Particulate fluxes and sediment dynamics on the Northwest Iberian margin

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1. Introduction

The aim of the IHb contribution to WP III is the understanding of processes affecting the particulate matter in oceanic systems. This main purpose is achieved by three tasks: 1) the identification of sediment main sources; 2) the recognition and quantification of processes acting in the suspended sediments and bottom sediments; 3) POC content in main nepheloid layers.

The Northwestern sector of the Iberian margin shows the following peculiarities:

a) a lengthy continental shelf, which is very narrow (with an average of 35 km wide);
b) several rocky outcrops;
c) the steepness of the slope associated with the Porto Submarine Canyon;
d) and finally it is strongly affected by continental inputs due to high river activity (the five major rivers are the Minho, the Lima, the Cávado, the Ave and the Douro).

Due to this characteristics first studies were concentrated in the Portuguese margin. During the second year they were extended further to the North covering the Galician Shelf and Rias.

2. Methodology

2.1. Data acquisition

During the year 2 of OMEX two cruises were promoted in the study area: *GAMINEX* and *OMEX99*.

GAMINEX:

Vessel: "*Côtes de la Manche*"
Dates: July 1998 (7 to 20)
Principal Scientist: Jean-Marie Jouanneau, Univ. Bordeaux I
Data collected: Surface sediments (collected with grab and multi-corer from Univ. Bordeaux I) in fine deposits.

OMEX99:

Vessel: NRP "*Almeida Carvalho*"
Dates: May 1999 (3 to 30)
Principal Scientist: João Vitorino, IH
Data collected: CTD + nephelometric profiles (in sections perpendicular to the coastline and 2 time series of 24 hours); SPM sampling (water sampling and filtration) in the nepheloid layers; Surface sediment sampling (with a grab sampler) in fine deposits located in the upper slope and middle continental shelf
Meteorological conditions: spring/summer conditions. Good weather (week wind and wave formation).

2.1.1. CTD, nephelometric profiles and SPM samples

The area was covered by E-W transepts, perpendicular to bathymetric contours. Surface SPM samples (collected at 5 m below sea level) were obtained by direct filtration while other layers were sampled using Niskin bottles and filtered on board by the classic vacuum system. All the SPM samples were immediately dried (at 40ºC) after collection.

Used filters had the following characteristics: *cellulose acetate* filters with 0.45-µm porosity and diameter of 47 mm (for mineralogical studies) and 142 mm (for grain-size analysis) and *glass fibre* filters with 0.7-µm porosity and diameter of 47 mm (for POC analysis).

2.1.2. Bottom sediments

Bottom sediments from the muddy deposits of the Portuguese inner and middle shelf were collected in the *CORVET* cruise, using a grab sampler and studied during the first year of OMEX.

Other sediment samples were collected during the cruise *GAMINEX* carried out in the Portuguese and in the Spanish shelf. During this cruise a few samples were also collected in the Spanish rias.

During the spring/summer 1999 cruise sediment samples were collected in the middle shelf and in the upper continental slope.

2.2. Laboratory studies

2.2.1. SPM samples

SPM samples studied during this second year were collected in previous cruises promoted by IH in late 1996 and 1997 (winter).

SPM samples collected during the 1999 cruise were not yet analysed. Future analysis will include grain-size analysis, POC content and mineralogical studies.

2.2.2. Bottom sediments

Bottom sediments were analysed in order to obtain:

- Granulometry;
- Mineralogy of the fraction <63 µm and fraction <2 µm (by X-ray difractometry in oriented aggregates);

Other sedimentological analysis (POC and $CaCO_3$ contents) will be realised by Univ. Bordeaux I.

