Quaternary International 352 (2014) 111–123

Contents lists available at ScienceDirect

Quaternary International

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

Changes in the water column structure and paleoproductivity in the western South Atlantic Ocean since the middle Pleistocene: Evidence from benthic and planktonic foraminifera

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ARTICLE INFO

Article history:
Available online 10 September 2014

Keywords:
Glacial-interglacial
Foraminifera
Paleoproductivity
Paleocirculation
Middle Pleistocene
South Atlantic Ocean

ABSTRACT

Based on an integrated approach (planktonic and benthic foraminifera and stable isotopes) carried out in two cores collected on continental slope of Santos Basin (central Brazil), the paleoceanographic oscillations of the last ~570 ka are documented. Benthic foraminiferal isotopic records coupled with foraminiferal assemblages analyses show ~100 ky long-term oscillation in the superficial productivity along the Middle Pleistocene. These long-term oscillations are interrupted by ~30 ky short-term changes that mark the transition periods of higher productivity (~425–400 ka and ~190–160 ka), and lower (~290–260 ka). The planktonic foraminifera species allowed the recognition of changes in the water column structure and in the superficial productivity observed in the area. Those changes in the superficial waters promoting different organic matter export to the sea floor might have resulted in changes on the more abundant and phytodetritus/opportunist benthic taxa (*Epistominella exigua* and *Alabaminella weddellensis*).

1. Introduction

The Quaternary has been punctuated by a series of global climatic oscillations, between warmer and cooler conditions controlled by cyclic variations in the Earth's orbital parameters (Imbrie et al., 1989; Lisiecki and Raymo, 2005). These shifts led to the expansion and retreat of continental ice sheets changing the ocean circulation and the position of oceanic fronts (Niebler and Gersonde, 1998; Ruddiman, 2003; Berger and Loutre, 2004; Kemp et al., 2010). This variability in ocean circulation changed the vertical distribution of carbon and nutrients affecting, in turns, the primary productivity into the deep ocean as well as in the surface waters (Bröecker and Peng, 1989; Sarnthein and Winn, 1990). Two major climatic changes, the Mid–Pleistocene Transition (MPT) and the Mid-Brunhes Event (MBE) characterized the Quaternary (Becquey and Gersonde, 2002). During the MPT (~1250–~600 ka), glacial-interglacial contrasts became more severe with long climate cooling phases interrupted by relatively rapid climate warming phase associated with ice decay (Becquey and Gersonde, 2002). A poor preservation of carbonates in the South Atlantic between ~920 ka (marine isotopic stage- MIS 24) and ~530 ka (MIS 13) is the result of reduction of North Atlantic Deep Water (NADW) production and an increase influence of more corrosive water from Southern Component Water (SCW) (Schmieder et al., 2000). Significant changes in the thermohaline circulation took place during this climate transition, causing a reduction of NADW input to the Antarctic Circumpolar Current (ACC), a weakening of the surface waters from the Indian Ocean to the South Atlantic via the Agulhas Current and an increased in biological activity was documented during glacial stages of the last ~600 ka (Schmieder et al., 2000; Sigman and Boyle, 2000; Kuhn and Diekmann, 2002). The MBE (~200–600 ka) represents a major climatic decoupling of climate conditions in different latitudes with glacial-to-interglacial

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http://dx.doi.org/10.1016/j.quaint.2014.07.061

contrasts up to 8 C° (Kunz-Pirrung et al., 2002; Holden et al., 2011). It is also marked by strong increase in the accumulation of carbonate in the oceans that might have been caused by the proliferation of phytoplankton (Flores et al., 2003; Barker et al., 2006).

Little is known about long-term temporal fluctuations of productivity and oceanographic changes during the MBE (Middle Pleistocene) in the southwestern Atlantic continental margin as only very few studies are available combining the faunal analysis of foraminifera and paleoenvironmental changes. The research conducted in this area was, mainly, focused on changes in the sedimentary processes, oceanographic patterns and fluctuations in productivity along the Late Quaternary (*e.g.* Mahiques et al., 1999, 2002, 2004, 2009; Modica and Brush, 2004; Duarte and Viana, 2007; Toledo et al., 2007, 2008; Pivel et al., 2010). Thus, the aim of this study is to document, on the basis of an integrated approach (benthic and planktonic foraminiferal, isotopic, and magnetic analyses), the long-term productivity and oceanographic changes in Santos Basin (east coast of Brazil, South Atlantic) during the Pleistocene glacial-interglacial events.

2. Study area and oceanographical settings

The water masses and the circulation regime of the South Atlantic have been well studied in the last decades (*e.g.* Stramma, 1989; Peterson and Stramma, 1991; Siedler et al., 1996; Silveira et al., 2000). Five main water masses with distinct signatures in the temperature–salinity plane are distinguished: the Tropical Water (TW), the South Atlantic Central Water (SACW), the Antarctic Intermediate Water (AAIW), the North Atlantic Deep Water (NADW) and the Antarctic Bottom Water (AABW) (Silveira et al., 2000) (Fig. 1a). The surface waters are driven to the south by the Brazil Current (BC). The BC originates near 10°S, where the southern branch of the South Equatorial Current (SEC) bifurcates to form also the North Brazil Current (NBC) (Stramma, 1991) (Fig. 1b). The anticyclonic South Atlantic Subtropical Gyre associated with the BC transports tropical warm and salty waters to the south flowing along the Brazilian margin to the Subtropical Convergence Zone and influences the middle and outer shelves as well as on the upper slope (Stramma et al., 1990; Souza, 2000; Mahiques et al., 2002). The offshore circulation is dominated by the BC flowing southward and meandering around the 200 m isobaths (Campos et al., 2000), transporting TW, at upper levels and SACW at pycnocline levels (Silveira et al., 2000; Rodrigues and Lorenzzetti, 2001; Mahiques et al., 2002).

