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Temporal variability and composition of settling particle fluxes on the Barcelona continental margin (Northwestern Mediterranean)

by P. Puig[1] and A. Palanques [1]

ABSTRACT

The results of a year-long sediment-trap experiment provide the first direct observations of sediment fluxes to the seafloor on the Barcelona continental margin. Time-series of vertical particle fluxes and major constituents (organic carbon, biogenic silica, calcium carbonate and aluminosilicates) were determined inside and in the vicinity of the Foix submarine canyon from May 1993 to April 1994. The spatial and temporal variability of bi-weekly total mass fluxes indicate significant high frequency variability related to physical and biological processes at this site. The Foix submarine canyon acts as an actual conduit for transport of sediment from the shelf to the slope, and as a mid-slope sedimentary depocenter. The shelf-slope sediment transfer through this canyon is sporadic and takes place during and immediately after an important storm event or a river discharge increase. During periods of low cross-margin sediment transfer injected through the canyon, the vertical flux of particles is controlled by the along-slope geostrophic circulation. Breaking of the summer water stratification and vertical mixing also appears to be a major process which contributes to increasing the vertical flux of particles.

Particle composition inside the Foix submarine canyon does not reflect any significant seasonal variations, but in the adjacent open slope, summer water stratification controls the composition of settling particulate matter. Retention of shelf-derived suspended particles along isopycnals in summer results in a decrease in total mass fluxes and an enrichment of organic carbon and clay mineral content in the settling particulate matter outside the canyon. During the spring biological bloom, the opal content increases particularly on the open slope, but the calcium carbonate does not because the high input of terrigeneous carbonate dominates that from biogenic carbonate production. The aluminosilicates fraction is the largest constituent of the vertical particle fluxes on the Barcelona continental margin, reaching higher percentages inside the Foix submarine canyon.

1. Introduction

During the last few decades, research into particulate matter vertical fluxes has focussed on a variety of aspects: studies of carbon fluxes and the estimation of the organic matter load to the seabed (Suess, 1980; Pace *et al.,* 1987 and Miquel *et al.,* 1994), the transfer of radionuclides through the water column (Kempe and Nies, 1987; Heussner *et al.,* 1990a and Buesseler *et al.,* 1990), the supply of trace elements to the sediment (Jickells *et al.,* 1984 and Grousset *et al.,* 1995) and the study of transport and budget of matter on

1. Institut de Ciencies del Mar (CSIC), Passeig Joan de Borbo s/n, 08039 Barcelona, Spain.

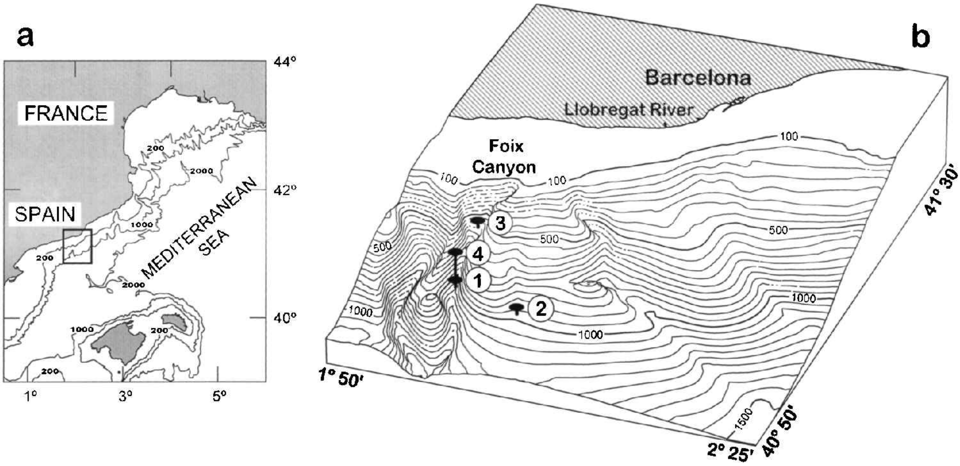

Figure 1. Location of the study area (a), and block-diagram showing trap locations in the Barcelona continental margin (b). Trap 1: mid-canyon near-bottom; Trap 2: open slope near-bottom; Trap 3: canyon head near-bottom; Trap 4: mid-canyon intermediate waters.

continental margins (Biscaye *et al.,* 1988; Monaco *et al.,* 1990 and Biscaye and Anderson, 1994). Settling particles are responsible for much of the transport of matter and energy from the upper ocean to the seafloor (Asper *et al.,* 1992). This transport is especially important in continental margins due to the large material inputs from both terrestrial and high productivity waters of this zone, which play an important role in the global oceanic biogeochemical cycles (Walsh, 1991).

In the context of two multidisciplinary studies of processes which affect biogeochemical fluxes and material budgets in the Northwestern Mediterranean margin (CONCENTRA and EUROMARGE-NB projects), sediment traps were deployed in the Barcelona continental margin simultaneously with other deployments in the Gulf of Lions and Balearic Islands margins.

