Palaeogeography, Palaeoclimatology, Palaeoecology 374 (2013) 164–172

Contents lists available at SciVerse ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

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

The Holocene onset in the southwestern South Atlantic

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ARTICLE INFO

Article history:
Received 8 March 2012
Received in revised form 4 January 2013
Accepted 17 January 2013
Available online 26 January 2013

Keywords:
Brazilian Continental Margin
Late Quaternary
Planktonic foraminifera
Oxygen isotopes
Paleotemperature
Paleosalinity

ABSTRACT

In this paper we present a paleoceanographic reconstruction of the southwestern South Atlantic for the past 13 kyr based on faunal and isotopic analysis of planktonic foraminifera from a high-resolution core retrieved at the South Brazil Bight continental slope. Our record indicates that oceanographic changes in the southwestern South Atlantic during the onset of the Holocene were comparable in strength to those that occurred during the Younger Dryas. Full interglacial conditions started abruptly after 8.2 kyr BP with a sharp change in faunal composition and surface hydrography (SST and SSS). Part of the observed events may be explained in terms of changes in thermohaline circulation while the other part suggests a dominant role of winds. Our data indicate that during the Early Holocene upwelling was significantly strengthened in the South Brazil Bight promoting high productivity and preventing the establishment of the typically interglacial menardiiform species. In general terms, oceanographic changes recorded by core KF02 occurred in synchrony with Antarctica's climate.

1. Introduction

Paleoceanography has seen an outstanding growth in the past decades partly due to the improvement of models and techniques and fundamentally by the increasing amount of high resolution proxy data with increasingly broader spatial coverage. Nevertheless, compared to the North Atlantic, the South Atlantic has received considerably less attention and its western margin even less than its eastern counterpart. In order to bridge this gap, in this paper we present a new paleoceanographic high-resolution record from the western South Atlantic based on the isotopic and faunal analyses of planktonic foraminifera from a core retrieved at the southeastern Brazilian Continental slope. The record spans the last 13 kyr and we focus especially on the Holocene onset.

Chronologically, the onset of the Holocene is defined as 11.7 calendar yr b2k (before AD 2000) (Walker et al., 2009), right at the end of the Younger Dryas (YD) event. However, the geomorphology and ecosystems of the Early Holocene were considerably different than today (Roberts, 1998). From the onset of the Holocene until 9 kyr BP the northern hemisphere was under maximum summer insolation but still largely influenced by large ice sheets (Wanner et al., 2008) and thus, the sea level was significantly lower. Deepwater geometry reached its modern configuration at about 9 kyr BP (Came et al., 2003). One of the possible factors leading to the resumption of North Atlantic Deepwater (NADW) production and the strengthening of the Meridional Overturning Cell (MOC) was the reestablishment of a strong connection between the Indian and Atlantic oceans through the Agulhas leakage (Peeters et al., 2004). The increased mass transport to the Atlantic ocean *via* the warm-route (Indian Ocean) and cold-route (Pacific Ocean) would have induced a rapid reactivation of the interglacial model of thermohaline circulation (THC) counterbalancing the entrance of freshwater from ice melting which would have led to a weakening of the THC (Knorr and Lohmann, 2003).

Although compared to glacial and deglacial times Holocene climate may be considered more stable, a closer look reveals that the difference between the Holocene and glacial times is real only in terms of the magnitude of the climatic changes but not in terms of variability frequency and abruptness of changes (e.g. Mayewski et al., 2004). Worldwide records provide evidences of important millennial-scale variability during the Holocene. For example, Mayewski et al. (2004) presented a compilation of paleoclimate records showing at least six rapid changes, most of them characterized by cooling at the poles, aridity in the tropics and significant changes in atmospheric circulation.

