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Palaeogeography, Palaeoclimatology, Palaeoecology 230 (2006) 319–334

PALAEO

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Middle to late Miocene fluctuations in the incipient Benguela Upwelling System revealed by calcareous nannofossil assemblages (ODP Site 1085A)

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Received 21 February 2005; received in revised form 28 June 2005; accepted 29 July 2005

Abstract

Middle to late Miocene calcareous nannofossil data of ODP Site 1085 from the eastern South Atlantic off Namibia were analysed to document spatial and temporal changes in surface-ocean circulation, upwelling initiation, and associated productivity.

Our data show that calcareous nannofossils constitute a significant part of the carbonate fraction throughout the investigated interval from 12.5 to 7.7 million years (Ma). Highest numbers of calcareous nannofossils (up to $38{,}000 \times 10^6$ nannofossils g^{-1} sediment) were observed during the intervals 9.9 to 9.7 and 8.7 to 8.0 Ma. These elevated numbers of calcareous nannofossils may generally be linked to the initiation of upwelling at about 10 Ma in the studied region. In contrast, diminished numbers of calcareous nannoplankton, as in the interval 9.6 to 9.0 Ma, probably characterise time intervals of weaker productivity resulting in a decrease of nannofossil carbonate contents in the sediments of Site 1085. This decrease in nannofossil production could be one possible explanation for the major $CaCO_3$ depression in between 9.6 and 9.0 Ma. Coccoliths of the genus *Reticulofenestra* are the most abundant taxa. Their occurrences are characterised by changes in the investigated time interval. In addition, *Coccolithus pelagicus*, *Calcidiscus leptoporus* and *Umbilicosphaera* spp. contribute a common part of the assemblage. Calcareous nannofossils account for more than half of the carbonate, with peak contribution up to 80% at 8.8 Ma.

Keywords: Calcareous nannoplankton; Namibia upwelling; Paleoceanography; Paleoecology; Miocene; South Atlantic

1. Introduction

The Middle to late Miocene is known as an interval of major changes in the climate system, such as the expansion of the Antarctic ice sheets, the cooling of surface and deep water masses, as well as the start of both Isthmus of Panama and Himalaya uplift (e.g., Zachos et al., 2001). These changing boundary conditions had significant impacts on ocean circulation, nutrient supply and, thus, on the productivity of the oceans. Previous investigations of the Miocene his-

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doi:10.1016/j.palaeo.2005.07.022

tory of the upwelling off southwest Africa concluded that the onset of high productivity was at about 10 Ma (e.g., Siesser, 1980; Meyers et al., 1983) and postulated that the modern Benguela Current and related upwelling migrated progressively from south to north within the late Miocene and Pliocene (Diester-Haass et al., 1990). Subsequent investigations on lithologic changes reflected by light–dark sediment cycles corresponding glacial interglacial successions in Pliocene and Miocene times were interpreted as reflecting shifts in the course of the Benguela Current main flow (Diester-Haass et al., 1992) and/or changes in the nutrient content of the upwelled waters linked with global hydrography (Hay and Brock, 1992).

Within this time interval, several especially remarkable paleoceanographic events occurred which are summarized as the so-called ‘Carbonate Crash’. During about 12 to 9 Ma, several sharp drops in $CaCO_3$ accumulation happened, in particular in the equatorial latitudes of the Pacific and Indian Oceans (e.g. Peterson et al., 1992; Berger et al., 1993; Farrell et al., 1995; Lyle, 2003), in the equatorial Atlantic (King et al., 1997), and in the Caribbean Sea (Roth et al., 2000). Changes in deep-water circulation, shoaling of the calcite compensation depth (CCD), and shallow-deep fractionation were generally considered as possible causes, although the ‘Carbonate Crash’ remains poorly understood. Recently, this event has also been described in the southeast Atlantic Ocean (Diester-Haass et al., 2004). The authors proposed an increase in the delivery of lithogenic matter from the Oranje River as principal cause of the ‘Carbonate Crash’ off southwest Africa since no clear evidence for carbonate dissolution was found. However, their interpretations are mainly based on the sand-fraction, which is only about 2–3% of the total sediment, whereas the bulk of the material is rather fine-grained nannofossil ooze (Wefer et al., 1998). The most pronounced carbonate crash event VI from 9.6–9 Ma was linked to an overall increase in nutrient flux into the world’s oceans and therefore to the development of poorly ventilated intermediate to deep waters or at least an expansion of the oxygen minimum zone at the continental slope (Diester-Haass et al., 2004; Westerhold et al., submitted).

Although calcareous nannofossils are the main contributers to the carbonate depositional system, they have not been studied in detail for this time interval. This is surprising, since calcareous nannoplankton is known as a sensitive indicator of environmental conditions because it directly depend on temperature, salinity, and nutrients, as well as the availability of sunlight (e.g., Giraudeau, 1992; Winter and Siesser, 1994). This plankton group responds to fluctuations in climate as well as changes in surface-water conditions. The potential of coccolithophores as paleoproxy for reconstructions of Quaternary surface-water conditions in the area off southwest Africa has already been shown by various authors. Core-top studies reveal a good correspondence of certain species and characteristic assemblages with oceanographic features of the overlying water masses (e.g., Giraudeau and Rogers, 1994; Baumann et al., 1999; Flores et al., 1999; Böckel and Baumann, 2004). In addition, shifts in species composition observed in several sediment cores were attributed to changes in upwelling intensity and eddy formation (Winter and Martin, 1990; Baumann and Freitag, 2004) or frontal movements (Flores et al., 1999).

In this study, we present middle to late Miocene calcareous nannofossil data from the eastern South Atlantic off Namibia. The studied ODP Site 1085 is located on the continental slope close to the mouth of the perennial Oranje River. The investigated time interval from 12.5 to 7.7 Ma is characterised by at least six ‘Carbonate Crash’ events (Westerhold et al., submitted for publication), which are assumed to be caused either by dilution due to enhanced terrigenous input linked to sea level lowering or by dissolution due to enhanced inflow of corrosive Southern Component Water (SCW) during Miocene glacial events. Besides dilution and/or dissolution the ‘Carbonate Crash’ events could also be explained by changing coccolithophorid assemblages. To test this hypothesis, this site has been investigated for its calcareous nannofossil composition, absolute numbers and relative abundances, and their calcareous nannofossil carbonate content. This approach allows us to assess the significance of calcareous nannofossils in sediments where planktic foraminifera are scarce and, in addition, the comparison of this data helps us to reconstruct some of the environmental changes at the onset of the upwelling off southwest Africa.