The hydrographic structure of the Barcelona continental margin is predominantly influenced by the presence of a permanent shelf-slope density front (Font *et al.,* 1988). Associated with this frontal structure, the Liguro-Provenço-Catalan current flows along isobaths from the northeast to the southwest between the front and the upper continental slope. This current represents the major dynamic feature of this region and its structure appears to be an along-slope frontal jet 250 m deep, with velocities of around 30 cm/s and a total flux of 1 Sv (Castellón *et al.,* 1990), although in winter it can reach maximum velocities of 40 cm/s off Barcelona (Castellón *et al.,* 1991).

The study area has a narrow shelf (8 km) with slope gradients of about 0.3–0.7° (Checa *et al.,* 1988), and receives sediment from the Llobregat and Besos Rivers. The most important submarine canyon of this margin is the Foix canyon, which is located in the southern part of the study area (Fig. 1). This canyon is strongly incised on the continental slope and has a very constricted morphology. The canyon head is located in the shelf break at around 90 m depth, and on the upper slope its walls are around 400 m high, reaching maximum gradients of about 23° in some places (Alonso *et al.,* 1984).

The objectives of this paper are: (1) to study the vertical fluxes of particulate matter on the Barcelona continental margin, analyzing their composition and their spatial and temporal variability; and (2) to identify the main processes that control the downward particle fluxes and the shelf-slope sedimentary transfer.

2. Methods

Three mooring lines equipped with four sequential sediment traps were deployed at selected sites of the Barcelona continental slope. The location of the sediment traps is illustrated in Figure 1. Three sediment traps were located 30 meters above bottom (mab), two inside the Foix canyon, at 1180 and 600 m depth (1 and 3 respectively), and one in the interfluve at 980 m depth (2). In the deeper mooring line deployed inside the canyon, another trap was installed in intermediate waters, 500 mab (4).

The sediment traps were Technicap model PPS3, which incorporates a carousel with 12 rotary collectors. The upper part of the internal trap collecting hull is cylindrical with a height of 100 cm and an inner diameter of 40 cm (aspect ratio $H/D = 2.5$), and the lower part is conical with a height of 54 cm and an included cone angle of 34°, which ends in a 10 cm long connecting cylinder with a 5 cm inner diameter. The carousel is controlled by a programmable motor that allows the presetting of variable sampling intervals for each of the 12 sample tubes (Heussner *et al.,* 1990b). In this experiment, the sample collecting interval was set at 15 or 16 days, depending on the month, and the sampling period comprised a complete year from April 1993 to May 1994, divided into two six-month deployments. Gaps in the temporal series were due to accidents caused by fishing activities and by mooring recovery periods.

Before trap deployments, the sample tubes were rinsed and filled with a 5% (~1.7 M) formalin solution prepared from Carlo Erba analytical grade 40% formaldehyde mixed with 0.2 μm filtered seawater to avoid the degradation of organic matter in the trapped sediment. The solution was buffered ($7.5 < pH < 8$) with Carlo Erba analytical grade sodium borate. Formaldehyde was chosen because it appears to be a more effective poison than azide and chloroform for inhibiting microbial activity on organic material and grazing by swimmers (Gundersen, 1988). After the trap recovery, the formaldehyde and the pH were checked to ensure that the solutions remained buffered.

The collected samples were processed in the laboratory according to the method described by Heussner *et al.* (1990b). The total sample was divided into several aliquots to obtain different subsamples for various analyses. Contaminating zooplankton, also called "swimmers," were removed by hand picking under a dissecting microscope using forceps and were stored for further analysis. "Swimmers" are not related to the passively-sinking flux, and they are considered those large zooplankters which have swum into the trap sample tube and been poisoned.

Sample dry weight was determined using three subsamples filtered onto 47 mm diameter and 0.45 μm pore preweighed Millipore filters, rinsed with distilled water and dried at 40°C for 24 h. Total mass flux was calculated from the sample dry weight, the collecting trap area and the time sampling interval.

Organic carbon and calcium carbonate were measured using a Leco induction carbon analyzer. These analyses were duplicated and four subsamples were filtered onto 47 mm diameter preweighed Whatman GF/F glass microfiber filters, previously combusted at 550°C for 24 h. Two subsamples were used to determine the total carbon percentage (TC%) and another two subsamples, previously acidified, were used to determine the organic carbon percentage (OC%). The acidification treatment was performed by adding in sequential steps a few drops of HCl (1M) onto the filter placed in a ceramic sample container until no effervescence was noticed. The difference between the two values is the percentage of inorganic carbon (IC%) which is used to calculate the calcium carbonate percentage ($CaCO_3$%).

Biogenic silica (opal) was analyzed using a wet-alkaline extraction with sodium carbonate using the method described by Mortlock and Froelich (1989). This analysis consisted of a differential wet-chemical extraction into a 2 M Na_2CO_3 solution at 85 °C for 5 h. The wet-chemical dissolution technique appears to be the most versatile in its application to marine samples of various types and compositions (DeMaster, 1991). However, the main difficulty in measuring the biogenic silica content in coastal sediments is extracting the silica from the biogenic phases without extracting silica from the coexisting aluminosilicates. Microscope slides were made in several sediment trap samples to recognize siliceous skeletons and to identify the main organisms contributing to the biogenic silica flux.

