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Benthic foraminiferal distributions on the Uruguayan continental margin (South-western Atlantic) and controlling environmental factors

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ABSTRACT

The data on benthic foraminifera analysed from 110 box-core samples collected on the Uruguayan continental margin (outer shelf and upper and middle slope, between 36.54–34.64°S and 51.66–53.71°W) were used to evaluate the distribution of the benthic foraminiferal fauna and its relationship with selected abiotic parameters. Primary productivity (PP) and the organic flux (Jz) reaching the sea floor were also estimated for comparison with the foraminiferal distributions. The study area was characterised by elevated PP and Jz values, mainly in the southernmost region, which were associated with thermohaline fronts due to the presence of the Subtropical Shelf Front. The dominant identified taxa were *Rhumblerella sepetibaensis* (this is the first study recording the ecology of this species) and the opportunistic species *Epistominella exigua*, *Bulimina* spp. and *Reophax fusiformis*, which displayed maximal densities at the southernmost stations, concurrent with the highest Jz levels. The dominant species and vertical foraminiferal distributions responded to the different environmental conditions impacting the area (e.g. PP, grain size, nutrient content), which were most likely related to the hydrodynamic conditions. Hydrodynamic conditions cause differences in PP according to the locations of water masses and their fronts at the surface, according to the depth and current intensity; they determined energetic differences across the benthic environment, controlling organic matter sedimentation as well as grain size, which influenced oxygen availability within sediments.

1. Introduction

The organic particle flux generated by surface waters with high primary productivity produces a layer of phytodetritus on the sea floor, which serves as food for benthic organisms (Lochte and Turley, 1988; Graf, 1989; Pfannkuche and Lochte, 1993). In situ data show that there may be up to a 4-week delay between a phytoplankton bloom and phytodetritus deposition over sediments (Fontanier et al., 2003, 2005; Sun et al., 2006; Murray, 2006).

Foraminifera respond to pulses in the organic particle flux by increasing their biomass. A quantitative relationship between the benthic foraminiferal density and ocean surface productivity has been recognised, which constitutes one of the best trophic proxies for the organic carbon flux to the seafloor (Altenbach, 1985, 1988, 1992; Altenbach and Sarnthein, 1989; Herguera and Berger, 1991; Linke et al., 1995; Loubere, 1996; Fariduddin and Loubere, 1997; Martins et al., 2007; Burone et al., 2011). The usefulness of foraminifera in reconstructions of productivity and oxygen availability in bottom waters has become evident in paleoceanographic studies (Kaiho, 1991; Sjoerdsma and Van der Zwaan, 1992; Moodley et al., 1998; Fontanier et al., 2003). This group provides some of the most numerous and easily collectable fossils on which such studies can be based. However, the accurate interpretation of these microfossils to reconstruct past changes depends on knowledge of the recent ecological features of living foraminifera.

To describe the vertical distribution of benthic foraminifera within sediments, these taxa are classified according to their microhabitats as epifaunal taxa (found in the first centimetre of the sediment), shallow infaunal taxa (found in the uppermost 2 cm), intermediate infaunal taxa (from 1 to 4 cm) (Jorissen et al., 1995), and deep infaunal taxa (found deeper than 4 cm). However, most species are able to modify their microhabitat in response to changes in environmental conditions, even temporarily at the same place responding e.g., to increases in organic carbon due to seasonal upwelling (Jorissen et al., 1995; Schmiedl et al., 2000). According to Schönfeld (2002a, 2002b), active microhabitat selection is pursued as a basic strategy of foraminifers to optimise their

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food acquisition, and this better access to food sources consequently stimulates reproduction.

In recent decades, several authors have highlighted the importance of organic carbon fluxes and oxygen concentrations as the main controlling factors explaining the deep sea vertical distribution of benthic foraminifera within sediments (Jorissen et al., 1995; Jorissen, 1999; Fontanier et al., 2002). In this regard, a conceptual model explaining the vertical foraminiferal distribution as a function of the relationship between the main controlling factors stands out (TROX model; Jorissen et al., 1995).

According to this model, in oligotrophic environments, food availability is the factor limiting the vertical distribution of species. In such environments it is expected that low diversities and densities of organisms will be found, limited to the topmost sediment layer, where the scarce food that arrives is rapidly consumed. In contrast, in eutrophic environments, the oxygen concentration acts as the limiting factor, with interstitial oxygen being consumed due to the high aerobic organic matter degradation rate in the first millimetres of the sedimentary column. Although there may be high contents of organic matter available in deep layers, the lack of oxygen limits the penetration of most fauna, resulting in a low-diversity fauna, but with high individual densities that are limited to the upper sediment strata. Under these conditions, typical infaunal taxa are found in surface sediments. Finally, the maximum penetration within sediments is expected to be found in mesotrophic environments, where organic matter and oxygen availability is observed deep within the sediment column. In these environments, organic particles are introduced within the sediment by bioturbation. The predictions of this model have been fully confirmed by Fontanier et al. (2002).