The most significant climate event that occurred during the Holocene was the 8.2 kyr BP event, at a time when the background climate was much like the present (Kobashi et al., 2007). This event presented a geographical pattern similar to the Younger Dryas (YD) although of smaller amplitude (Alley et al., 1997) and it was described for several locations around the northern hemisphere (Baldini et al., 2002). The event is believed to have been triggered by the abrupt release of large amounts of freshwater from the melting of the Laurentide Ice Sheet (e.g. von

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0031-0182/$ – see front matter
http://dx.doi.org/10.1016/j.palaeo.2013.01.014

Grafenstein et al., 1998; Barber et al., 1999), a hypothesis supported both by proxy data and modeling experiments (e.g. Bauer et al., 2004; LeGrande and Schmidt, 2008).

2. Present setting

Core LaPAS-KF02 (further referred to as KF02) was retrieved at Santos Basin in the South Brazil Bight, southeastern Brazilian Continental slope. Present surface hydrography is dominated by the presence of the warm, salty and oligotrophic Tropical Water, transported southwards by the Brazil Current (BC), the western branch of the South Atlantic subtropical gyre (Fig. 1). Upper waters are eventually fertilized by the upwelling of nutrient-rich South Atlantic Central Water (SACW). Upwelling may result from two different processes (Palma and Matano, 2009): (a) a wind-driven inner-shelf upwelling which peaks during austral summer and decreases during winter and, (b) a geostrophic, shelf-break upwelling extending yearlong.

Present sedimentation in the upper slope of the South Brazil Bight is a combined response to bottom morphology, the cross-isobath flow associated to the BC meandering and the Coastal Water seaward transport (Mahiques et al., 2002). The present supply of terrigenous sediments to the area is limited because only small rivers drain to the ocean due to the presence of the Serra do Mar coastal mountain range (Conti and Furtado, 2006). Eventually, however, the Plata River plume from the south enters the inner-shelf during winter reaching a northernmost position at around 23°S under favorable wind conditions (Campos et al., 1999).

3. Material and methods

The analyzed core was retrieved by Petrobras at the southeastern Brazilian Continental upper slope at 25.84°S 45.2°W and at 827 m water depth. The core length is 489 cm. Faunal and isotopic analyses were performed every 4 cm except for the section comprised between 185 and 215 cm which was used by the company for other analyses. Based on our age model (see below) the excluded section corresponds to the time interval comprised between 4.8 and 4.2 kyr BP.

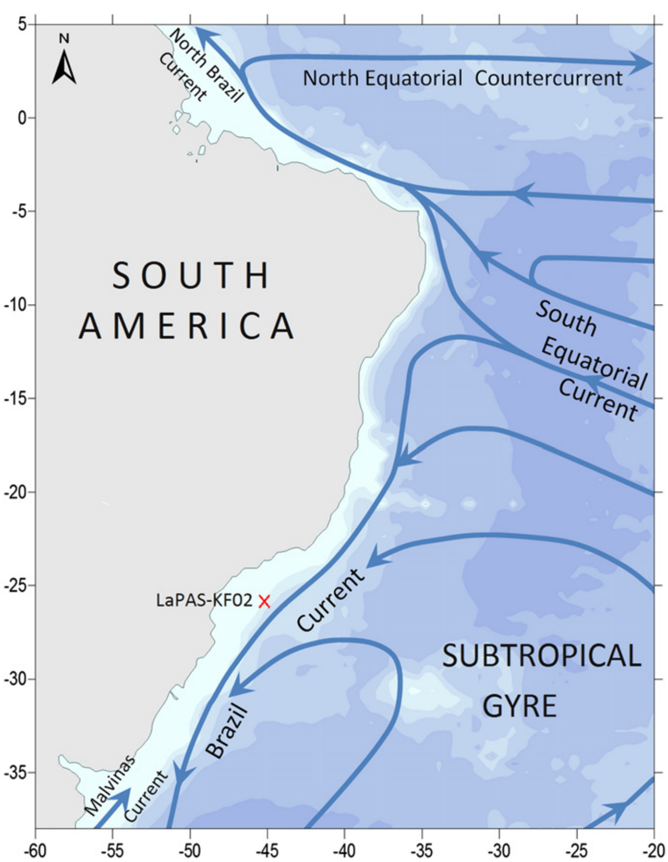

Fig. 1. Core location relative to surface circulation in the western South Atlantic. Surface currents based on Peterson and Stramma, 1991.