The abiogenic component was computed as the difference between the total mass and the sum of the biogenic components (organic matter [twice the percentage of organic carbon], calcium carbonate and opal), as lithogenic components or aluminosilicates.

The mineralogical analysis was made using one subsample retained in a 0.45 μm Millipore filter, rinsed with distilled water and dried at 40 °C for 24 h. X-ray analysis was then carried out by means of a SIEMENS D-500 diffractometer.

The Llobregat daily river discharge was obtained from the "Sant Joan d'Espi" water control station managed by the "Societat General d'Aigües de Barcelona;" and the significant wave height, recorded each three hours by a hydrographic buoy located off the Llobregat River mouth, was supplied by the "Direcció General de Ports i Costes." These data were used to discriminate the effects of river sediment discharge and those caused by the storm sediment resuspension events in the collected particle fluxes.

3. Results

The total mass fluxes of settling particulate matter collected by sediment traps are illustrated in Figure 2. As a consequence of an accident caused by fishing activities, the trap located at the canyon head (trap 3) had a shorter register. Time-series of total mass flux

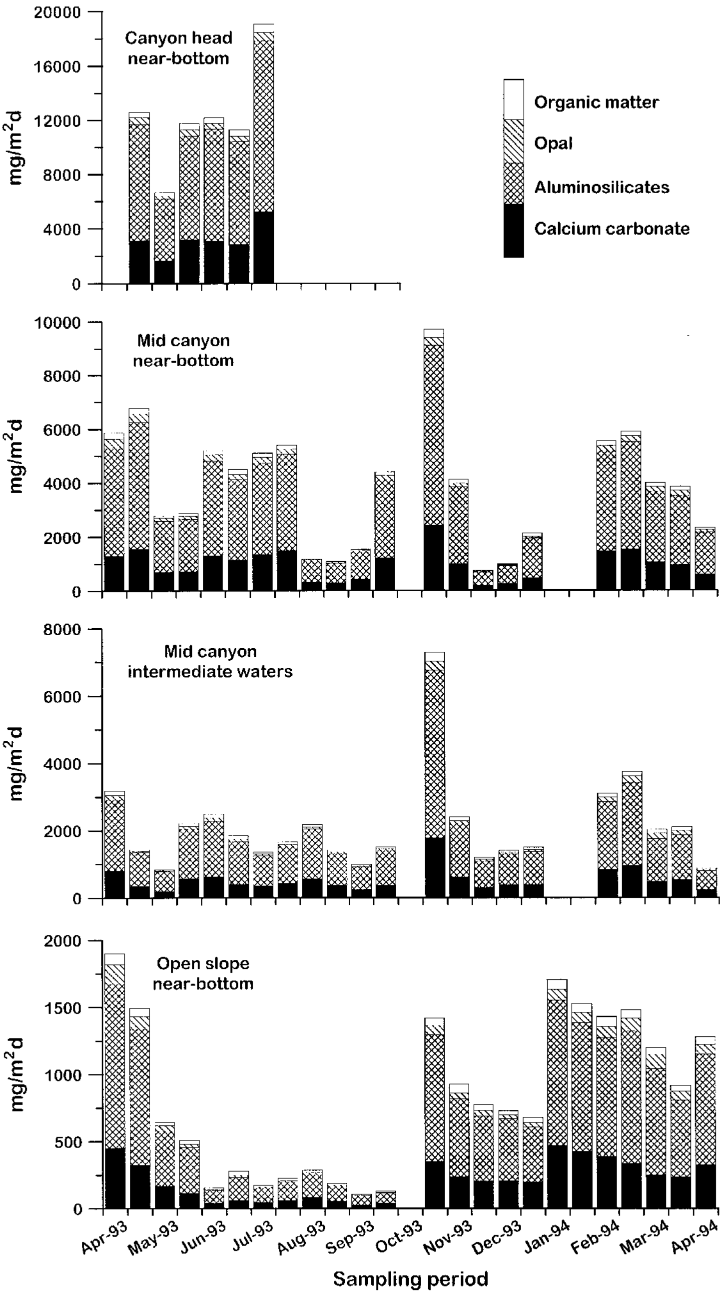

Figure 2. Time series of total mass and major constituents fluxes of particulate matter on the Barcelona continental margin for each sampling site during the period studied.

Table 1. Mean annual values of total mass fluxes and major constituents contents and fluxes in mg/m^{2}d of settling particulate matter in the Barcelona continental margin for each sampling site. Trap 1: mid-canyon near-bottom; Trap 2: open slope near-bottom; Trap 3: canyon head near-bottom; Trap 4: mid-canyon intermediate waters.

