise M95 in 2013, several new carbonate mound sites were discovered in the NNW-SSE striking Santaren Channel, which connects the Nicholas and Old Bahamas Channel with the Straits of Florida between Cay Sal Bank (CSB) and GBB. By the means of multichannel seismic, Parasound, multibeam, ADCP and CTD data as well as surface samples this study shed new light on the interplay of the factors controlling the habitat of these bioherms (Fig. 1).

Habitats of relatively strong bottom currents and sufficient food supply are typical for biogenic carbonate mounds. The Great Bahama Carbonate Platform bathed by the waters of the Gulf Stream system provides an ideal environment for the survival of epibenthic mound communities. The significance of the prevailing bottom current regime has long been overlooked in carbonate platform development. The same applies to Great Bahama Carbonate Platform that serves as a key area for tropical carbonate sequence stratigraphy, ground-truthed by five wells on the slope and in the basin by the Ocean Drilling Program Leg 166 (Eberli et al., 1997). The sequence stratigraphic model describes its geometry and depositional setting as a response to relative sea-level changes (e.g. Catuneanu et al., 2011). However, recent studies show that slope and basin floor sedimentation is controlled by bottom currents (Anselmetti et al., 2000; Betzler et al., 2014). Comparable results have been reported for the Maldives, Marion Plateau and Mallorca slope, where over long time periods sea-level fluctuations play only a minor rule in platform development (Eberli et al., 2010; Lüdmann et al., 2012, 2013; Betzler et al., 2013). For a better understanding of the hydrodynamic regime that shapes platform architecture and mound geometries new high-resolution reflection seismic, hydroacoustic and oceanographic data were collected. In this manuscript, we are focusing on the present depositional environment.

2. Regional setting

The study area lies north of Cuba and east of US Florida in the Bahamian archipelago comprising several isolated shallow water carbonate platforms (Fig. 1). The largest platforms are GBB, Little Bahama Bank and CSB. They are separated by seaways likewise the Old Bahamas Channel, Nicholas Channel, the Straits of Florida, the Santaren Channel and Northwest Providence Channel. The Santaren Channel has a sill depth of approx. 530 m and a mean width of approx. 65 km. The channels represent major conduits for the Gulf Stream that consists of water arriving via the Caribbean/Gulf of Mexico. These deep-water areas are demarcated from the shallow-water platforms by steeply dipping slopes. Due to the prevailing southeasterly winds, slope gradients are generally higher on the eastern (windward) side, and lower on the

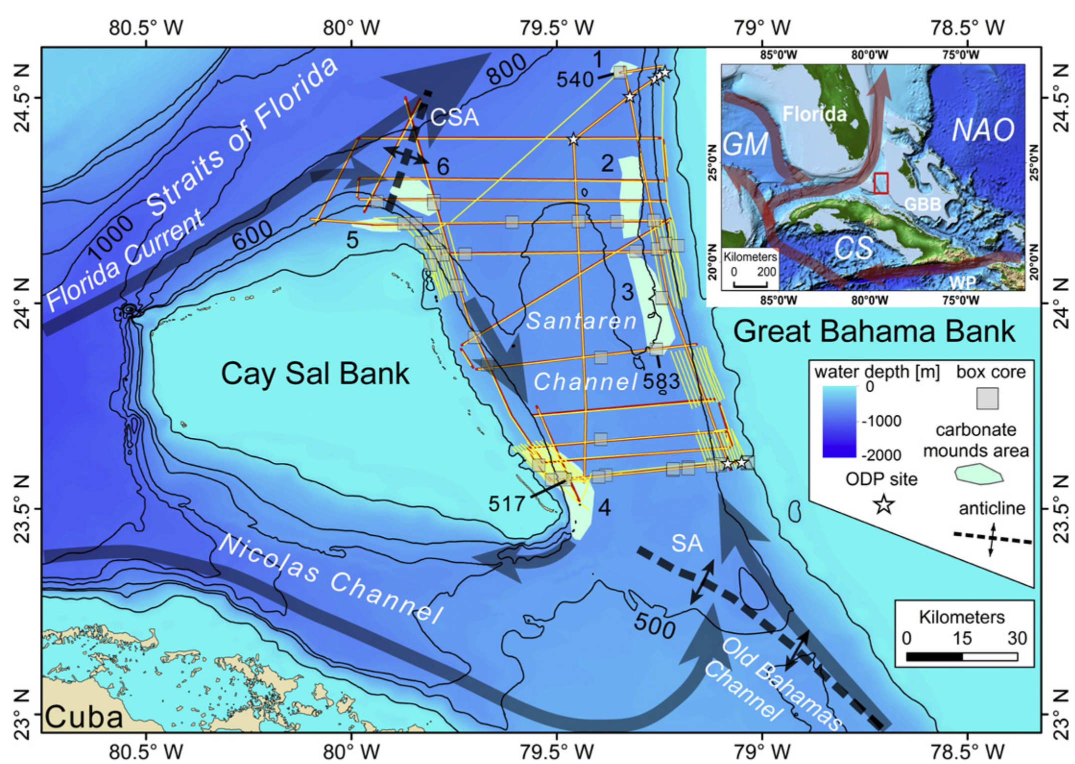

Fig. 1. Geographical map of the study area in the Santaren Channel. ETOPO bathymetry with isobaths in meter. Red lines: MCS; yellow lines: MBES and Parasound; white stars: ODP sites leg 166; gray boxes: box grab stations; 1–6: carbonate mound areas; gray arrows: bottom water flow; CSA: Cay Sal Anticline; SA: Santaren Anticline; dashed black lines: fold axes. Inset: regional overview; GM: Gulf of Mexico; NAO: North Atlantic Ocean; CS: Caribbean Sea; GBB: Great Bahama Bank; WP: Windward Passage (Greater Antilles); red arrows: Gulf Stream system with Loop (GM) and Florida Current; red rectangle: study area.

Please cite this article as: Lüdmann, T., et al., Carbonate mounds in the Santaren Channel, Bahamas: A current-dominated periplatform depositional regime, Marine Geology (2016), http://dx.doi.org/10.1016/j.margeo.2016.03.013