Located in the western tropical South Atlantic on the Brazilian coast between 23° and 28°S, the Santos Basin is a large sedimentary basin (~350.000 km^2) with high sedimentation rates (Pereira and Feijó, 1994; Moreira et al., 2007) (Fig. 1). It extends from the present coastline to the outer boundary of the São Paulo Plateau (water depths >3500 m). It is separated from the Campos Basin, in the north, by Cabo Frio High and from the Pelotas Basin, in the south, by the Florianópolis High (Moreira et al., 2007). Cabo Frio marks the transition between the tropical (to the north) and the subtropical (to the south) environments that are characterized by different oceanographic conditions as well as distinct sedimentary dynamics (Rocha et al., 1975). In the Santos Basin, the Neogene to Recent sedimentation was dominated by oceanic circulation that redistributes the sediments transferred to the basin during both relative sea-level high- and low-stands (Duarte and Viana, 2007). During the Quaternary, the morphotectonic control on sedimentation was overprinted by the transgressive/regressive events related to the sea-level changes, mainly the desiccation and submersion of the shelf during the Last Glacial Cycle (Mahiques et al., 2004). The Quaternary sediments are inserted in the Marambaia Formation (sequence N50–N60) and are dominated by muddy sediments (shale gray and light gray marl) (Pereira and Feijó, 1994; Moreira et al., 2007). The sediments between the inner and outer shelf present characteristics that vary from the siliciclastic to carbonate respectively, while the slope is characterized by deposition of hemipelagic sediments and turbidites (Kowsmann and Costa, 1979; Mahiques et al., 2002). It was suggested the area off São Sebastião Island marks the boundary

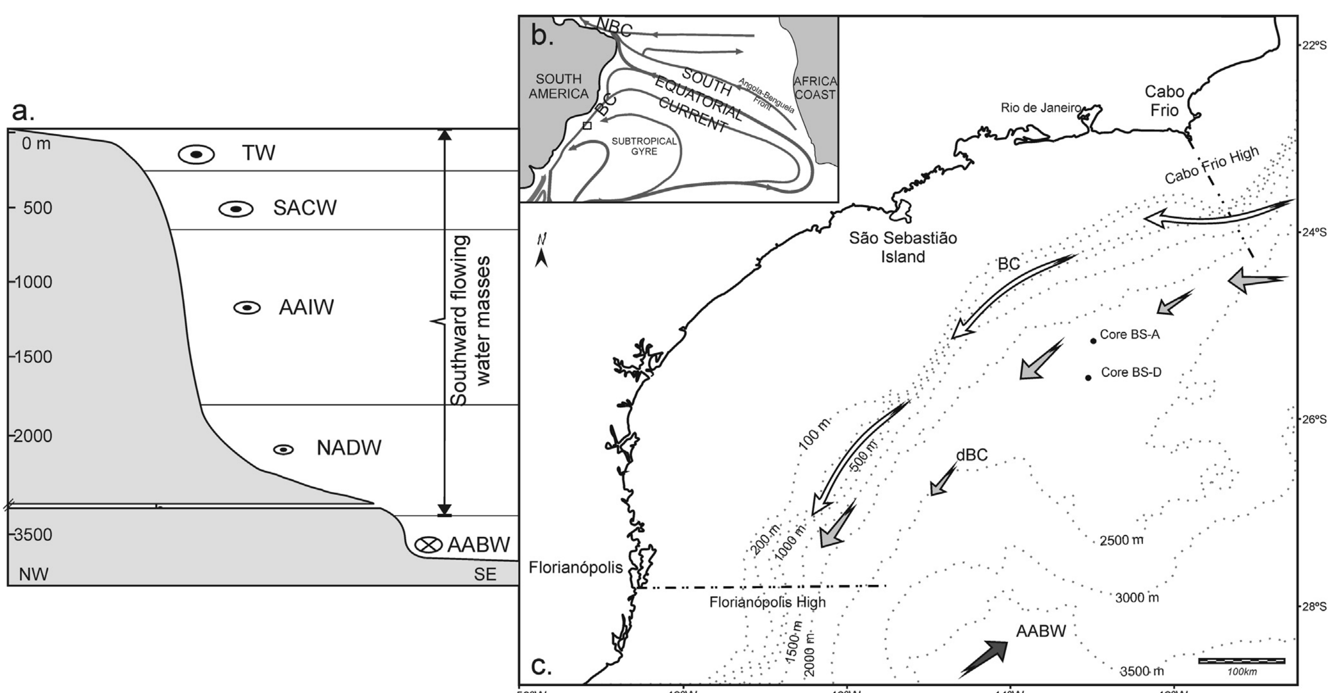

Fig. 1. a) Present day water masses in the Santos Basin: TW = Tropical Water; SACW = South Atlantic Central Water; AAIW = Antarctic Intermediate Water; NADW = North Atlantic Deep Water; AABW = Antarctic Bottom Water (modified after Duarte and Viana, 2007). b) Large scale surface circulation (modified after Peterson and Stramma, 1991). c) Location map of the study area with cores BS-A and BS-D sites and the present-day circulation pattern in the Santos Basin, BC = Brazilian Current, dBC = deep Brazilian Current (SACW + AAIW + NADW) (modified after Duarte and Viana, 2007).