	Trap 1		Trap 2		Trap 3		Trap 4	
	%	Flux	%	Flux	%	Flux	%	Flux
Total flux	100.00	3799	100.00	810	100.00	12267	100.00	2058
Organic matter*	3.48	132	5.97	48	3.44	422	4.46	92
Opal	4.02	153	5.53	45	3.61	443	4.12	85
Carbonates	25.65	974	25.59	207	25.91	3178	24.97	514
Lithogenics	66.85	2540	62.91	510	67.04	8224	66.45	1367

*Twice of organic carbon.

show alternating periods of high and low values that indicate a significant high-frequency temporal variability.

The mean annual values of total mass fluxes, listed together with the major constituents content and fluxes for each sampling site, are presented in Table 1. Total mass fluxes varied by more than two orders of magnitude, ranging from a maximum of 19.059 mg/m^{2}d recorded in the canyon head at 600 m depth to approximately 108 mg/m^{2}d recorded outside the canyon at 980 m depth (Fig. 2). In fact, the maximum value corresponded to the last sample collected in the canyon head just before the accident caused by the fishing activities. This sample recorded a total mass flux of 47.203 mg/m^{2}d, more than twice the preceding one, but it was not taken into account due to a probable local overtrapping effect caused by the influence of the trawling resuspension around the trap position. The fact that a simultaneous total mass flux increase was not recorded down canyon supports this interpretation.

Inside the canyon, the mean annual total mass fluxes measured near the bottom decrease from 600 m to 1180 m by a factor of three. However, at 1180 m water depth inside the canyon, the mean annual total mass fluxes increase with depth from 500 to 30 mab by a factor of two, although during periods of minimum fluxes the values are comparable at the two levels (Fig. 2). The mean annual mass flux in the adjacent open slope at 980 m depth is 4.5 times lower than that recorded inside the canyon at a similar depth and 2.5 times lower than that recorded in intermediate waters inside the canyon. However, it is important to point out that during periods of minimum fluxes the values recorded at the interfluve have the same order of magnitude as those recorded inside the canyon at 1200 m water depth.

The content of all major components is quite constant throughout the year, with only slight differences between traps (Fig. 3). As a result of the low variability in the composition of the settling particulate matter during the whole experiment, the major component fluxes have the same temporal and spatial trends as the total mass fluxes (Fig. 2).

The OC content of the settling particulate matter ranges from 1.33 to 5.73% (Fig. 3a). There are slight differences between the values recorded inside the canyon and in the

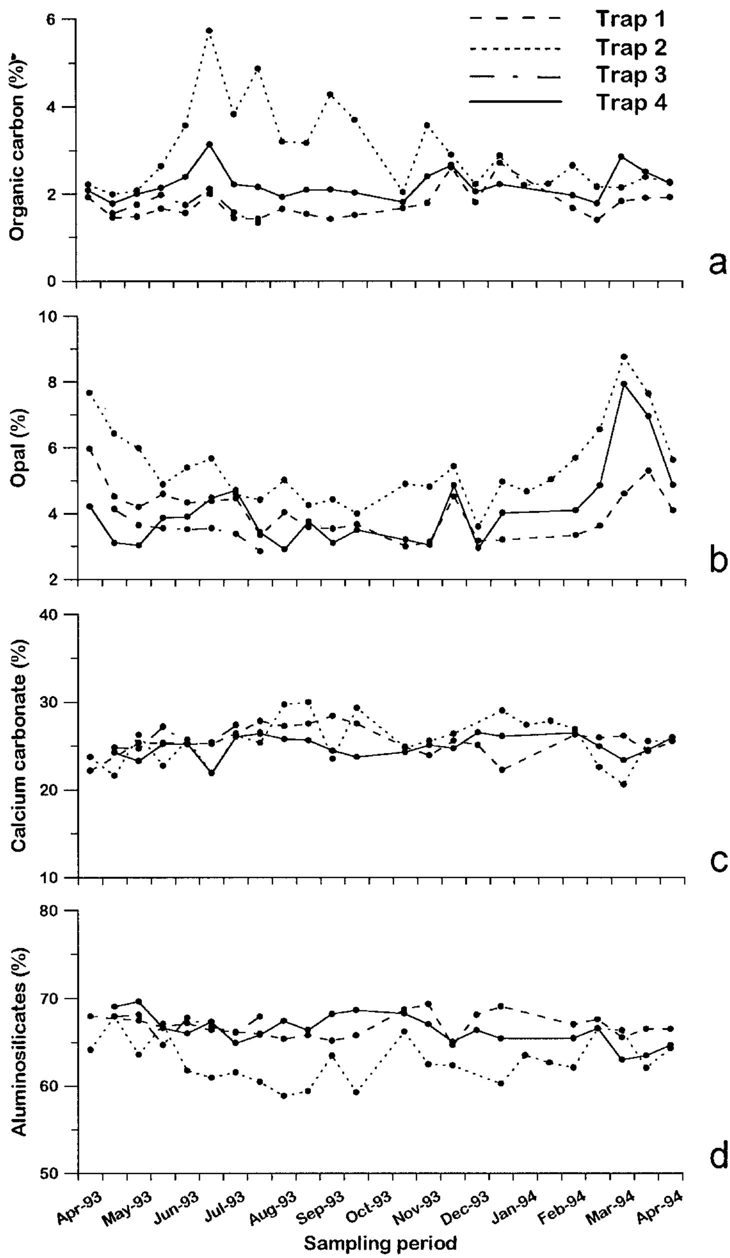

Figure 3. Time series of contents of settling particulate matter on the Barcelona continental margin during the period studied: organic carbon (a), opal (b), calcium carbonate (c) and aluminosilicates (d). Trap 1: mid-canyon near-bottom; Trap 2: open slope near-bottom; Trap 3: canyon head near-bottom; Trap 4: mid-canyon intermediate waters.

