Riverine Carbon and the Sedimentary Record on the Continental Shelves

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LONG-TERM GOALS

The aim of our contribution (as part of the EuroSTRATAFORM Program) was to improve a more complete understanding of organic matter (OM) transport, deposition and burial in the Gulf of Lions and Adriatic Sea. Continental shelves represent the largest modern repository of particulate organic carbon (OC); nevertheless, some major river systems may be sites where a substantial portion of terrestrial inputs bypass the shelf, and are discharged onto the continental slope and beyond. Characterizing the origin of OM delivered to the ocean and defining the processes that affect its ultimate burial may provide a better understanding of the mechanisms that influence organic carbon preservation in the ocean.

OBJECTIVES

During this year our research was mainly focused on the Gulf of Lions: collecting sediment samples and carrying out elemental and stable carbon isotopic analysis. The field work was carried out in the Gulf of Lions taking into account three different depositional elements: the prodelta Rhône area, the continental shelf, and the array of submarine canyons, which incise the shelf and the slope. Our approach was to use the signature of the organic matter in order to:

1) trace the initial distribution of terrigenous material accumulated in the prodelta Rhône area and follow its transport along the continental shelf;

2) characterize qualitatively the riverine input defining the amount of soil and woody debris, respectively;

3) define the amount of riverine OC sequestered by the canyons and exported towards abyssal plain;

4) verify the influence of minor rivers besides the Rhône river (such as the Têt river).

APPROACH

Terrestrial and marine organic matter burial in marine sediments is an important reservoir, representing the predominant long-term sink in the global biogeochemical cycle of OC (Berner, 1989). Deltas and

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14. ABSTRACT
The aim of our contribution (as part of the EuroSTRATAFORM Program) was to improve a more complete understanding of organic matter (OM) transport, deposition and burial in the Gulf of Lions and Adriatic Sea. Continental shelves represent the largest modern repository of particulate organic carbon (OC); nevertheless, some major river systems may be sites where a substantial portion of terrestrial inputs bypass the shelf, and are discharged onto the continental slope and beyond. Characterizing the origin of OM delivered to the ocean and defining the processes that affect its ultimate burial may provide a better understanding of the mechanisms that influence organic carbon preservation in the ocean.

15. SUBJECT TERMS

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continental shelves, considered to be the main repositories for organic carbon in marine sediments, receive large inputs from both autochthonous and allochthonous sources and account for ~90% of the OC burial in the ocean (Hedges and Keil, 1995). However, these same massive storage systems are often sites of efficient remineralization (Aller and Blair, 2004): some studies suggest that in highly reactive mobile shelf muds, physical reworking, bioturbation, exposure, and reoxidation inhibit high carbon burial (Aller, 1998, Aller and Blair, 2004). In the Gulf of Lions and the Adriatic Sea a simple two-end-member mixing model, in which vascular plant debris is diluted by marine phytoplankton detritus, can describe the composition of OM in coastal marine sediments. The isotopic signature and elemental composition of the sedimentary OC are widely used as proxies for decoding origin and fate of OM on various continental margins. Vascular plants of terrestrial origin exhibit many bulk chemical and isotopic proprieties that distinguish them from marine organisms. For example, the predominance of nitrogen-free biomacromolecules (e.g. tannin, lignin, cellulose, cutin and suberin) over proteins (C:N ≈ 3-4) makes higher plant tissues characteristically carbon-rich (C:N ≈ 20-500) versus phytoplankton (C:N ≈ 6.6) and bacteria (C:N ≈ 4). The organic matter absorbed by soil shows a value between vascular plants and bacteria (C:N ≈ 8-14). Carbon isotopic signatures (δ^{13}OC) can distinguish organic matter photosynthesized by C3 plants (from -25 up to -28 ‰) from temperate marine phytoplankton (from -18‰ up to -22‰) (Hedges et al., 1997).

WORK COMPLETED

Concerning the Gulf of Lions, box cores were collected:

- in the Têt and Rhône delta along shore-normal transects;
- near the heads of Cap de Creus and Lacaze-Duthiers Canyons along transects, as well as a smaller number in the deeper portion of these canyons;
- along a mud wedge on the shelf following the bathymetry of 75 m;

Vertical sediment profiles from selected box and kasten cores were also collected. The samples were collected in October 2004 on *R/V Oceanus* and in February and May 2005 on *R/V Endeavor*. The uppermost and the lowest sediment slices were subsampled from each box-core.

Concerning the Adriatic Sea, we completed the OC analyses. For both the Adriatic Sea and the Gulf of Lions, approximately 750 samples were collected and analyzed for carbon stable-isotopes, OC, and total N determination at ISMAR, using a FINNIGAN Delta Plus mass spectrometer directly coupled to the FISONS NA2000 Element Analyzer.

