ARTICLE IN PRESS

Journal of Sea Research xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Journal of Sea Research

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

Deep-sea benthic response to rapid climatic oscillations of the last glacial cycle in the SE Bay of Biscay

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ARTICLE INFO

Keywords:
Paleoclimatology
Foraminifers
Ostracods
Benthic response
MIS 1–MIS 5
Bay of Biscay

ABSTRACT

Paleoclimatic evolution of the last 140 ka (Marine Isotopic Stages MIS 1 to MIS 5) in the South Bay of Biscay has been studied by considering microfossil changes in sediment samples of deep core PP10-17. This core was retrieved at 2882 m water depth (mwd) in the Landas Plateau and is formed by 1792 cm of clay-silt continuously deposited sediment. For this study, a total of 114 samples have been examined, yielding approximately 60 thousands of specimens of foraminifers (181 benthic species, BF) and ostracods (70 spp.). Reconstruction of the benthic response is based on the main foraminifer and ostracod species by considering their oxic/anoxic character as well as other ecological features of the assemblages. Detailed quantification of microfossils (planktonic and benthic foraminifers, ostracods) together with grain size analyses and magnetic susceptibility of the sediments allow us to characterize many of the climatic events registered in this core. Based on a robust chronostratigraphy by correlation with reference core MD95-2002 and Greenland ice core records (GICC05modelext), we are able to characterize a detailed response of benthic environments to cooling/warming, oxygen-content and productivity cycles in the region. MIS 5 has been characterized by oscillations of the planktonic/benthic foraminifer ratio (Oceanity index, OI; 60–90%); this index was higher (90–100%) and stable through the MIS 4–MIS 3 intervals. We found BF species indicators of different climatic-related events. Thus, MIS 5a, c, e interstadials are evidenced by *Bulimina gibba* and *B. aculeata* while the stadials MIS 5b, d are shown by the occurrence of *Melonis pompilioides*. Heinrich events, with massive iceberg discharges into the N Atlantic Ocean, are indicated by presence of *Globobulimina affinis*, particularly during the MIS 4 to MIS 2 interval. The beginning of MIS 4 is indicated by the appearance of new species of BF and an increase of *Cassidulina laevigata*. *Krithe* spp. and *C. laevigata* are good indicators of the LGM (Last Glacial Maximum, 19–23 ka) when the OI decreased. Other cooling periods (e.g. Younger Dryas, YD, around 12–13 ka) are shown as well by an increase of *M. pompilioides*, similar to that of the MIS 5d stadial. The Holocene (11.5 ka to present) is marked by an increase in the oceanity index, disappearance of cold-water indicators and the occurrence of *Uvigerina peregrina*. A shallow infaunal microhabitat of benthics foraminifers (*Cibicides*, *Cassidulina*, *Uvigerina*) and ostracods (*Krithe*, *Argilloecia*) has been linked to favorable bottom conditions, with oxic to slightly suboxic conditions (high diversity and equitability of assemblages) reflecting an active Atlantic Meridional Overturning Circulation (AMOC) during many D/O interstadials. The opposite conditions were established for deep infaunal BF (*Bulimina*, *Globobulimina*) where the strong dysoxic bottom conditions are indicative of poor ventilation produced by a reduction or shutdown of the AMOC during Heinrich stadials.

1. Introduction

The relationship between paleoceanography and paleoclimatology has largely been established in the comparative study of biological and bio-geochemical proxies evaluating the different responses of the sea surface and the deep sea to the atmospheric fluctuations (e.g. Cronin, 2009 and references therein; Povea et al., 2016). Though imperfect, deep-sea benthic foraminifera oxygen isotopes are the best stratigraphic reference for the study of glacial-interglacial changes (Tzedakis et al., 2009).

For example, the rapid alternation of warm (interstadials) and cold (stadials) intervals in the Atlantic Ocean have been proposed as distinctive climatic oscillations during the last glacial cycle (Lisiecki and Raymo, 2005), and climatic connections with the Atlantic have been described for the Mediterranean (Cacho et al., 1999; Moreno et al., 2007). Though cold Heinrich stadials (HS) and warm-cold Dansgaard-

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http://dx.doi.org/10.1016/j.seares.2017.06.002
Received 4 November 2016; Received in revised form 16 March 2017; Accepted 6 June 2017
1385-1101/

Oeschger (D/O) events are reasonably well known during MIS 3 (Sierro et al., 2005; Naughton et al., 2009, 2016), details about the duration of events are yet in discussion (Long and Stoy, 2013). Rapid climate variability in N Atlantic represented by the alternation of cold and warm phases has been linked to significant changes in the strength of the AMOC (Atlantic Meridional Overturning Circulation), but particular responses during D/O interstadials inside the Heinrich events were associated with overturning circulation rapidly transmitted across the Atlantic (Gottschalk et al., 2015).

On the other hand, the benthic response to these rapid climatic changes has been evaluated in several works for the deep N Atlantic (Baas et al., 1998; Cronin et al., 1999, 2000; Rasmussen et al., 2002; Yasuhara et al., 2008; Hoogakker et al., 2015, 2016; Grunert et al., 2015) as well as in the Bay of Biscay, with particular emphasis to shelf environments during the Marine Isotope Stage MIS 3 to Holocene (Pascual et al., 2008; García et al., 2013; Martínez-García et al., 2013, 2014, 2015).