adjacent open slope. Inside the canyon and near the bottom, the OC content is generally quite constant (about 1.7%), whereas in intermediate waters the OC percentage is slightly higher than near the bottom during almost the whole year, and particularly during the summer season. At the open slope the OC% content is more variable (2–6%), but it is higher than in the canyon during most of the experiment and particularly from June to November. However, the mean OC fluxes are higher inside the canyon due to the total mass flux contribution.

The calcium carbonate percentage of the settling particulate matter in the study area is very constant during the whole experiment (Fig. 3c). The mean percentages are about 25%, and there are no significant differences between the calcium carbonate composition of the particles collected inside the canyon and those collected at the open slope.

The opal percentage values of settling particulate matter are similar in the whole study area from May to February, although they are slightly higher on the open slope (Fig. 3b). In March and April, during the spring season, the opal content increases, especially on the open slope and in the canyon intermediate waters, reaching a maximum value of 8.75% in late April 1994. Most of the biogenic silica particles that reached the sediment traps were silicoflagellates, with a small contribution of diatoms.

The lithogenic components (aluminosilicates) constitute the main contributor of almost all the settling particulate matter samples (Fig. 3d). The mean annual aluminosilicates content is about 67% inside the canyon, whereas on the adjacent open slope it is 63% (Table 1).

The mineralogical content of settling particles shows small spatial and temporal differences (Fig. 4). Clay minerals such as illite and chlorite show a higher content on the open slope than in the canyon from June to October (Figs. 4b and 4c), whereas the quartz content is lower on the open slope than in the canyon during the same period (Fig. 4a). Between November and May, the mineral content is very similar for all trapped sediment except dolomite, which increases sporadically near the bottom inside the canyon (Fig. 4d).

4. Discussion

Near-bottom total mass fluxes inside the Foix canyon at 600 and 1180 m show a similar temporal evolution, excluding the last sampling period at 600 m during which a sharp increase occurred, reaching a total mass flux of about 47 g/m^2d. This high value has been interpreted as being generated by resuspension from fishing activities at the canyon head. However, maximum fluxes of a similar magnitude have been measured at similar depths in the Lacaze-Duthiers canyon head (Monaco *et al.,* 1996), and it remains unclear whether those recorded at the Foix canyon head were caused by human or natural factors.

The decrease in near-bottom mass flux along the canyon axis from 600 to 1200 m depth may be due to suspended sediment dispersion outside the canyon and/or deposition of particles along the canyon floor. Taking into account that the Foix canyon is strongly incised, dispersion outside the canyon is difficult, at least in the upper canyon. Thus, the near-bottom flux decrease is probably more related to a sedimentary deposition. This

