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Editorial

Carbonate slopes and gravity deposits

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ABSTRACT

In this special volume a series of papers are presented that concentrate on sedimentation patterns observed on the slopes and within the basins surrounding shallow-water carbonate depositional systems. Four papers discuss depositional patterns on the slope to basin transect of the Cainozoic sedimentary system of the Bahamas; four other papers examine gravity deposits of Jurassic and Cretaceous carbonate depositional systems.

1. Introduction

Re-sedimented deposits on carbonate slopes and adjacent basins have recently gained renewed interest because they represent a substantial part of the sediment volume deposited along carbonate platforms. The main reasons for this are probably the increased focus on new industrial targets, particularly for the oil and gas industry and the academic interest to integrate these deposits in global and local models of carbonate depositional systems. However, compared to their equivalents along siliciclastic margins carbonate slope deposits remain less understood and do need further research, especially because they are the product of complex interacting processes that control carbonate systems such as: the carbonate production depending on the carbonate factories, the geodynamic and oceanographic evolution and climatic and eustatic changes.

For almost 50 years, numerous data on carbonate platform to basin sedimentation patterns were collected with a large focus on the modern and ancient Bahamian sedimentary system and various outcrop examples on the Tethyan margins. However, with the improvement of offshore geo-data acquisition and outcrop geo-modelling techniques new discoveries are still being made, especially in 3D, that call for the re-evaluation of depositional processes shaping the slopes and basinal deposits of carbonate depositional systems. In this volume a series of four papers concentrates on the offshore theme using Cainozoic examples. The volume is completed by four studies on gravity deposits of various Mesozoic depositional systems.

2. Bahamian carbonate platform systems and slopes

Read (1985) extensively described various models of slope systems within ramp-type, shelf and rimmed flat-topped carbonate platform sedimentary bodies. Various facies models associated with these concepts were also highlighted in Read's study. Carbonate ramp systems show a maximum slope declivity of 1° by definition, but in the literature angles of up to 5° are commonly accepted as general angles of repose in carbonate ramp systems. The transition through rimmed flat-topped carbonate systems to distally steepened ramps and carbonate shelves shows many variations (Read, 1985). Rimmed flat-topped carbonate platforms, like Great Bahama Bank, show a fairly protected shallow (present-day water depth < 10 m) inner platform environment with depositional environments dominated by muds to coarse-grained sands (Enos, 1974; Reijmer et al., 2009; Swart et al., 2009; Kaczmarek et al., 2010; Harris et al., 2014). On the Bahamas, the inner platform areas are, at many places, protected from the open ocean high-energy waves by an elevated topography (barrier) marking the transition to the slope. The barrier may consist of reefs made up of lithified frame-building organisms, sand shoals, including ooid sand bars (Harris, 1979; Rankey and Reeder, 2011) or islands. This consolidated carbonate margin can be a source of lithified blocks avalanching on the barrier-toe and further along the steepened slope (Crevello and Schlager, 1980; Mullins and Hine, 1989; see Reijmer et al., this volume). The latest studies describing the facies patterns on the rimmed flat topped carbonate platform of the Bahamas are given by Harris et al. (2014) for Great-

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and Little Bahama Bank, by Purkis et al. (2014) for Cay Sal Bank and by Rankey et al. (2009) for Caicos Island.

3. Bahamian slope morphology

The platform margin to upper slope transition on the Bahamian platform is marked by a sharp shift from a sub-horizontal shallow-water topography to a steeply inclined upper slope realm with angles up to 90° (Wilber et al., 1990). Schlager and Ginsburg (1981) noted that the slope morphology varied when comparing windward and leeward slopes and showed that the platform morphology had changed through time. A series of studies showed that the uppermost slope shows inclinations of 3° to 10° for both Little Bahama Bank (Mullins and Neumann, 1979; Harwood and Towers, 1988; Rankey and Doolittle, 2012; Fig. 1) and Great Bahama Bank (Wilber et al., 1990; Grammer et al., 1993; Ginsburg, 2001). These bank edge depositional realms pass over a relative short distance, 500–600 m on the western Great Bahama Bank (Wilber et al., 1990) to over 1 km on the northern Little Bahama Bank (Rankey and Doolittle, 2012), to steeply inclined slopes with small terraces and small 1–5 m high vertical steps with angles of up to 90° (Wilber et al., 1990). This transition occurs at water depths of around 50 to 70 m. The almost vertical slopes reach down to 120 m at Tongue of the Ocean (Grammer et al., 1993), 160 m at the western Great Bahama Bank (Betzler et al., 2014), and 200 m at the northern Little Bahama Bank (Rankey and Doolittle, 2012), thus producing 50–150 m high submarine vertical carbonate cliffs.

The next part of the slopes surrounding Tongue of the Ocean, at a water depth from 150 to 200 m, shows a change to partly cemented sediments (Grammer et al., 1999) with slope angles ranging between 35° and 45° (Schlager and Chermak, 1979; Grammer et al., 1993). At 250 m water depth the slope angle changes to 25° to 30° with ridges and gullies dissecting an unconsolidated sediment wedge that onlaps the steeper slopes.

The transition from the steep cliff to the next part of the slope on the western margin of Great Bahama Bank is marked by an erosional trough (Wilber et al., 1990) or slope parallel depression (Betzler et al., 2014). The slope flattens basinwards from slope angles of around 8° at 160 m water depth to 2° at 300 m water depth (Betzler et al., 2014), which is related to the mud content of the Holocene sediment wedge (Wilber et al., 1990; Eberli et al., 1997; Rendle and Reijmer, 2002; Roth and Reijmer, 2004, 2005; Mulder et al., 2012a, 2012b) onlapping the cemented pre-Holocene slope (Grammer et al., 1999).