3. Results and Discussion

3.1. Amount, Character, Distribution and Composition of Suspended Particulate in nepheloid and Clear Water Layers (Task III.1.1)

- General interpretation allowed us to present several results, regarding:
- River run-off (which show a clear signature in the composition and distribution of SPM);
- Concentration of SPM in the water columns (two main layers that are mixed and homogenised by storm events);
- When differentiated the bottom nepheloid layer is mainly terrigenous (with affinity to bottom sediments) while the surficial one has an increasing content of biogenic particles with the increasing distance to river mouths; Its dynamic are strongly related with wind forcing.
- The grain-size analysis of terrigenous SPM (Malvern 3600E) in both surface and near bottom layers indicates three major classes of particles: 1.*Very fine silt and fine silt* (5-10µm) - actual particles injected by rivers and are continuously in suspension in winter conditions; 2. *Medium silt* (15-18µm) - biogenic remains and some terrigenous aggregates; 3. *Coarse silt* (>30µm) – only present near the bottom are ressuspended particles from the muddy deposits.
- During winter the current velocities are sufficiently high to prevent settling and to resuspend bottom sediments resulting in a significant presence of BNL over the continental shelf and slope. The main transport of particles in winter, most likely, is therefore in the BNL.

- A more detailed study of SPM and a fully comparison between the two winter periods were made during this late year in order to allow the interannual variability study.

Winter 1996 (Fig. 1 and Fig. 3a)

The *CORVET* cruise was performed by the end of an upwelling season (with NW winds) despite the occurrence of a strong storm from W (waves higher than 12 m and periods of 12 s) that has affected the general hydrological conditions (see contribution of partner 8a). The distribution map of SPM concentration (mg l^{-1}) shows a separation line that corresponds to this event. The SPM concentration was higher in the bottom proximity and in the stations near the rivers. In the surface waters (5 m) the SPM concentration are quite constant throughout the mid and outer shelf (from 0.13 to 1.4 mg l^{-1}, average: 0.5 mg l^{-1}) with an increase to the inner shelf, up to 3 mg l^{-1}. Near bottom, the SPM concentration becomes much higher, up to 13 mg l^{-1} (inner shelf), due to the terrigenous input both from the Lima and Douro rivers and from ressuspension events.

POC content (expressed in terms of % of SPM) shows values lower than 6% in areas where the SPM concentration was higher, especially at bottom and in inner shelf. In the SNL the POC increases westward (from 6% to 32 %) due to the increasing depth (that attenuates ressuspension) and distance to river input. These observations suggest an increasing of organic (plankton) SPM with the decrease of terrigenous components.

Before the storm the water column was stratified (both salinity and temperature) showing a well defined SNL and BNL (extending until the shelfbreak) separated by clear waters. With the onset of the storm (wind direction changing from NW to SW and stormy waves) the SNL was confined to inner shelf and the BNL becomes more developed and intense.

Winter 1997 (Fig. 2 and Fig. 3b)

In *CLIMA* cruise the winter regime was well developed with the ocurrence of several storms from west and winds from SW.

Near coast, a continental water mass with lower salinity and temperature and high turbidity (concentration values > 10 mg l^{-1}) was observed. During this period, the concentration values were very similar to the final period of *CORVET96*, but with different distribution. The water column was vertically homogeneous. The SNL was absent and the BNL was well represented extending through the shelf break.

The surficial POC content has a mean value of 14%. The higher values (> 30%) are related with the intrusion of oceanic waters masses richer in biogenic particles, namely coccoliths and diatoms. Near the bottom POC has a mean value of 7%. Despite the half mean content between the two layers, the maximum value is similar, being observed in the upper slope.

3.2. Sediment Distribution, Properties and Composition along Selected Transepts (Task III.1.4)

From previous works it is known that the sedimentary cover in the continental shelf is mainly sandy. Other peculiarities are the presence of rocky outcrops in the outer and inner shelf and also some finer deposits with muddy affinity characteristics (Dias, 1987; Magalhães, 1993; Rodrigues *et al.*, 1991). In the Portuguese margin there two: the Douro Muddy deposit and the Minho Muddy deposit. This later one is part of a major one that extends further north

In the OMEX II-II framework it is intended to realise a more accurate study of the bottom sedimentary cover, with special attention to the interface between the muddier deposits and the bottom nepheloid layer. This approach is essential to understand the dynamic processes affecting sediment particles in the continental shelf and slope.

The muddy deposits of the Portuguese and Galician continental shelf were sampled and several studies indicate its terrigenal origin.