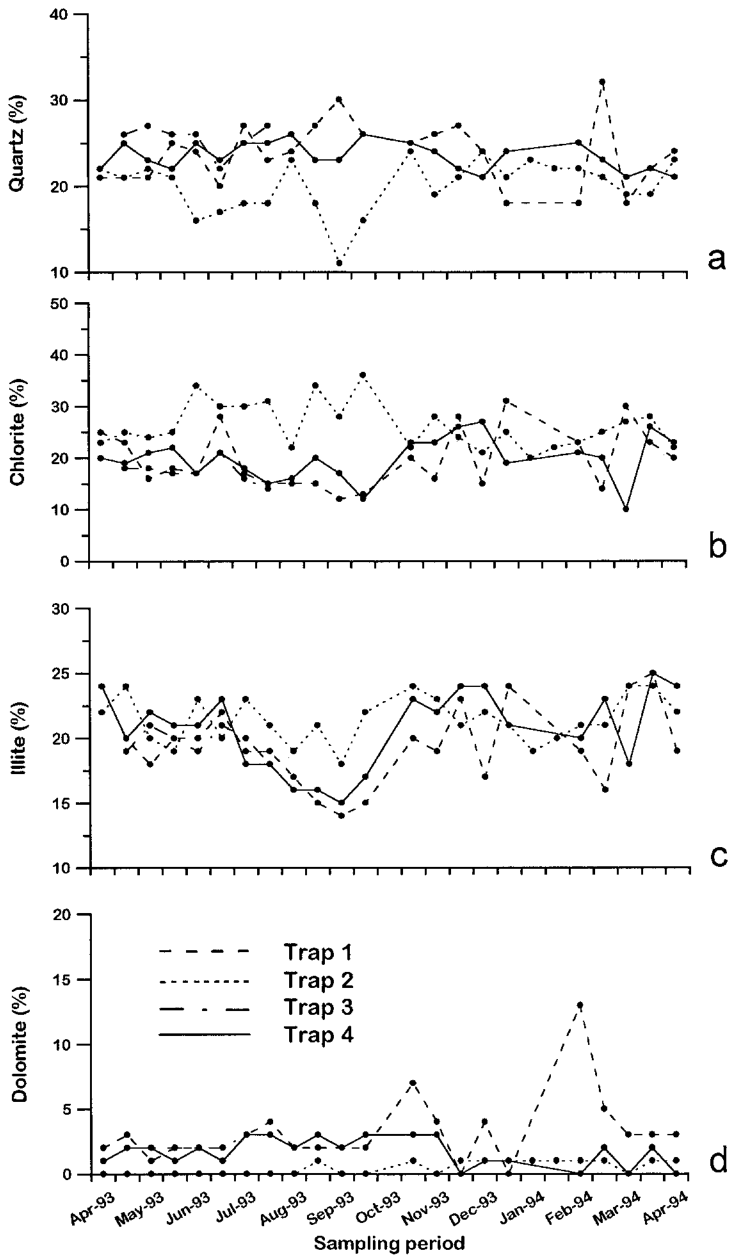

Figure 4. Time series of mineralogical content of settling particulate matter in the Barcelona continental margin during the period studied: quartz (a), chlorite (b), illite (c) and dolomite (d). Trap 1: mid-canyon near-bottom; Trap 2: open slope near-bottom; Trap 3: canyon head near-bottom; Trap 4: mid-canyon intermediate waters.

interpretation supports the hypothesis of a present depocenter in the upper canyon section. This accumulation zone has also been identified in the Gulf of Lions (Courp and Monaco, 1990) and on the New England continental slope (Biscaye and Anderson, 1994). Nevertheless, some sediment dispersion also takes place seaward from the canyon axis between 250 and 500 m depth, where a detachment of a mid-slope intermediate nepheloid layer related to a shelf slope density front (Font *et al.,* 1988) has been observed in transmissometer transects along the Foix submarine canyon (Puig and Palanques, 1998). However, the shelf slope density front also retains suspended particles where the foot of the front intersects with the seabed. This retention probably contributes to increasing the vertical total mass fluxes at the canyon head site.

The time-series of total mass fluxes in intermediate and near-bottom waters inside the canyon at 1200 m depth show a similar behavior (Fig. 2). However, during periods of maximum fluxes, the near-bottom values are twice those of the intermediate waters, whereas during periods of minimum fluxes the values are very similar at the two water levels. This data indicate that the transfer of particulate matter through the canyon takes place in both intermediate and near-bottom waters most of the time, although the transport is more intense near the bottom during high flux events.

The total near-bottom mass fluxes inside the canyon at 1180 m water depth are higher than, and show a different temporal trend to, those of the adjacent open slope (980 m water depth), excluding the periods of minimum mass fluxes when the values of the canyon are similar to those of the open slope and intermediate waters. This relation indicates that there is an alternation of periods during which high sediment fluxes take place inside the canyon without affecting the mid open slope, and other periods during which the sediment fluxes in the canyon are low and similar to those of the open slope area. During these periods, the Foix submarine canyon does not work as a preferred sediment conduit to deeper parts of the slope and the vertical fluxes of particulate matter have the same order of magnitude inside and outside the canyon, with a mean total mass flux of about 1000 mg/m^{2}d. Thus, this value can be considered as the vertical flux controlled by the along-slope geostrophic circulation in the absence of significant cross-margin sediment transfer injected through the canyon. Nevertheless, the along-slope mean flow transports sediment which has previously been transferred from the continental shelf to the open slope waters either across the shelf break or through other submarine canyons, and controls the distribution of slope water suspended particulate matter (Durrieu de Madron *et al.,* 1990 and Puig and Palanques, 1998).

Outside the canyon there is a clear difference between the summer and winter season: the total mass fluxes in winter are 5 times higher than in summer. This seasonal variability is related to a low sediment transfer from the shelf to the open slope during the summer season, which is associated with the seawater stratification and with the absence of storm resuspension events and major river discharges. The seawater stratification causes retention of fine particles detached from the shelf along isopycnals and mainly along the thermocline, developing a wide intermediate nepheloid layer over the shelf and upper slope