RESULTS

Gulf of Lions.

Fig. 1 shows the OC content on surface sediments in the GOL. The OC exhibits the highest values in the prodelta Rhône area up to 1.44 %. On going offshore, the OC content decreases rapidly down to 0.46 %. In contrast, the Têt prodelta exhibits lower values ranging from 0.29 to 0.88 %. Consequently, the Rhône plays a much more important role than the Têt in the flux of OC to the sea floor. The sedimentary OC in the prodelta Rhône area is isotopically depleted compared to the material

accumulated on the rest of the shelf (Fig. 2). These depleted values in δ^{13}OC indicate a clear terrestrial OM origin that moving offshore is diluted by marine phytoplankton detritus. The "refractory" organic material delivered by the Rhône, being partially degraded, especially in the soil fraction, is more efficiently accumulated and preserved in the surficial sediment than fresh and "labile" algal compounds. For that reason, the OC content exhibits a drastic drop-off when going offshore far away from any direct terrestrial input. The high correlation (r^2= 0.91) among OC content and δ^{13}OC along a transect across-shelf confirms this (Fig. 3).

The compositional characteristics of OM in the Cap de Creus Canyon indicate a primarily marine source. The samples on the shelf close to the canyon head are still slightly terrestrial, showing isotopically depleted δ^{13}OC values, whereas the deepest samples in the canyon are plainly marine. Based on these OC contour maps, it seems that the organic material from the Rhône prodelta is driven westwards by the LPC (Liguro-Provencal Current), and on its way the OC is degraded efficiently, showing low concentrations (up to 0.10%) at the head of the Cap de Creus canyon.

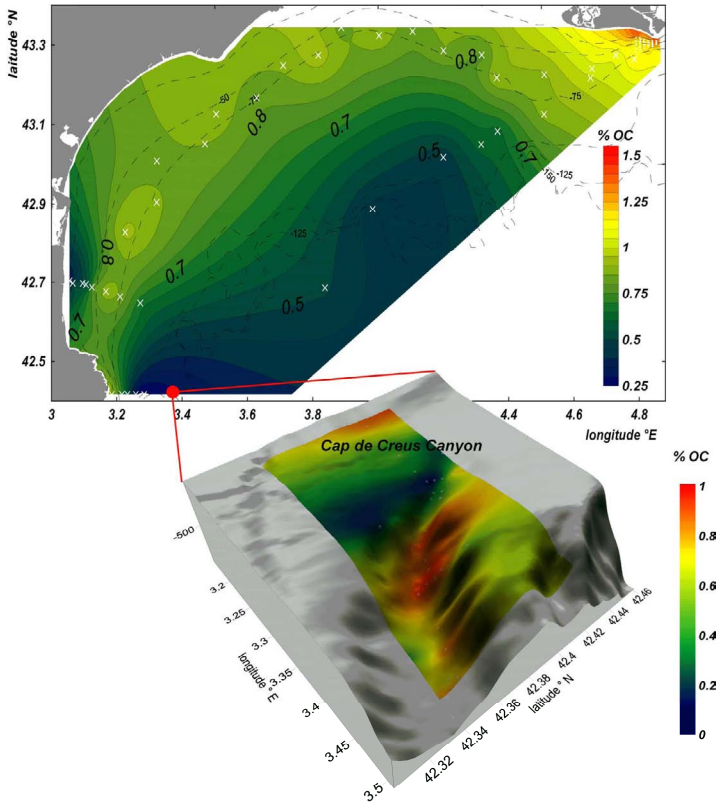

Figure 1. Distribution of OC content (% wt) on surface sediment in the shelf of Gulf of Lions and in the Cap de Crues Canyon. White crosshairs indicate station locations.