Recent deep benthic foraminifer distributions are well known in the Bay of Biscay (Caralp et al., 1968; Pujos-Lamy, 1973, 1984). Benthic foraminifer distribution is influenced by organic carbon flux into the sea floor, bottom currents and grain size, oxygen content and carbonate saturation of sediment (Mackensen et al., 1995; Jorissen et al., 2007). The relationship between opportunistic benthic foraminifers, primary production and oxygen content was analyzed in several studies along depth transects from the shelf to the bathyal Bay of Biscay by Fontanier et al. (2002, 2003, 2006) and Mojtahid et al. (2010). These authors monitored changes in the benthic microhabitat responding to the trophic conditions of the water-sediment interface following the TROX-model (TRopic conditions and OXigen concentrations) of Jorissen et al. (1995).

Several aspects of the paleoceanography of the Bay of Biscay have been previously considered. Zaragosi et al. (2001) considered surface and deep conditions in the Meriadzek Terrace. The Last Glacial Maximum (LGM) was characterized by a gradual warming with at least two pulses of the North Atlantic Drift (NAD) that finally lead to the collapse of Heinrich event H1.

Naughton et al. (2009, 2016) performed a detailed chronostratigraphic characterization of the Heinrich events (H4 to H1) in NW Iberia by comparing marine and terrestrial records in the region. This robust chronostratigraphic framework allowed the authors revealing the complex nature of H1, describing detailed cooling/warming trends. Sánchez-Goñi et al. (2013) described the MIS 5a-4 transition in N Atlantic with three cold events (C20, C19, C18; 80–70 ka BP). The thermal gradient between sea surface temperatures (SST) and air temperature (warm surface ocean in the W European marginal areas) resulted in increased input of humidity that fed the continental ice sheets in the North Atlantic.

The aim of this study is to provide with new evidence of deep-sea benthic response to rapid climate changes produced during the last glacial cycle, based on detailed new data of benthic foraminifers and ostracods completed with sedimentary analyses in a bathyal settlement in the SE Bay of Biscay.

1.1. Environmental setting

Surface circulation in the Bay of Biscay is characterized nowadays by a general oceanic current formed by anticyclonic ENACW (Eastern North Atlantic Central Water) (Koutsikopoulos and Le Cann, 1996) and proximally by the Iberian Poleward Current (IPC), with a strong seasonal component counter-clock winter slope current (Durrieu de Madron et al., 1999; Fig. 1). In the southern area surface water circulation is mainly induced by winds and water density variations produced by freshwater runoff from French and Spanish rivers (Koutsikopoulos and Le Cann, 1996; Ferrer et al., 2009), finally producing seasonal oscillations in salinity and nutrient discharges in surface waters (Puillat et al., 2004). Inceptions of IPC current into the Bay of Biscay have been correlated to negative NAO (North Atlantic Oscillation) phases (Decastro et al., 2011).

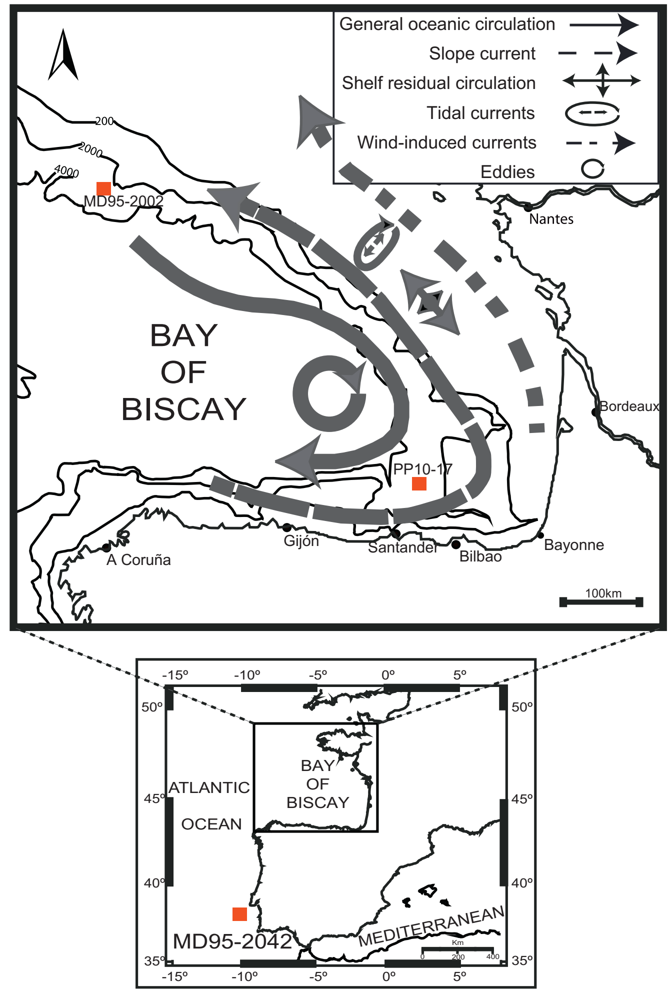

Fig. 1. Location of studied area with core PP10-17 and cores MD95-2002 and MD95-2042.

Main water masses in the Bay of Biscay are AABW (Antarctic Bottom Water; > 3000 mwd), NEADW (North East Atlantic Deep Water; 3000–1300 mwd), the high-saline MOW (Mediterranean Outflow Water; 1300–700 mwd) and the ENACW (East North Atlantic Central Water; < 700 mwd) (van Aken, 2000a, 2000b, 2001). Core of this study is located in the lower NEADW.

2. Material and methods

2.1. Core PP10-17

Data for this work come from core PP10-17, retrieved in 2010 at 2880 mwd (43° 58.91 N - 03°14.02 W; Fig. 1) during the SARGASS