Earth and Planetary Science Letters 499 (2018) 107–121

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

www.elsevier.com/locate/epsl

Seismic stratigraphy of Cretaceous eastern Central Atlantic Ocean: Basin evolution and palaeoceanographic implications

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ARTICLE INFO

Article history:
Received 9 January 2018
Received in revised form 3 June 2018
Accepted 17 July 2018
Available online xxxx
Editor: J.P. Avouac

Keywords:
seismic reflection
contourite
palaeobathymetry
palaeoceanography
Cretaceous
Central Atlantic Ocean

ABSTRACT

The evolution and resulting morphology of a Cretaceous contourite drift in the eastern Central Atlantic oceanic basin is investigated in unprecedented detail using seismic imaging and age-calibrated cross-margin sections. The margin, from the shelf, slope to deep-water and abyssal plain is constructed by a succession of erosive and depositional mounded structures that relate to bottom-water currents and sediment winnowing. The regional mapping of these drifts, sediment waves and gravitational sedimentary systems allows us to test the Upper Cretaceous paleocirculation model. Combined with flexural backstripping of the regional cross section, it reveals the water-depth range at which the observed sedimentary features occur. A possible late Albian to Turonian contourite drift system is observed from Guinea to Mauritania. The development of a shallow to deep oceanic circulation system is a key element in the rock record, with implications for the palaeoceanography and layering of the Cretaceous ocean. The Cretaceous geological interval and oceanic model mirrors the stratification of the modern ocean and the morphology of its seafloor from offshore Morocco to Guinea.

1. Introduction

The sedimentary architecture of passive margins is generally shaped by both gravitational processes (e.g. turbidites, debris flows) and along-slope oceanic bottom currents (contourite drifts) (e.g. Rebesco et al., 2017). The modern ocean seafloor records the interaction between surface and deep bottom-water currents through their expression in the erosion and deposition of sediments (Heezen and Hollister, 1964). Features such as mounded contourite drifts mark some of the most extensive expression of interactions between sediment and water masses across the seafloor of modern oceanic sedimentary basins (Faugères et al., 1999; Stow et al., 2002; Mosher et al., 2017). The acquisition of seafloor photography, subsurface seismic reflection profiles and the sampling of marine sediments has allowed the identification of sediment transport by bottom-water currents in various bathymetric domains (e.g. abyssal plain and shelf). This is particularly well known in the Atlantic, Pacific and Indian Oceans (Faugères et al., 1999; Hernández-Molina et al., 2008a and 2008b; Rebesco et al., 2014).

During the Cretaceous, palaeoceanographic circulation patterns in the Tethys, Atlantic, Indian and Pacific Oceans have been inferred from the tracking of oceanic water masses using the neodymium (Nd) isotope character of fish teeth. In addition, global and regional modeling combining atmospheric and oceanic circulation has been performed to illustrate possible ocean circulation patterns and specify water mass exchanges between the different oceans (Poulsen et al., 2001; Donnadieu et al., 2016; Uenzelmann-Neben et al., 2016). However, these simulations could not resolve the full water column stratification because they investigated the surface and intermediate oceanic currents without any constraints on the paleo-seafloor and its interaction with deep bottom-water currents.

Studies based on Nd isotope character of Upper Cretaceous fish teeth sampled in the Equatorial Atlantic domain (MacLeod et al., 2008; Martin et al., 2012) propose two intermediate oceanic currents: a first one originating in the Demerara Rise region (Demerara Bottom Water: DBW, Fig. 1) and a second initiating from the South Atlantic Ocean and circulating toward the Central Atlantic Ocean through the Equatorial Gateway (Southern Component Wa-

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https://doi.org/10.1016/j.epsl.2018.07.023

