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Seasonal export and sediment preservation of diatomaceous, foraminiferal and organic matter mass fluxes in a trophic gradient across the SE Atlantic

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Abstract

Seasonal deposition fluxes of sinking phytoplankton, zooplankton and major mass compounds (i.e. calcium carbonate, biogenic opal and organic matter), intercepted by deep-moored sediment traps, are contrasted with their sediment accumulation rates over the 2700 m deep central Walvis Ridge in the oligotrophic SE Atlantic. These data provide the first seasonally resolved record of biogenic particle fluxes in the South Atlantic Central Gyre and serve as the oligotrophic end member of a gradient across the Benguela system to the highly productive coastal upwelling off Namibia. Maximum fluxes at the central Walvis Ridge were deposited in early austral spring, following winter deepening of the surface mixed layer and associated nutrient entrainment. Nearly 25% of the annual mass flux arrived in October, when sea surface temperature rose, deep vertical mixing halted and surface production collapsed. The annual flux of diatoms was dominated by small specimens of *Nitzschia bicapitata* (60%) whereas *Globorotalia inflata* dominated the foraminiferal fluxes (25%). Diatom diversity dropped significantly during the bloom periods, when up to 80% was composed of small *N. bicapitata*, but foraminiferal diversity remained about constant. The diatom flux maximum, together with those of biogenic silica and organic matter, preceded those of the foraminifera, pteropods, carbonate and total mass by 1 week. Fluxes of the left- and right-coiled shells of the deep-dwelling foraminifer *Globorotalia truncatulinoides* peaked in different seasons, a distinctive ecological behaviour which merits their taxonomic recognition as separate species. These findings testify to recent evidence for the existence of several genetic species within *G. truncatulinoides* and now suggest that such species may also have different seasonal responses.

The Benguela trophic gradient showed a shoreward increase in particle fluxes, but differences were surprisingly small, testifying to only moderately enhanced export productivity and deposition at the Namibian margin relative to the oligotrophic central gyre. From the open ocean toward coastal upwelling, small and weakly silicified diatoms were substituted by other, larger and more heavily silicified species, possibly in response to decreased silica limitation. Foraminiferal deposition fluxes were increasingly dominated by *G. inflata*, accompanied by a change-over from many

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warm- to few cold-water minor species. The late winter maximum at the Namibian margin and the early spring maximum at the central Walvis Ridge were generated by the same process of collapsing surface productivity in response to the shut down of nutrient entrainment at the winter to summer transition, although delayed by up to 2 months in the Central Gyre. At the sediment–water interface, intense degradation of organic matter and biogenic silica resulted in poor preservation accompanied by pronounced changes in the species composition of siliceous phytoplankton. Of all particle groups at the central Walvis Ridge, only the export of foraminiferal shells appeared to be fully transferred into the sediment, and through their species assemblage to provide a sedimentary record of past seasonal productivity conditions of the upper ocean.

Keywords: Planktic foraminifera; Diatoms; Seasonal export and deposition flux; SE Atlantic; Sediment preservation; *Globorotalia truncatulinoides* (sin), *Globorotalia truncatulinoides* (dex); *Globorotalia inflata*; *Nitzschia bicapitata*

1. Introduction

Planktic foraminifera and diatoms are perhaps the most important global producers of carbonate and silicate particles in the pelagic ocean, respectively (e.g. Lisitzin, 1985; Schiebel and Hemleben, 2000). Their biogeography is governed by ocean circulation, ambient temperature, light and nutrients among other factors, in the upper water column where they live (e.g. Burckle, 1978; Hemleben et al., 1989; Wefer et al., 1999). These properties together characterise productivity regimes with which specific foraminiferal or diatom species are associated. This tight relationship between species distribution patterns and environmental characteristics allow a first order approximation of past pelagic ecosystems to be reconstructed from sediment cores. Our poor understanding of the eco-physiology of modern species, however, limits the robustness of palaeoceanographic interpretations. One complicating factor is that diatoms and foraminifera often show strongly seasonal export fluxes in response to the changing oceanography (e.g. Thunell and Honjo, 1987; Deuser and Ross, 1989; Sautter and Sancetta, 1992; Schiebel and Hemleben, 2000; Romero et al., 2002; King and Howard, 2003). In addition, the plankton deposited is modified by diagenesis during burial, which may introduce selective preservation effects (e.g. Treppke et al., 1996a; Koning et al., 2001; Conan et al., 2002; Bárcena et al., 2004).

In this study we quantitatively analyse the seasonal deposition fluxes of diatoms and planktic foraminifera along with related major flux constituents (i.e. calcium carbonate, biogenic opal and organic matter) collected by time-series sediment traps on the central Walvis Ridge (CWR) and contrast the annual deposition fluxes with the accumulation fluxes in the surface sediment directly beneath the traps. We aim to document changes in magnitude, composition and timing of the particle fluxes and examine the importance of the spring bloom within the Benguela ecosystem. Furthermore, we quantify sediment preservation and address the impact of interannual variability at the same site. Previous studies of the spatial and temporal response of calcareous and siliceous microplankton have been mainly focused on the highly productive systems associated with seasonal or year-round Benguela upwelling along the African continental margin (e.g. Berger and Wefer, 1990; Giraudeau, 1993; Fischer and Wefer, 1996; Treppke et al., 1996b; Müller et al., 1997; Romero et al., 2002). The new data from the CWR site situated in the oligotrophic South Atlantic Central Gyre allow us to assess the trophic gradient across the Benguela Current from the open SE Atlantic (own data from CWR site) to coastal upwelling off Namibia (NU site, Romero et al., 2002, and WR1-4 sites, Fischer and Wefer, 1996; Treppke et al., 1996a).

2. Material and methods

2.1. Hydrographic observations

At the central Walvis Ridge site (CWR; Fig. 1) the entire water column was profiled during three MARE cruises using a Neill-Brown CTD-rosette sampler operated at JGOFS standards or better (Veth, 2000). We