Finally, it is important to note that the trophic state and other environmental conditions (e.g., energy and nutrient contents) are reflected in benthic foraminiferal assemblages (e.g., in their density, specific composition, diversity and vertical distribution). Thus, knowledge of the foraminiferal community structure makes it possible to infer environmental conditions (Jorissen et al., 2007).

The aim of this report is to contribute to the understanding of trophic processes based on living benthic foraminiferal assemblages and oceanographic conditions on the Uruguayan continental margin (outer shelf and upper and middle slope). Thus, the relationships between this fauna and primary productivity, carbon fluxes and sediment variables are analysed (nutrient content and grain size). Finally, the identification of marker species to organic carbon flux in the area is also expected.

2. Study area

The study area is located on the Uruguayan continental margin (outer shelf, upper and middle slope) between 36.54–34.64°S and 51.66–53.71°W (Fig. 1).

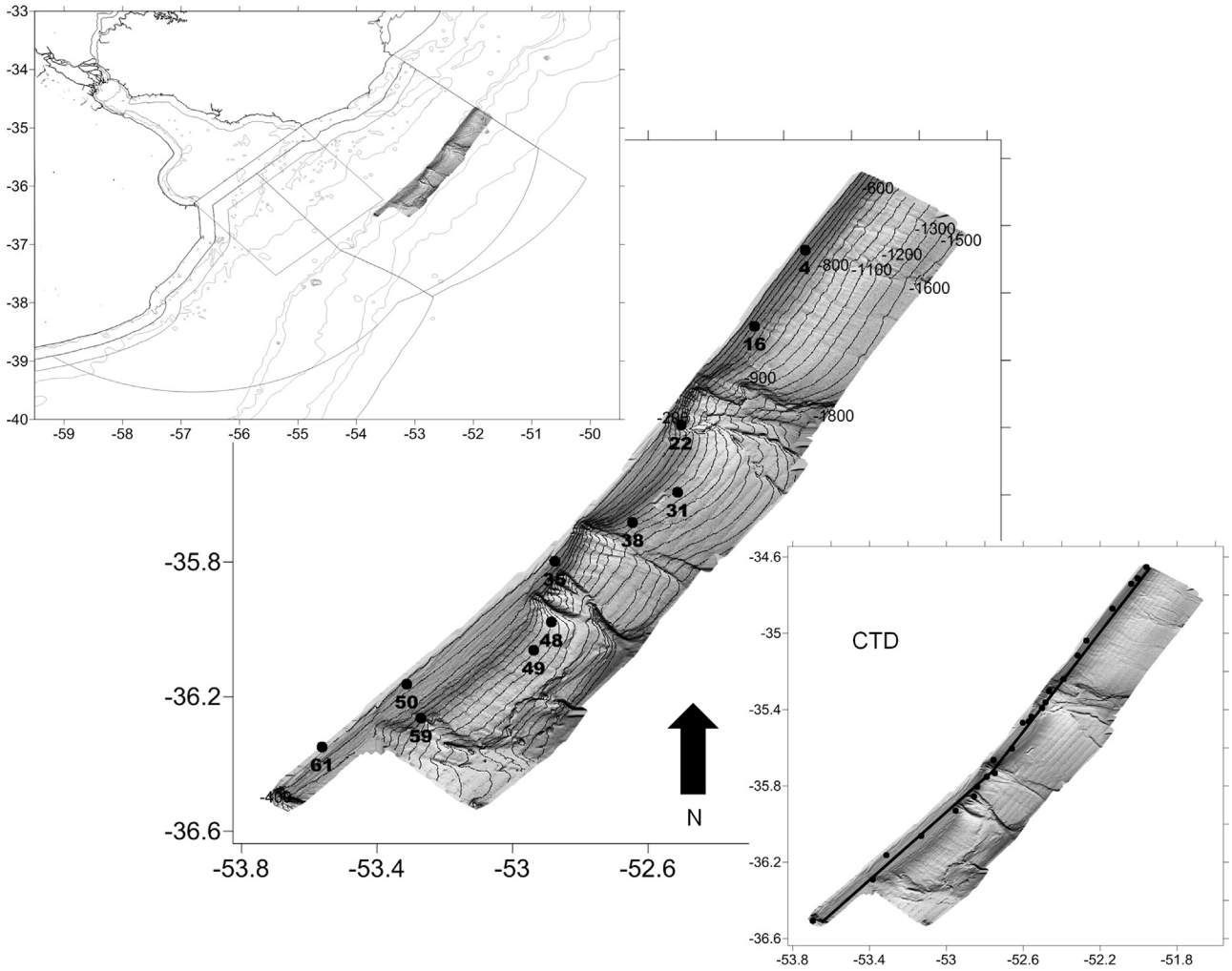

Fig. 1. Study area, bathymetric characteristics and canyons present in the area, sedimentological and microfaunal stations are shown as well as the CTD transect are analysed.