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Live foraminifera from the open slope between Grand Rhône and Petit Rhône Canyons (Gulf of Lions, NW Mediterranean)

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ABSTRACT

We present an ecological study of live (Rose Bengal stained) foraminifera from 6 deep-sea stations sampled on the open slope between the Grand Rhône Canyon and the Petit Rhône Canyon (eastern part of the Gulf of Lions, NW Mediterranean). The 6 stations describe a bathymetric transect from ~350 to ~2000 m depth. The main objective of our study is to investigate the changes of the foraminiferal density, composition and microhabitat along this transect in response to the physico-chemical conditions at and below the sediment–water interface. All our observations underline the general meso-oligotrophic character of our inter-canyon open-slope setting where low-quality organic matter originating from both marine and continental sources settles. The input of organic matter at the sediment–water interface leads to a classical succession of redox reactions within the sediment. The shallowest station (~350 m) appears as an active sedimentary environment, where coarse sediments characterized by lower-quality organic matter and biogenic material accumulate. The 550-m-deep station presents bioturbated sediments with the highest concentration of labile organic compounds. The deeper stations, between about 750 and 2000 m deep, show decreasing sedimentation rates with water depth and are characterized by a background of low-quality organic matter. The foraminiferal changes recorded along the bathymetric transect are related to a complex association of physico-chemical parameters. We think that the quality of organic matter in the surficial sediment, as expressed by the lipid concentration, is the major parameter controlling the foraminiferal distribution at our open-slope stations. From the 550- to the 2000-m-deep station, the foraminiferal standing stocks and diversity decrease with depth, as a result of the increasing scarcity of labile organic compounds at the sediment–water interface. Oxygen concentration and penetration depth and the intensity of bioturbation seem to play only a secondary ecological role. Other, putative hydro-sedimentary processes (winnowing by strong bottom currents, sand-bed deposition) appear as additional parameters controlling the foraminiferal community structure. At the 350-m-deep station, the live foraminiferal fauna can be considered as a non-equilibrium assemblage thriving in frequently disturbed and

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food-impoverished sediments. At the 745- and 980-m-deep stations, the occurrence of suspensivorous epibenthic/epilithic species suggests the presence of strong bottom-water current velocities and the related suspension of organic particles.

