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Two abyssal sites in the Southern Ocean influenced by different organic matter inputs: Environmental characterization and preliminary observations on the benthic foraminifera

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Abstract

The abundance and diversity of the deep-sea benthos are intimately linked to inputs of organic matter from the euphotic zone. However, it is often difficult to isolate the influence of surface productivity on benthic ecosystems from other environmental factors. To this end, two abyssal sites (~4200 m water depth) located under contrasting productivity regimes around the Crozet Plateau, in the Indian Ocean sector of the Southern Ocean, were sampled during the austral summer of 2004/2005. One site (M5), east of the Crozet Isles, was located beneath an area where there was an enduring seasonal phytoplankton bloom. The second site (M6) was located in an oligotrophic high-nutrient low-chlorophyll (HNLC) region to the south of the islands. Organic fluxes to the seafloor at these sites are thought to reflect the overlying productivities, so that the benthic environment to the east of the islands was more eutrophic than at the southerly station. All other environmental variables were similar at the two sites, which are located just 460 km apart.

The concentrations of chlorophyll-*a* and total organic carbon in the surficial sediments were significantly greater at the relatively eutrophic site, east of the islands (M5), than at the southerly site (M6). Total nitrogen, however, was similar at both sites. Significantly higher phytopigment concentrations were observed in the surficial sediments at the eutrophic site; in particular, the concentration of chlorophyll-*a* was 3 times greater than at the southern site, although the freshness of the labile component, as measured by chlorophyll-*a* to pheophorbide ratio, was not different between sites. These results confirm that fluxes of organic matter to the seafloor were higher at the site located beneath the bloom region. This was reflected in the abundance and diversity of live (stained) and dead benthic foraminifera (>125 μm), which were greater at the eutrophic site. The species composition of the dead foraminiferal assemblages were similar at both sites, however, and were dominated by *Nuttallides umbonifera*, *Pullenia bulloides*, and *Melonis pompiloides*. An exception was the "phytodetritus species" *Epistominella exigua*, which was more abundant at the eutrophic site, indicating a larger seasonal component to the export under the bloom region. Differences in the organic matter input regimes at the two sites appear to influence the abundance and diversity, but not the overall species composition, of the foraminiferal assemblages.

Keywords: Deep sea; Abyssal; Organic fluxes; Photosynthetic pigments; Total organic carbon; Benthic foraminifera

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1. Introduction

The Indian sector of the Southern Ocean is one of the remotest locations in the world ocean. In addition, the often unwelcoming sea conditions and the general difficulties associated with sampling have resulted in a paucity of information on the deep-sea benthic environments in this region (Gaillard, 1997). The Crozex cruises, carried out in November 2004–January 2005, presented an opportunity to obtain benthic samples from this area (Pollard et al., 2007a). This is important to the overall aims of the Crozex program, as understanding the relationships between water-column processes and the benthic environment is critical for carbon cycling models, flux budgets, ecology, and palaeoceanographic interpretations.

It is thought that changes in surface-water productivity drive variations in the biodiversity of deep-sea sediments (Levin et al., 2001; Snelgrove and Smith, 2002; Lambshead et al., 2002). Biogeochemical provinces evident in surface waters (Longhurst, 1998) are mirrored in benthic community structure at the broad scale (Sokolova, 2000). However, the relationship between the two is not simple; for instance, dramatic changes in megafaunal species dominance in the abyssal North Atlantic (Billett et al., 2001) do not appear to be related to changes in total export flux (Lampitt et al., 2001), but instead to changes in the composition of the organic matter arriving at the seafloor (Billett and Rice, 2001; Wigham et al., 2003). To further understand the link between organic fluxes and processes occurring at the seafloor, the "Benthic Crozex" program investigated the variation in the response of benthic ecosystems to the differing productivity regions apparent around the Crozet Plateau.

Here we provide preliminary descriptions of two benthic sites, located to the east and south of the Crozet Isles at approximately 4200 m water depth, based on samples taken during the austral summer of 2004/2005 (R.R.S. *Discovery* cruises 285/286; Pollard and Sanders, 2006). The sites were chosen so that they were both situated at the same water depth, in the same physical (topographic and hydrographic) setting, with no physical barrier between them, and possessed an essentially flat area large enough to allow for trawling for megafauna. Here we describe the bathymetry of the sampling area, sedimentary composition, detailed analyses of phytopigments, and elemental (CHN) analyses of the sediments. Based on satellite images of surface productivity, we hypothesized that differences would exist in the amount of organic matter reaching the seafloor at these two sites, which could be reflected in the benthic faunas. To test this hypothesis, we undertook a preliminary analysis of the benthic foraminiferal assemblages. Foraminifera were chosen as their abundance and distribution are intimately linked to organic carbon fluxes in the deep sea (e.g., Loubere and Fariduddin, 1999), and their diversity trends often mirror those seen in metazoan taxa (Gooday et al., 2000, 2001). Also, a few opportunistic foraminiferal species are known to undergo rapid population increases in response to seasonal phytodetritus inputs (e.g., Gooday and Rathburn, 1999; Gooday, 2003). The rapid deposition of phytodetritus has been observed at a range of abyssal locations, including oligotrophic regions (Beaulieu, 2002).

Discovery cruises 285/286 were precursors to a dedicated benthic cruise carried out the following year (R.R.S. *Discovery* cruise 300; Wolff, 2006). The results reported here relate mainly to the data generated on the earlier cruises, with supplementary information obtained during the final cruise. Subsequent publications will focus on more specific aspects of the benthic ecology of these two areas based on samples collected during the latter cruise.

1.1. The study sites

The Crozet Isles are situated in an area of the Southern Ocean considered to be a high-nutrient, low-chlorophyll (HNLC) region (Treguer and Jacques, 1992). Iron is believed to be the primary limiting factor for phytoplankton growth in this area, with silicic acid imposing a secondary limiting factor on diatoms (Fiala et al., 2004). To the north of the Crozet Isles, however, there is an enduring annual phytoplankton bloom observed in SeaWIFS satellite images from September to January (Pollard et al., 2002; Venables et al., 2007). This bloom is thought to result from natural iron fertilization of seawater from the sediments on the Crozet Plateau (Planquette et al., 2007).

The Crozet region therefore presents a large, clearly defined area with elevated primary productivity, surrounded by oligotrophic waters. There is a systematic correlation between primary productivity in the euphotic zone and organic carbon flux to the seafloor (Eppley and Peterson, 1979; Suess, 1980; Berger et al., 1989; Lampitt and Antia, 1997;