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Rapid bottom-water circulation changes during the last glacial cycle in the coastal low-latitude NE Atlantic

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ABSTRACT

Previous paleoceanographic studies along the NW African margin focused on the dynamics of surface and intermediate waters, whereas little attention has been devoted to deep-water masses. Currently, these deep waters consist mainly of North Atlantic Deep Waters as part of the Atlantic Meridional Overturning Circulation (AMOC). However, this configuration was altered during periods of AMOC collapse. We present a high-resolution reconstruction of bottom-water ventilation and current evolution off Mauritania from the last glacial maximum into the early Holocene. Applying redox proxies (Mo, U and Mn) measured on sediments from off Mauritania, we describe changes in deep-water oxygenation and we infer the evolution of deep-water conditions during millennial-scale climate/oceanographic events in the area. The second half of Heinrich Event 1 and the Younger Dryas were recognized as periods of reduced ventilation, coinciding with events of AMOC reduction. We propose that these weakening circulation events induced deficient deep-water oxygenation in the Mauritanian upwelling region, which together with increased productivity promoted reducing conditions and enhanced organic-matter preservation. This is the first time the effect of AMOC collapse in the area is described at high resolution, broadening the knowledge on basin-wide oceanographic changes associated with rapid climate variability during the last deglaciation.

Introduction

Greenland ice-core records show that climate amelioration during the last deglaciation in the North Atlantic and surrounding regions was not smooth but rather included a series of abrupt changes and reversals (e.g., Dansgaard et al., 1993; Grootes and Stuiver, 1997). Our understanding of rapid climate changes, and the role played by ocean circulation through heat and salinity redistribution, still remains incomplete. This is partly due to the scarcity of suitable sedimentary material exhibiting high sedimentation rate and containing appropriate proxy variables that are able to resolve the timing and phasing of atmospheric and ocean responses during abrupt climate reversals, such as the Heinrich Events (HEs), Bølling–Allerød (B–A) and Younger Dryas (YD), thus undermining efforts to document the role played by ocean circulation during these events. The significance of oceans in global redistribution of heat and their ability to switch between different states of equilibrium have suggested that changes in the Atlantic Meridional Overturning Circulation (AMOC), and associated modes of deep-water formation, were responsible for the sharp climate shifts seen in Greenland ice-core records (e.g., Rahmstorf, 2002). Several of these rapid AMOC shifts since the last glacial maximum (LGM) had a global imprint detected at localities at different latitudes, such as the Southern Iceland Rise (Thornalley et al., 2011), the Bermuda Rise (Hall et al., 2011; McManus et al., 2004), or the Southern Ocean (Rutberg et al., 2000), though their effect in the eastern North Atlantic is still poorly described (e.g., Chapman and Shackleton, 1998; Skinner and Shackleton, 2006), particularly for deep-water masses. Furthermore, a decreased AMOC could facilitate the intrusion of deep Antarctic Bottom Waters (AABW) flowing northwards along the eastern margins (e.g., Labeyrie et al., 2005; Skinner and Shackleton, 2006).

Due to its location on the easternmost border of the North Atlantic Subtropical Gyre, the upwelling system off NW Africa is very sensitive to variations of the AMOC (Kim et al., 2012). In addition to surface-water processes (Romero et al., 2008; Kim et al., 2012), variations of deep-water conditions underlying this highly productive area are also recorded in down-core sediments (Filipsson et al., 2011). Thus, it is important to distinguish between the effects of oxygen consumption related to export of organic matter and the result of decreased deep-water ventilation. Hence, interpreting the record of deep-water conditions linked to deep currents, compared to the possible effect of primary

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productivity on the geochemical conditions at the sediment–water interface, can deliver important insights for the interpretation of the local paleoceanographic setting and its possible extrapolation to other regions of the North Atlantic Ocean.

Much attention has been paid to processes and mechanisms that occurred during short-term Quaternary climate variations in the lower atmosphere in NW Africa (de Menocal et al., 2000a,b; Kuhlmann et al., 2004; Kim et al., 2007; Mulitza et al., 2008), and the adjacent upper waters (Romero et al., 2008). However, much less is known about bottom-water processes affecting the paleoceanographic signal preserved in the sedimentary record. To assess variations of deep-sea conditions off Mauritania, we build on Romero et al. (2008), Filipsson et al. (2011) and Kim et al. (2012) and reconstruct redox conditions and their significance for deep-water circulation during the last glacial cycle in the gravity core GeoB7926. We use a set of geochemical proxies for oxygen availability, sedimentary regime and paleoproductivity. Mo/Al and U/Al ratios and their relative co-variation were used to infer down-core variations in redox conditions. The Mn/Al profile allowed the reconstruction of oxidation fronts in the sedimentary column. K/Al and Ca/Al were used as proxies for variations in the sedimentary regime, and C_{org} and C_{org} Accumulation Rate (AR) served as paleoproductivity indicators.