The age model was built based on the correlation of the planktonic foraminifera oxygen isotope record and the Lisiecki and Raymo (2005) stack using nine ^{14}C AMS datings converted to calendar ages (Table 1) as control points. The oxygen isotope analyses were conducted on monospecific samples of *Globigerinoides ruber* (white morphotype) from the > 0.15 mm size fraction at the Woods Hole Oceanographic Institution (WHOI) Micropaleontology Mass Spec Facility using a Finnigan MAT252 with a Kiel III Carbonate Device. All radiocarbon datings were performed on samples of *G. ruber* containing both white and pink morphotypes except for the core-top sample for which there weren't enough specimens and the analysis was conducted on a mixed sample of *G. ruber* and *Globorotalia menardii*. Analyses were performed at the National Ocean Sciences Accelerator Mass Spectrometry Facility (NOSAMS–WHOI). Radiocarbon ages were transformed into calendar ages by first subtracting an estimated reservoir age of 271 years according to Butzin et al. (2005) using the program available at http://radiocarbon.LDEO.columbia.edu/ and by applying the Fairbanks et al. (2005) calibration curve (version Fairbanks0107).

Sea Surface Temperature (SST) estimates were based on planktonic foraminifera census counts of subsamples containing at least 300 specimens of the size fraction larger than 0.15 mm. Taxonomic criteria used for species identification come from Bé (1967, 1977), Bolli and Saunders (1989), Hemleben et al. (1989), and Kemle von Mucke and Hemleben (1999). Relative abundance data were transformed into SST estimates applying the Artificial Neural Network (ANN) Technique (Malmgren and Nordlund, 1997). This technique yields the most precise results for faunal based SST estimates according to comparative studies by Malmgren et al. (2001) and Kucera and Darling (2002). Calculations were performed by Prof. Michal Kucera at Tübingen University. The method, the calibration dataset, and the networks are the same as in Kucera et al. (2005), using the South Atlantic MARGO dataset in order to avoid problems related to the possible grouping of cryptic species given that individual genetic types among modern planktonic foraminifera display a much greater degree of endemicity than morphologically defined species. Each SST estimate corresponds to the average value of the outputs from ten independent networks. Standard errors for each sample were calculated based on the standard deviation of these ten analyses.

The oxygen isotopic composition of seawater ($\delta^{18}O_{SW}$) was estimated by extracting the temperature effect from the oxygen isotopic composition of *G. ruber* (white) ($\delta^{18}O_{ruber}$) after applying the paleotemperature equation of Kim and O'Neil (1997) and the calibration of Wang et al. (1995). According to Wang et al.'s calibration for the low-latitude Atlantic, $\delta^{18}O_{ruber}$ mainly reflects the summer

Table 1
Radiocarbon datings and respective calendar ages for core KF02.

Sample depth (cm)	Analyzed species	^{14}C age	Error (^{14}C yr)	Reservoir corrected ^{14}C age	Calendar age	Error (1σ) (calendar age)
2	*G. menardii* + *G. ruber*	615	30	344	404	57
45	*G. ruber*	850	15	579	579	34
99	*G. ruber*	1080	50	809	720	41
149	*G. ruber*	2910	20	2639	2750	9
234	*G. ruber*	5230	25	4959	5673	30
318	*G. ruber*	7750	30	7479	8319	39
360	*G. ruber*	9660	60	9389	10,611	78
420	*G. ruber*	10,550	60	10,279	12,048	102
436	*G. ruber*	11,150	40	10,879	12,776	45