Peri-platform drifts resulting from the interplay of contour currents and off-bank transport through density cascading mark the western leeward flank of Great Bahama Bank (Betzler et al., 2014). The transition between the cemented upper slope and less consolidated sediments in deeper water seems to represent an important geomechanical limit for sediment stability and a source area for mass failure processes (Betzler et al., 2014: see Jo et al., this volume; Principaud et al., this volume; Tournadour et al., this volume). The transition to the basin is marked by erosional features resulting from bottom currents flowing at the toe-of-slope to basin transition (Rendle et al., 2000; Bergman, 2005). Parts of the toe-of-slope sedimentation realms in the Santaren Channel show cold-water coral colonies positioned on slope derived mass transport complexes (Correa et al., 2012a,b; Hebbeln et al., 2012; Mulder et al., 2012a).

Large-scale drift deposits characterize the basin infill of the western and northern deep-water channels surrounding the Bahamas (Mullins et al., 1980; Bergman, 2005). According to the classification of Faugères et al. (1999) the sediments correspond to separated drifts when a moat exists (e.g., Santaren drift along the Great Bahama Bank; Principaud et al., this volume), plastered drifts when the current velocity is low (e.g., western part of the Little Bahama Bank; Tournadour et al., this volume), or detached drifts when two currents with different directions merge, like the Antilles current and the Florida current forming the Great Bahama Bank drift in the westernmost part of the Little Bahama Bank and the northernmost part of the Great Bahama Bank (Bergman, 2005).

The inner platform channels, Tongue of the Ocean and Exuma Sound, show slope apron fans at the toe-of-slope (Schlager and Chermak, 1979; Crevello and Schlager, 1980) and periplatform ooze dominated basin floors. The steepest slope values in the carbonate system with near vertical walls are in fact observed at the platform margins and in the deepest part of the system (Fig. 1), for example within the San Salvador

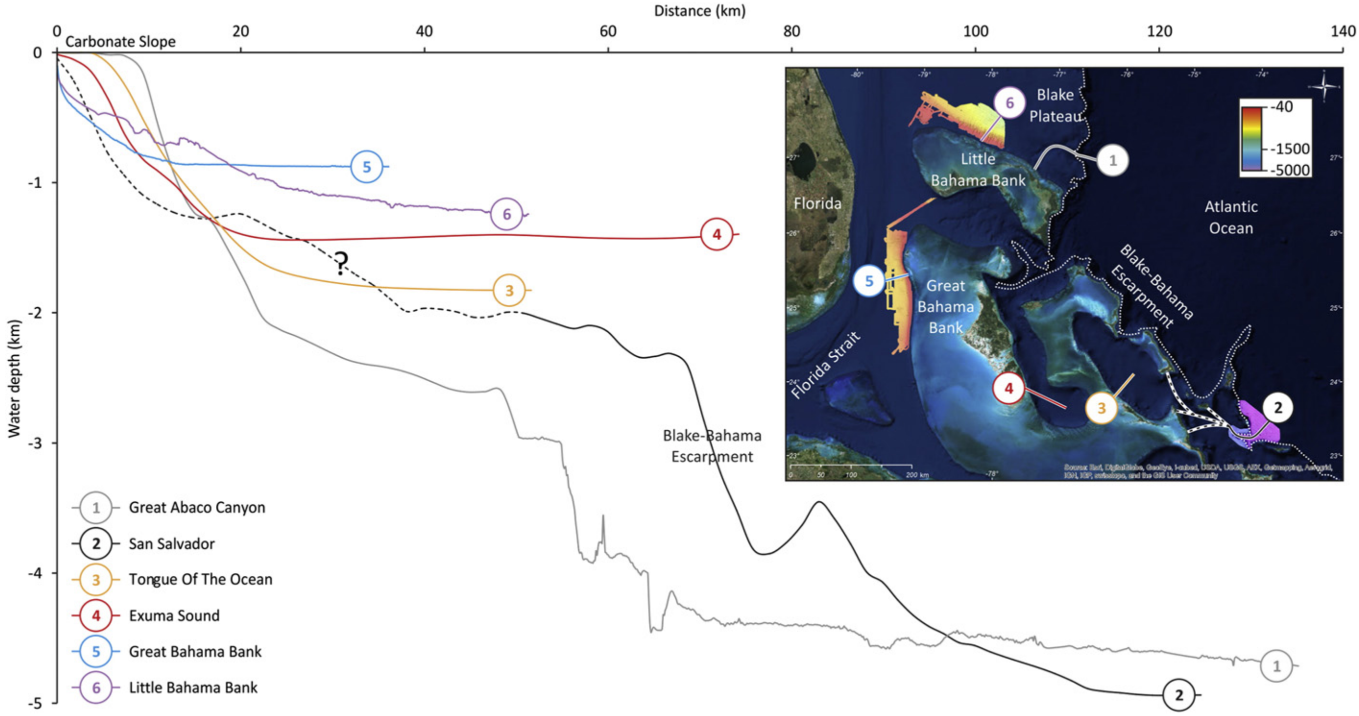

Fig. 1. Bahamian slope profiles modified from Schlager and Ginsburg (1981). West of Great Bahama Bank (data: Carambar cruise; Mulder et al., 2012a). North of Little Bahama Bank (data: Carambar cruise, Mulder et al., 2012b; and NOS NG 17-3 map — Walker Cay, NOAA, 1988) and San Salvador (data: Bacar 1 cruise).