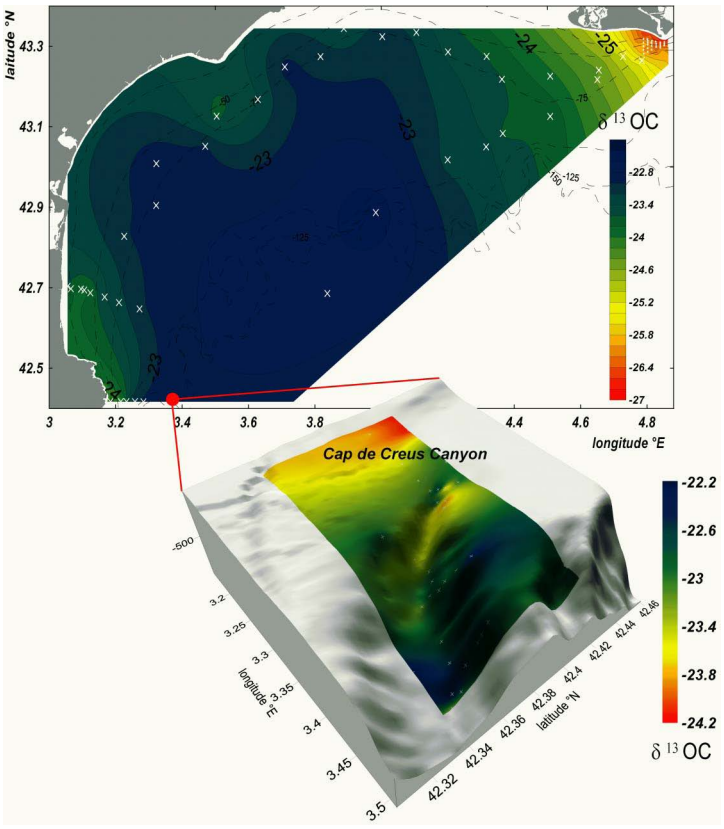

Figure 2. Distribution of $\delta^{13}OC$ (‰) in surface sediment on the shelf of Gulf of Lions and in the Cap de Crues Canyon. White crosshairs indicate station locations.

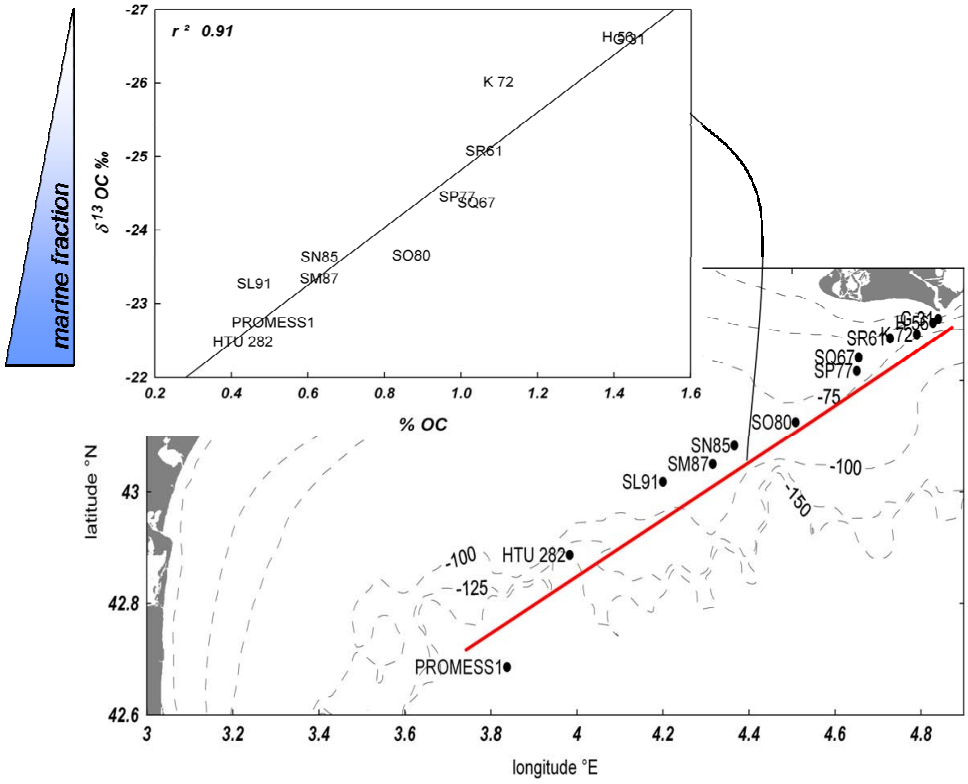

Figure 3. OC content (% OC) and its isotopic OC composition (δ^{13}OC ‰) in surface sediment along a transect across-shelf from the prodelta Rhône area up to shelf break. [The strong correlation (r^2=0.91) indicates the highest contents are associated to the terrigenous material].

Adriatic Sea.

Fig. 4 shows the OC content in surface sediments on the western Adriatic continental shelf. In the Po prodelta, the high primary productivity and the considerable amount of OC delivered by the Po River directly affect the surface sediments. Organic carbon content higher than 1% composes a crushed depocenter developing around the delta, probably as a result of high and rapid sediment accumulation enhanced by large rapidly sinking flocs (Fox et al., 2004), which prevent grain-size sorting. Furthermore, four smaller isolated depocenters, just in front of each distributary, seem to underline the key role of river load on surface marine sediments.

On going southward, the region closest to the Po seems to remain under the influence of organic material supplied to the Po River, which spreads southwards driven by the anticyclonic circulation.

Beyond this region, on the shelf, OC values increase offshore. Because of water dynamics, the river sediment load delivered to the sea is hydraulically sorted in grain size, in accordance with the classic modern sedimentation pattern on continental shelves: costal sands, mid-shelf muds and relict shelf sands further offshore (Brambati et al., 1983). The deposition of fine sediment, which generally has elevated levels of associated OM relative to their coarse counterparts (Hedges and Keil, 1995), strongly influences the OC distribution in surface sediments.