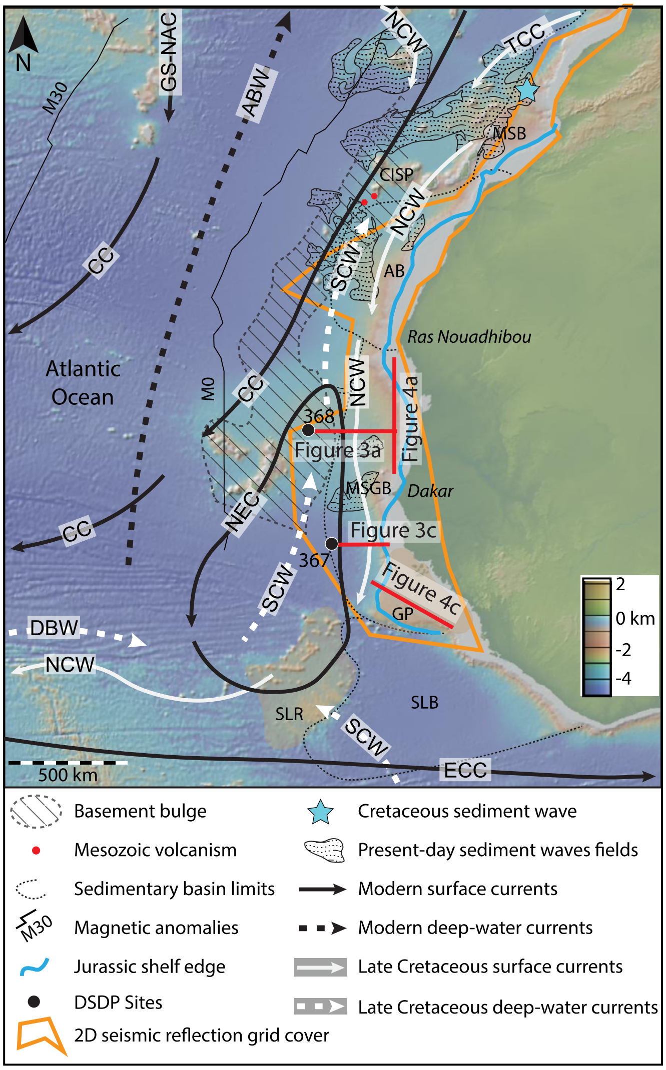

Fig. 1. Shaded bathymetric map of the eastern Central Atlantic Ocean showing the geomorphological and oceanographic framework of the studied margin between the Canary Island Seamount Province (CISP) and the Guinean Plateau (GP). Interaction between oceanic currents and terrestrial sedimentary export is illustrated by four regional seismic sections indicated by red lines through Deep Sea Drilling Project (DSDP) Sites 367 and 368. Grey area represents the basement bulge off the margin identified by Patriat and Labails (2006) and the location of the Jurassic shelf edge mapped by Purdy (1989). Magnetic anomalies are reconstructed by Labails (2007). Cretaceous sediment waves observed by Dunlap et al. (2013) are indicated by the blue star. Present-day sediment wave fields are sourced from Wynn et al. (2000). Present-day oceanic circulation with GS–NAC: Gulf Stream–North Atlantic Current. CC: Canary Current. NEC: North Equatorial Current. ECC: Equatorial Counter–Current. ABW: Antarctic Bottom Water. Cretaceous oceanic currents correspond to the Tethys Circumglobal Current (TCC) proposed by Pucéat et al. (2005), the Demerara Bottom Water (DBW) proposed by Berrocoso et al. (2010), the North Component Waters (NCW) and the Southern Component Waters (SCW) proposed by Robinson and Vance (2012). MSB: Morocco Salt Basin. AB: Aaiun Basin. MSGB: Mauritania Senegal Guinea Basin. SLB: Sierra Leone Basin. SLR: Sierra Leone Rise. Base map sourced from the Geomapapp© (http://www.geomapapp.org/). (For interpretation of the colors in the figure(s), the reader is referred to the web version of this article.)

ters: SCW, Fig. 1) (Robinson and Vance, 2012). Other studies, also based on Nd isotopes, assume that in the northern Central Atlantic Ocean, a surface current originating in the Tethys Ocean would have run through the Central Atlantic to the lowest latitudes (Northern Component Waters: NCW, Fig. 1) (Pucéat et al., 2005; MacLeod et al., 2008). However, these Upper Cretaceous large-scale ocean circulation patterns remain debated because recent studies have emphasized the importance of paleobathymetric obstacles. Indeed, critical topographic barriers could have limited connections between the ocean basins, forcing water masses to evolve in more restricted areas (Voigt et al., 2013; Uenzelmann-Neben et al., 2016).

The present day water column in the eastern Central Atlantic Ocean is stratified into the following layers: shallow (0–500 m depth, e.g. South Atlantic Central Water – SACW), intermediate (500–1500 m depth, e.g. Antarctic Intermediate Water – AIW) and deep (1500 m-seafloor, e.g. Antarctic Bottom Water – ABW) water masses (Emery and Meincke, 1986). The present day shallow subsurface oceanic layers have been also well studied by the oceanographic and marine geology communities. Many sedimentary structures related to bottom-water currents and gravity-driven processes have been identified on the modern seafloor along the Northwest African Margin between Morocco and Mauritania (e.g. Wynn et al., 2000; Schwab et al., 2007). In contrast to these well documented features related to modern bottom-water currents, only a few examples of Cretaceous sedimentation related to bottom current processes are found. These studies are restricted to the northern Central Atlantic Ocean (Morocco: Dunlap et al., 2013; Northwest Iberia: Soares et al., 2014). Between 24° and 8° N from the Western Sahara to Guinea (Fig. 1) the authors found no studies that document Cretaceous sedimentation in relation to processes that involve interaction between the seafloor and deep bottom currents.

This study aims at understanding the occurrence of specific sedimentary features present in the deep-sea Cretaceous Ocean record and their implication for the oceanic circulation. This paper uses 2D seismic reflection profiles, borehole data from Deep Sea Drilling Project (DSDP) Sites 367 and 368 located along the Northwest African margin.

We document a variety of sedimentary features observed over a range of palaeobathymetry from the continental shelf, the slope to the deep abyssal plain during the Cretaceous. We also quantify paleobathymetric domains both in the shelf and the deep basin using flexural decompaction of regional geological sections where we have observed bottom-water current-related sedimentary features. These new results allow to understand deep-water oceanic circulation in the eastern Central Atlantic Ocean during the Cretaceous.

2. Data and methods

2.1. Seismic stratigraphy

In this study, we use a combination of both 2D seismic sections and drilling data from the shallow to deep-water Central Atlantic margin (30°–10° N; Fig. 1; Fig. S1, Shipboard Scientific Party and Bukry, 1978) to reconstruct the sedimentary architecture of this margin with the objective of better understanding the Upper Cretaceous palaeoceanography. The average spacing between lines is ∼10 km with exception in the distal offshore domain where only regional lines exist. The margin is described with standard seismic stratigraphic techniques based on reflection terminations and seismic reflection facies, as well as the relationship to the geometry of individual seismic reflections (terminations). This approach allows the seismic profile to be divided into chronostratigraphic packages. Thus, eight seismic surfaces were used to define seven seismic units in the studied interval. An age calibration was obtained using well data (e.g. Hardenbol et al., 1981; Davison, 2005; see Table 1; Figs. 1 and 2). These data provide important evidence for the timing of formation and the distribution of several sedimentary features related to channel-levees, deep-sea fans and mass transport complexes (Posamentier and Kolla, 2003). The data are also used to understand sediment remobilization by bottom ocean currents (e.g., contourite drift) in both the basin and