1. Introduction

Knowledge about the ecology of deep-sea benthic foraminifera has improved considerably during the two last decades, mainly as a result of the increased demand for information from the paleoceanographical community. This information on benthic foraminiferal ecology was needed for the improvement of benthic proxies (e.g. Gooday, 2003; Jorissen et al., 2007). Ecological studies based on in-situ collection allowed understanding of how the major physico-chemical parameters control the spatial and temporal dynamics of live (Rose Bengal stained) foraminiferal communities (e.g. Corliss, 1985; Gooday, 1988; Mackensen and Douglas, 1989; Corliss and Emerson, 1990; Jorissen et al., 1998; Jannink et al., 1998; van der Zwaan et al., 1999; Kitazato et al., 2000; Fontanier et al., 2002; Schönfeld, 2002; Licari et al., 2003; Hess et al., 2005; Eberwein and Mackensen, 2006; Langezaal et al., 2006; Fontanier et al., 2006; Schumacher et al., 2007; Koho et al., 2007). On the basis of these studies, it appears that the density, composition and vertical distribution of live foraminiferal faunas in the sediment are constrained by organic-matter fluxes derived from primary production, bottom and pore-water oxygenation, sedimentary processes and current velocity at the sediment–water interface (see reviews by Gooday, 2003 and Jorissen et al., 2007). These conclusions based on in-situ observations are largely confirmed by culture experiments (e.g. Heinz et al., 2002; Geslin et al., 2004; Langezaal et al., 2004; Ernst and van der Zwaan, 2004; Nomaki et al., 2005; Ernst et al., 2005). Temporal and spatial dynamics of deep-sea foraminifera are controlled mainly by the organic-matter flux reaching the sea floor (e.g. Altenbach and Sarnthein, 1989; Herguera and Berger, 1991). Densities of hard-shelled foraminifera are generally much lower in oligotrophic basins than in upper-slope areas with high organic-matter export fluxes. Consequently, if the often diverse soft-shelled component (Nozawa et al., 2006) is ignored, then live foraminiferal faunas from oligotrophic settings are often less diverse than those from eutrophic areas (e.g. Jorissen et al., 1998; Fontanier et al., 2002; Licari et al., 2003; Eberwein and Mackensen, 2006). In terms of vertical distribution, foraminiferal faunas from oligotrophic environments are concentrated at the sediment–water interface to take optimal advantage of the scarce organic detritus exported to the sea floor. In environments where high organic-matter fluxes at the sediment–water interface allow the burial of fresh organic matter in deeper sediment layers, some foraminiferal taxa occupy deeper microhabitats. Consequently, the composition of foraminiferal fauna changes according to the trophic levels at the sea floor (Jorissen et al., 1995). After phytoplankton blooms, foraminiferal faunas may respond to seasonal organic-matter supply by a density increase. This response generally leads to the dominance of a number of small-sized opportunistic species that are able to feed on ephemeral phytodetritus, freshly deposited at the sediment–water interface (e.g. Gooday, 1988; Kitazato et al., 2000; Fontanier et al., 2003, 2006; Langezaal et al., 2006). Areas where very high organic-matter fluxes induce severe oxygen depletion in pore and bottom waters are more complex. In such settings, the vertical distribution of foraminiferal faunas below the sediment–water interface is limited by the oxygen penetration depth (OPD), and only some highly tolerant taxa are able to persist at or below the zero-oxygen boundary (e.g. Sen Gupta and Machain-Castillo, 1993; Jannink et al., 1998; Bernhard and Sen Gupta, 1999; Schönfeld, 2001; Schumacher et al., 2007).

Living foraminiferal faunas from canyon systems have been poorly studied, despite the fact that canyons represent complex biotopes where the sedimentary dynamics and organic-matter focusing results in very unusual ecological conditions compared to open-slope environments (Jorissen et al., 1994; Schmiedl et al., 2000; Anschutz et al., 2002; Hess et al., 2005; Fontanier et al., 2005; Koho et al., 2007).

The Gulf of Lions (NW Mediterranean) presents a continental margin that is incised by a succession of canyons separated by narrow open-slope areas (Berné and Gorini, 2005). Complex hydro-sedimentary processes induce a preferential focusing of organic carbon (OC) in the canyon systems, and consequently, less organic matter is deposited at the open-slope areas between the canyons (Buscail et al., 1990, 1997; Buscail and Germain, 1997). Schmiedl et al. (2000) found more abundant and diverse living (Rose Bengal stained) foraminifera in organic-matter-enriched sediments from the axis of Lacaze-Duthiers Canyon (western part of the Gulf of Lions) than in organic-matter-depleted slope sediments. In this paper, we present an ecological study of live (Rose Bengal stained) foraminifera from 6 deep-sea stations sampled on the open slope between the Grand Rhône Canyon and the Petit Rhône Canyon (eastern part of the Gulf of Lions) (Fig. 1). At 200 m depth, this open slope is only ~4 km wide. At 1500 m depth, it is more than 30 km wide. The 6 stations describe a bathymetric transect from about 350 to 2000 m depth. Following the observations of Buscail et al. (1990), Buscail and Germain (1997) and Buscail et al. (1997), the continental slope area is characterized by (1) a lower-OC flux compared to adjacent canyons and (2) a predominance of low-quality organic compounds. The investigation of our 6 stations during the *BEHEMOTH* cruise in September 2006 provided a large environmental data set, which allowed us to investigate the main ecological characteristics of the live foraminiferal faunas sampled in our inter-canyon open-slope area. The main objectives of our study are: (1) to present and to discuss