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 faunai 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 subsurface 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 conversion 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 devoid of autochthonous 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 abundance 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.

Descriptive approach
Such an approach has been developed during the ECOMARGE program on two working sites located at the northwestern Mediterran-
near (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 asymmetry 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 receives 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, Girone 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 factor 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 (e.g. 14C-Glutamic acid 14C catechol) injected at sediment-water interface samples taken from box cores.

Analyzing the 14C 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) et "NAUTILE" a
allowed first attempts to in situ measure-
ments of microbial activity in the abyssal
zone (CAHET and SIBUET, 1986). An orig-
inal 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 14C-labelled dissolved
and particulate material was found to be
much higher at 1000 m depth in the Mediter-
ranean as compared with surface tests
(BUSCAIL, 1991; GUIDI, pers. comm.).
Although still debated, the hypothesis of
rapid processes in the deep-sea (for in-
stance, microbial utilization of 14C-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 sub-
marine vehicles (DESBRUYERES et al.,
1980). The recent availability of subsiders-
bs has allowed to multiply and diversify in
situ operations at the sediment-water inter-
face (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 exchange processes and
should preferentially be used in the study of
the deep-sea benthic boundary layer.

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