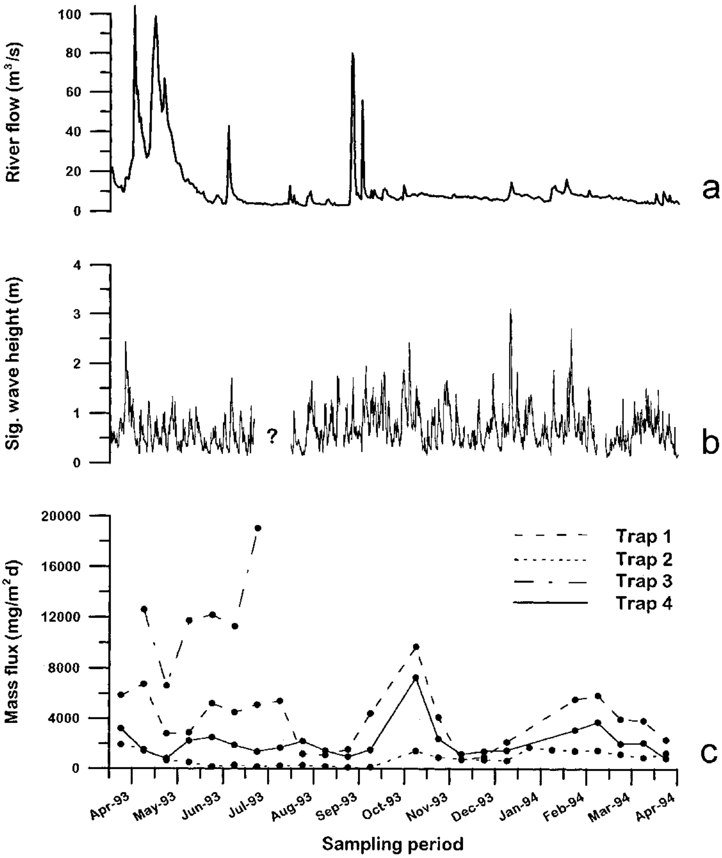

Figure 5. Temporal evolution of the Llobregat River water discharge (a), the significant wave height recorded off Llobregat River mouth (b) and the total mass fluxes of particulate matter in the Barcelona continental margin (c). Trap 1: mid-canyon near-bottom; Trap 2: open slope near-bottom; Trap 3: canyon head near-bottom; Trap 4: mid-canyon intermediate waters.

(Puig and Palanques, 1998). This nepheloid structure controls and retains shelf-derived suspended particulate matter, reducing the slope vertical fluxes. Moreover, the decrease in the vertical total mass fluxes in summer could also be favored by the lower mesoscale activity of the along-slope geostrophic current (Font *et al.,* 1995) and by the reduction in the biological activity in surface waters due to the restriction on the diffusion of nutrients from deep layers to the photic zone (Estrada *et al.,* 1985).

In spite of the bi-weekly resolution of the sediment trap samples, the maximum total mass fluxes seem to be related either to the highest peaks of the significant wave height recorded near the coast or to increases in the Llobregat River daily water discharge (Fig. 5). Some examples of this relationship are the high fluxes related to the increases in river discharges in April-May 1993 and in September-October 1993, and those associated with the storms that took place in early January 1994 and late February 1994. These enhancements in the total mass fluxes occurred during or immediately after a major storm or a river discharge event. Currents recorded during the experiment in the sediment trap sites inside the canyon (Durrieu de Madron *et al.,* 1996) reached maximum speeds of 13 cm/s and were presumably not high enough to resuspend slope bottom sediments at the sampling sites. Thus, high sediment fluxes inside the Foix submarine canyon seem to be mainly related to river sediment discharges and also to sediment resuspension events on the shelf produced by storms. These sporadic high-energy processes supply suspended or resuspended particles to the continental shelf water column, which are transported by currents, trapped at the canyon head and transferred rapidly through the canyon axis, affecting both near-bottom and intermediate waters through suspended particulate matter detachments. Outside the canyon these events were also recorded by increases in the total mass fluxes, although they were less accentuated.

The October-November maximum fluxes were the highest ones recorded within the canyon, although the Llobregat River flow was more important in April-May 1993. This can be explained by the fact that the October-November enhancement in total mass flux was not only related to the increase in the river water discharge and to the storm that occurred in late October 1993, but also to the breaking of the seawater stratification. During the late summer, suspended particulate matter is retained by the strong stratified water along isopycnals. At this stage, well developed intermediate nepheloid layers have been observed in the study area (Puig and Palanques, 1998). When this situation ends, vertical water mixing takes place and the suspended particles retained along isopycnals and over the thermocline probably settle down. Thus, this phenomenon can also contribute to increasing the total mass fluxes recorded during the October-November sampling periods.

At mesoscale, by comparison with other experiments conducted in the Northwestern Mediterranean margin, the mean annual total mass fluxes inside the Foix submarine canyon tend to be slightly higher than those recorded at similar depths in the Gulf of Lions submarine canyons (Heussner *et al.,* 1996 and Monaco *et al.,* 1996). One of the factors that probably generates higher fluxes in this canyon is the physiography of the Barcelona continental margin. The Barcelona continental shelf is narrower (8 km) and steeper (0.3–0.7°) than the Gulf of Lions shelf, and has a shorter distance between the canyon head and the main sediment source (river mouth). These factors favor a more effective transfer of sediments through the Foix submarine canyon. However, on the Barcelona continental slope the mean annual fluxes of the open slope are slightly lower than those recorded at similar locations in the Gulf of Lions. This could be explained by the fact that the Gulf of Lions continental slope is more frequently incised by submarine canyons. Suspended particulate matter distribution in these canyons reveals the presence of nepheloid structures extending seaward along isopycnals (Durrieu de Madron *et al.,* 1990). This contributes to a more frequent injection of sediment to the slope water column, which probably increases the sediment fluxes in the open slope.

