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Particle transfer and benthic biological processes at continental margins. Results from the Atlantic and Mediterranean ECOMARGE program

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Abstract: The benthic boundary is the ultimate place where decisive processes occur for organic fluxes. It is in the upper layer of sediment that most of the organic matter reaching the bottom is either converted into biomass or loss through burial. Assessing both ways of transformation of POM seems therefore important with respect to a carbon budget in the ocean. A classical approach to the problem is to measure different benthic parameters (e.g., abundance of the different faunal components, viable counts of bacteria, organic matter content in sediment, etc...) from which a "benthic response" to fluxes is assessed. It is emphasized that such an approach brings severe limitations because of sampling bias when operated from the surface and lack of information on the biological and geochemical processes. On the contrary, recent underwater technology developments, especially manned submersible availability for scientific research, allow us to make first attempts to an *in situ* approach of the deep-sea dynamic processes, taking into account the pressure factor. Examples of *in situ* experiments currently runned on the french continental margins are given (e.g., colonization, radioisotope-labelling of sediment and/or organisms, microbial metabolism, bottom oxygen consumption, etc...) and their interest is discussed in the scope of oceanic flux studies.

Introduction

Considering the fate of particulate fluxes in the ocean, the benthic boundary is the ultimate place where decisive processes occur for organic compounds. It is in the sediment, and particularly in its upper layer (first centimeters) that most of the organic matter attaining the bottom is subject to changes leading either to its convevsion in biomass or to its loss through burial. Thus, with respect to a carbon budget in the ocean, it seems important to assess both ways of transformation of particulate organic matter (POM). During the past decade, the approach to the question has been widely descriptive. In a first step, studies were conducted with the aim of quantifying the sedimentary POM and the benthic biomass which are normally related to the pelagic fluxes, especially in the deep zones devoided of autochtonous production. While at the world ocean scale the general trend is a concordance between highest organic accumulations in sediments and more dense benthic populations (ZENKEVITCH *et al.*, 1971) poor agreement (sensu correlation) is found at the level of standard faunal and biochemical parameters. In particular, the fauna aboundance is rather unexplained by factors such as organic carbon and nitrogen (DINET and KHRIPOUNOFF, 1980). Spatial and temporal variability of the factors appears responsible for the lack of correlation, thus leading to a new strategy in the descriptive approach: the time-series surveys.

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Descriptive approach

Such an approach has been developed during the ECOMARGE program on two working sites located at the northwestern Mediterranearn (Gulf of Lions) and northeastern Atlantic (Bay of Biscay, Cap Ferret Canyon).

In the Gulf of Lions, the particulate transfers mainly generated by the Rhône river discharge are forced by the Liguro-Provençal Drift, a powerful hydrodynamic structure of this oceanic area (MILLOT, 1990). This feature induces an asymetry in the advective inputs to the deep varying with in a ratio 1:7 from the east to the west (DURRIEU DEMADRON *et al.*, 1990) open slope recieves a mere 10 to 20% of the flux. An increase of organic carbon is pointed out in the sediments of the lower continental slope.

In the Bay of Biscay, Gironde estuary provides the main source of particulate matter which is channelized towards the deep sea through the Cap Ferret Canyon. Stratification of water masses and setting up of a front at certain periods are the limiting factors for advection. Under these conditions nepheloid layers are detected just below the euphotic zone, close to the canyon walls and in the upper reaches of submarine valley (DINET *et al.*, 1990).

In both areas, all measurements and observations confirm the fertilizing influence of shelf-and slope-derived material and underlines the prominent role of canyons in the energetic transfer to the deep sea. Several biological and biogeochemical parameters were measured repeatedly (i.e., monthly to bimonthly) at the Mediterranean site over a two-years period to evaluate the benthic response to the particulate inputs, mainly advective, on the shelf-slope break. Standing crops as well as activities varied according to the flux seasonal variations estimated by sediment traps deployed in the water column (MONACO *et al.*, 1990) and by chlorophyllous pigments in sediments (GUIDI, 1987; BUSCAIL, 1987; BUSCAIL *et al.*, 1987) and the entire ecosystem appeared forced by phytoplanktonic blooms. Apart from the quantitative fluctuations (estimated range of variation: 1 to 40) of organic material reaching the bottom, the quality of POM is also highly variable with time and is likely a major governing facter for benthic activity. Over a year cycle, the proportion of amino-acids in the upper first cm of sediment may vary between 12 and 43% and the total hydrolyzable fraction ranges from 35 to 73% of the material (BUSCAIL *et al.*, 1990). From the set of data cited above, a tentative budget of organic carbon has been calculated for the Mediterranean site. It shows that some 60% of sedimented POM is remineralized at the water-sedimented interface, the remaining (40%) being lost through burial (BUSCAIL *et al.*, 1990). Following this statement, two remaining questions are: which processes may lead to the recycling of sedimented organic carbon and what is the relative importance of biotic vs. abiotic ways of remineralization? Here are the problems which have originated the experimental phase of the ECOMARGE program presented hereafter.

In situ Experimental approach

Radioisotope-labelling experiments were performed by BUSCAIL (1987, 1991) and GUIDI *et al.* (in prep.) using different organic substrates refering to marine and/or continental material (i.e, ^{14}C-Glutamic acid ^{14}C catechol) injected at sediment-water interface samples taken from box cores.

Analyzing the ^{14}C distribution in the upper layers of sediment and adjacent water, several pathways of organic matter transformation have been assessed such as respiration, assimilation, adsorption and polimerization. However because these assays were conducted on board research vessels under atmospheric conditions, their interpretation has been restricted by the fact that pressure, at least a major factor in the deep, was neglected in the protocol.

With the advances in underwater technology accomplished during the seventies, solutions to the problem now do exist. Remote submarine vehicles (ROV) and submersibles are the tools for a heuristic approach to the deep-sea dynamics involving biological and biogeochemical processes. In France, the availability of the IFREMER manned subm ersibles "CYANA" (3000 m) and "NAUTILE" has allowed first attempts to *in situ* measurements of microbial activity in the abyssal zone (CAHET and SIBUET, 1986). An original instrumentation designed by GUIDI and GUIDI (in prep.) for radioisotope-labelling experiments and parallel *in situ* vs. on board atmospheric assays conducted during ECOMARGE operations have confirmed the prominent influence of pressure in deep-sea processes. Uptake of ^{14}C-labelled dissolved and particulate material was found to be much higher at 1000 m depth in the Mediterranean as compared with surface tests (BUSCAIL, 1991; GUIDI, pers. comm.). Although still debated, the hypothesis of rapid processes in the deep-sea (for instance, microbial utilization of ^{14}C-glucose) has received some support from this type of assays (CAHET and SIBUET, 1986). Other evidence of an intense biological activity is also provided by recolonization of defaunated and/or organically-enriched substrates placed on the bottom by "CYA NA" (DINET, unpublished) or in free submarine vehicles (DESBRUYERES *et al.*, 1980). The recent availability of submersibles has allowed to multiply and diversify *in situ* operations at the sediment-water interface (e.g., sediment and organism sampling, water filtering, trap deployment, video recording, etc...) and particularly to conduct them in a very accurate way, under visual control. It is clear that such methodological progress might significantly improve our knowledge of energy echange processes and should preferentially be used in the study of the deep-sea benthic boundary layer.

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