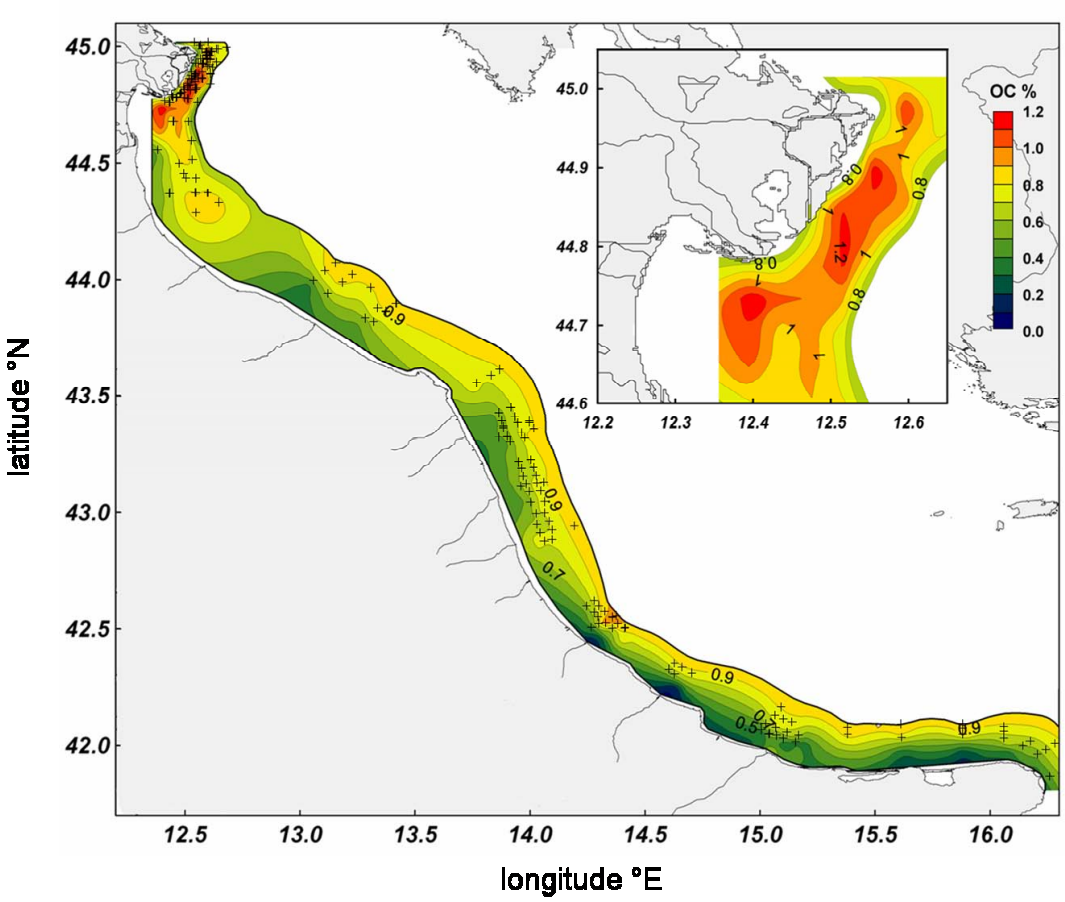

Figure 4. Distribution of OC content (% wt) on surface* sediment *in the western Adriatic Continental shelf. Black crosshairs indicate station locations.

IMPACT/APPLICATIONS

Studying the sedimentary processes, which affect the distribution and preservation of organic matter on the continental shelves will provide key insights to understanding the role this environment as sinks for OC with respect to the global carbon cycle**.**

RELATED PROJECTS

Our research is related to other groups. First we are collaborating with T. Milligan (BIO), in order to examine the relationship between organic carbon and particle grain size.

Second, we are working with D. Orange and A. Garcia (UCSC) in evaluating the origin of anomalous sub-surface shallow gas concentrations in the Rhône prodelta delta and in the Cap de Creus Canyon. Our hypothesis is that, away from the flood-related sediments off the Rhône delta (where methane content is up to 87440 ppm), the organic matter is being reworked and remineralized on its way down the western coast of the Gulf of Lions, so that the recent deposits in the canyon contain little reactive carbon.

Finally, we are cooperating with J. Fabres and A. Calafat (CRG Marine Geosciences) in carrying out elemental and isotopic analysis on suspended material collected with sediment traps deployed in all canyons of GOL. The suspended material collected during flood events (Rhône and Têt) showed a

clear terrestrial source, improving the understanding of the factors that control sediment transfer across shelf breaks.

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