The content of the major constituents of the settling particles in the Barcelona continental margin is very similar during the whole experiment. This homogeneity in the composition of the particles that reach the continental slope indicates that the sedimentary origin is the same during the whole year. However, there are small differences between traps which reflect spatial and temporal variability.

Inside the canyon, the measurements of OC percentages are quite constant throughout the year, without reflecting a seasonal change in the composition of settling particles transferred through the Foix canyon. However, in the adjacent open slope, the higher OC% values measured from June to November indicate a different particle OC content between summer and winter seasons. The maximum OC% values are associated with the very low total mass fluxes recorded in summer outside the canyon. During this period the energy of shelf-slope transport processes is lower and there is a retention of particles by the stratified water. This situation leads to a lower supply of lithogenic particles from the shelf and to the consequent increase in the biogenic fraction of the settling particles.

Maximum opal percentages were recorded in the spring season during the April 1993 and March-April 1994 sampling periods. These high values are related to the biological "spring bloom" and to the consequent higher sedimentation rate of siliceous skeleton organisms, principally silicoflagellates and diatoms. The percentage of opal by weight was higher on the open slope throughout the year due to the lower input of terrigenous sediment. However, the opal fluxes were higher inside the submarine canyon during most of the experiment due to the lower total mass fluxes recorded on the open slope.

The absence of differences in calcium carbonate content between the sediment collected inside and outside the canyon also indicates a homogeneity in the major composition for all the slope vertical fluxes. During the spring bloom event, the calcium carbonate content does not increase as a consequence of the high terrigenous carbonate content of the samples that minimize the calcium carbonate signal of biogenic origin.

Aluminosilicates constitute the principal component of almost all samples. On the open slope, the aluminosilicates content is lower than in the canyon as a consequence of the lower detritic input and the consequent higher content of biogenic components which are less diluted than in the canyon.

The mineralogical temporal series indicate that some mineral phases can be used as tracers of sedimentary processes. These series show that the dolomite content increases when storm events occur (Figs. 4d and 5b). In the study area, similar high dolomite contents are only found in sediments of the inner shelf and not in the slope sediments. Thus, only high-energy events can resuspend sediments from the inner shelf and transfer them to deeper areas, increasing the dolomite content of the vertical particle flux in the slope. These increases were only recorded near the bottom inside the canyon, indicating that most of the resuspended sediment on the shelf is transferred preferentially through the Foix submarine canyon.

During the period affected by storms, from November to May, the average content of quartz, illite and chlorite was similar in all traps as a result of an efficient particle mixing. However, during the summer season (June-October), the higher content of illite and chlorite and the lower content of quartz in the open slope also indicates a higher selection of settling particles by decantation, controlled by water stratification and by a lower storm mixing effect.

5. Conclusions

The dynamics regulating vertical particle fluxes on the Barcelona continental margin are closely related to physical and biological processes. The Foix submarine canyon acts as a conduit for transport of sediment from the shelf to the slope, and as a mid-slope sedimentary depocenter. However, the relation between total mass fluxes indicates an alternation of periods of high fluxes during which the Foix submarine canyon works as a preferred pathway of sediment, without affecting the open slope, and periods of minimum fluxes during which the vertical flux of particles is controlled by the general along-slope circulation affecting both canyon and open slope. These periods of high transference are sporadic and take place during and immediately after a storm event or a river discharge increase, and they are observed inside the canyon, mainly near the bottom but also at intermediate depths. Winter water mixing also appears to be a major process that contributes to increasing the vertical flux of particles.

The concentration of the major constituents of the settling particulate matter indicates that it has a common sedimentary origin, although small differences between traps reflect spatial and temporal variability. Particle composition inside the Foix submarine canyon does not show any significant seasonal variation, but summer water stratification appears to control the settling particulate matter composition on the open slope. The opal percentage increases particularly on the open slope during the spring biological bloom, and the maximum OC% is also recorded outside the canyon during the summer season, and is related to a low total mass flux and associated with a lower supply of lithogenic particles from the shelf. The calcium carbonate comes mainly from a terrigenous rather than a biogenic source, and the aluminosilicates are the most important contributor to the vertical particle fluxes on the Barcelona continental margin, reaching higher percentages inside the Foix submarine canyon.

Summer water stratification also controls the mineralogical composition. During the summer season the clay minerals content is higher in the open slope due to a better textural selection of the settling particulate matter, whereas during the period affected by storm events and vertical water mixing, the quartz, illite and chlorite content is more similar in the whole study area, and the dolomite content can be used as a tracer of shelf resuspension events.

This study contributes to a more precise understanding of the general and local factors controlling particle transfer in the Catalan margin and in submarine canyons. Further specific studies of trace metals and radionuclides based on these sediment trap samples will contribute to a better understanding of the vertical particle flux dynamics in this area.

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