Materials and methods

Core GeoB7926 and study area

Our high-resolution record was obtained from the gravity core GeoB7926, (20°13′N, 18°27′W, 2500 m water depth, Fig. 1, 1328 cm length). We present results for the depth interval between 113 and 803 cm (~10–25 ka). The dominant lithology is foramifer-bearing nannofossil or diatom ooze, with short intervals marked by clay and quartz-bearing beds and a few turbidite layers in the upper 820 cm (Romero et al., 2008). This core was recovered below the major upwelling region along the northwestern African continent (Romero et al., 2008). The Mauritanian shelf is generally narrow (about 45–55 km wide) and the continental slope is about 45 km wide with an average inclination of 2–3°.

Site GeoB7926 is ideally situated to monitor past variations in the climate and hydrography of northwest Africa, being on the confluence of different oceanic currents and within the latitudinal migration of the Intertropical Convergence Zone (ITCZ). The main oceanic currents affecting the area at present (Fig. 1) are the Canary Current (CC) flowing southwards at the sea surface, and the South Atlantic Central Waters (SACW) immediately below (from 200 to

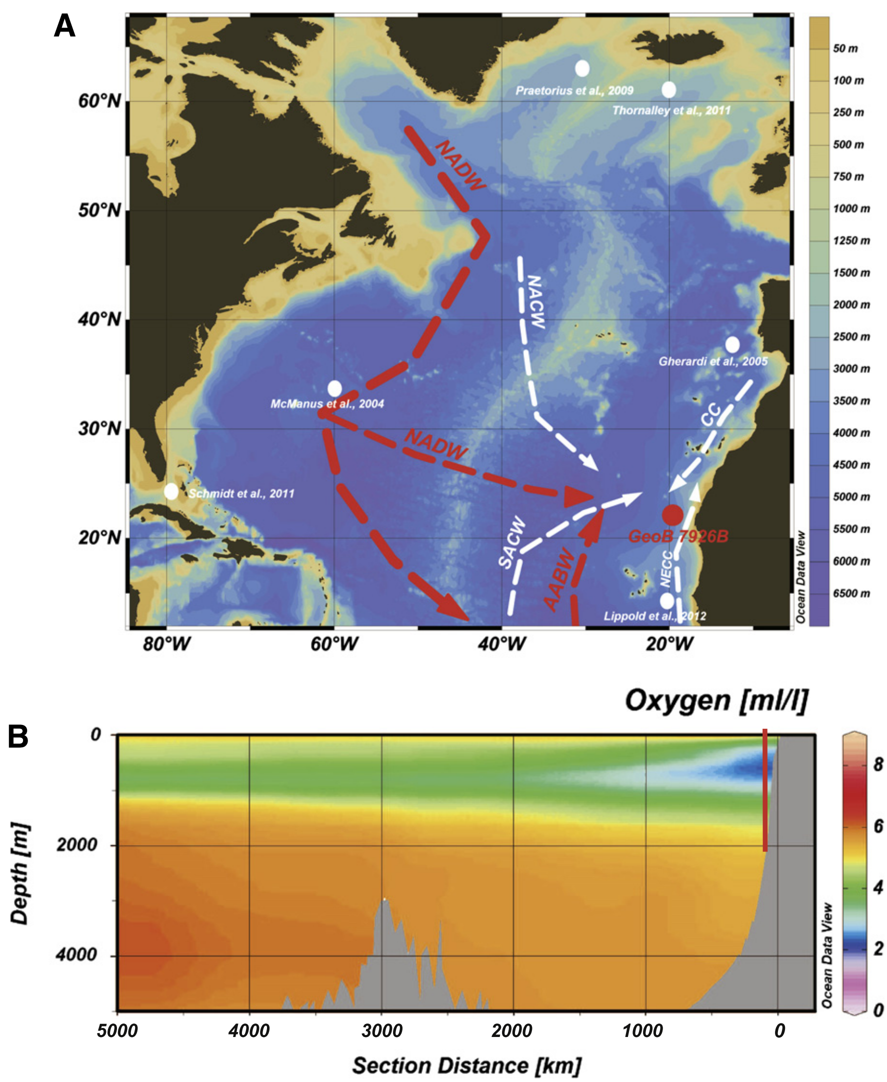

Figure 1. A) Locality map showing the position of site GeoB7926 and location of sites studied by Gherardi et al. (2005), Lippold et al. (2012), McManus et al. (2004), Praetorius et al. (2008), Schmidt and Lynch-Stieglitz (2011) and Thornalley et al. (2011). North Atlantic Deep Water (NADW); Antarctic Bottom Water (AABW); North Atlantic Central Water (NACW); South Atlantic Central Water (SACW); Canary Current (CC); North Equatorial Counter Current (NECC). B) Present-day water column dissolved-oxygen profile. Red vertical line indicates the position of site GeoB7926.