The mineralogical composition of the sediment first centimeter allowed the following conclusions:

a. The mineralogy of sediments of the Portuguese deposits is very similar to the mineralogy of the Galician deposits. This fact indicates the common source.

b. The main mineral is quartz (Fig. 4) with an average content of 45% (min=17%, max=85) followed by mica ($\bar{x}$=14%, min=14%, max=40%), plagioclase and by potassium feldspar ($\bar{x}$=12% and 10% respectively). Other identified minerals are calcite, dolomite, siderite, pyrite, gypsum, zeolites and opal.
c. Concerning clay minerals the illite is the predominant one (100% smectite + illite + chlorite + kaolinite matrix), with averages values of 77% (min=71, max=84), followed by kaolinite ($\bar{x}$= 17.5). In general kaolinite has an opposite trend of the illite. Chlorite enrichment is related to finer areas. Smectite is vestigial (0.1 to 5%) with a located pick value (10%) in the middle shelf (Fig. 5). This value is located westward Minho River mouth.

3.3. Dominant sediment Transport Processes at Contrasting Margins (Task III.1.5)

The work carried out in this task is not complete but a few headlines can be highlighted:

a. The river run-off definitely contributes to the SPM character and dynamic in water column.
b. The distribution pattern of minerals also reveals a well marked influence of the Portuguese rivers. From these the Douro River is the main source.
c. The Northward decreasing of immature minerals (*e.g.*, plagioclases) and the associated increase of quartz possibly indicates a net transport to North.
d. This is a very energetic continental margin. The oceanographic conditions (*i.e.*, predominant waves from NW and W and N-S currents) are the main responsible for the transport of terrigenous particles.
e. SPM with a continental origin can, especially in storm events, reach the shelfbreak and enrich the intermediate nepheloid layers in the continental slope;
f. Sedimentary characterisation (in muddy deposits) seems to indicate that particles settle in the middle and outer shelf. In stormy winter conditions (with high SW waves), sediments can be ressuspended and transported northward, to the Galician shelf and westward, to deeper domains. This process can be considered as SPM sources to the benthic nepheloid layer.
g. After ressuspension particles can be transported to deeper domains or they can be affected by the N-S currents and then will be transported further to the north or to the south, depending of the wind regime.
h. From our analysis we see no relevant indication of mineral (<63 µm) exportation from the rias systems, mainly the Arosa and Muros rias.
i. Indicating an intense remobilization or/and weak or absent present terrigenous sediment supply, the middle and outer shelf off Ria Muros has a general deficiency in minerals. Quartz (85-70%) and kaolinite (24%) make exception.

4. Dissemination of results

Some of the above described results have been presented in formal and informal meetings. Abstracts are attached to this report.

4.1. Meetings

Oliveira, A.; Rodrigues, A.; Jouanneau, J.M.; Weber, O. (1999). “Nepheloid layers off the northern Portuguese coast”. *OMEX II-II workshop*, Plymouth, 25-27 April 1999.

Oliveira, A.; Rocha, F.; Rodrigues, A.; Jouanneau, J.M.; Weber, O. (1999). “Mineralogy of fine deposits of Galician-Portuguese shelf: an overview”. Plymouth, 25-27 April 1999.

Oliveira, A.; Rodrigues, A.; Jouanneau, J. M.; Weber, O.; Dias, A.; Vitorino, J. (1998) – “Sedimentos em suspensão, sua dinâmica em situação de Inverno e relação com a cobertura sedimentar”. *V Congresso Nacional de Geologia*, Lisboa.

4.2. Papers

Oliveira; A. Rodrigues; J. M. Jouanneau; O. Weber; A. Dias and J. Vitorino (1998) – "Sedimentos em suspensão, sua dinâmica em situação de Inverno e relação com a cobertura sedimentar". *Comunicações do Inst. Geol. Mineiro*, Tomo 84, fasc.1 pp. C3-C6.

5. Future activities

a) SPM and bottom samples collected during the spring/summer 1999 cruise will be analysed.
b) Integration of results that were not included until this date, namely the new data collected in the spring/summer cruise promoted in May 1999 in the north Portuguese margin.
c) Integration and discussion of results with other WP III partners;
d) Participation on OMEX II-II workshops and meetings to present and integrate results and discuss future activities.

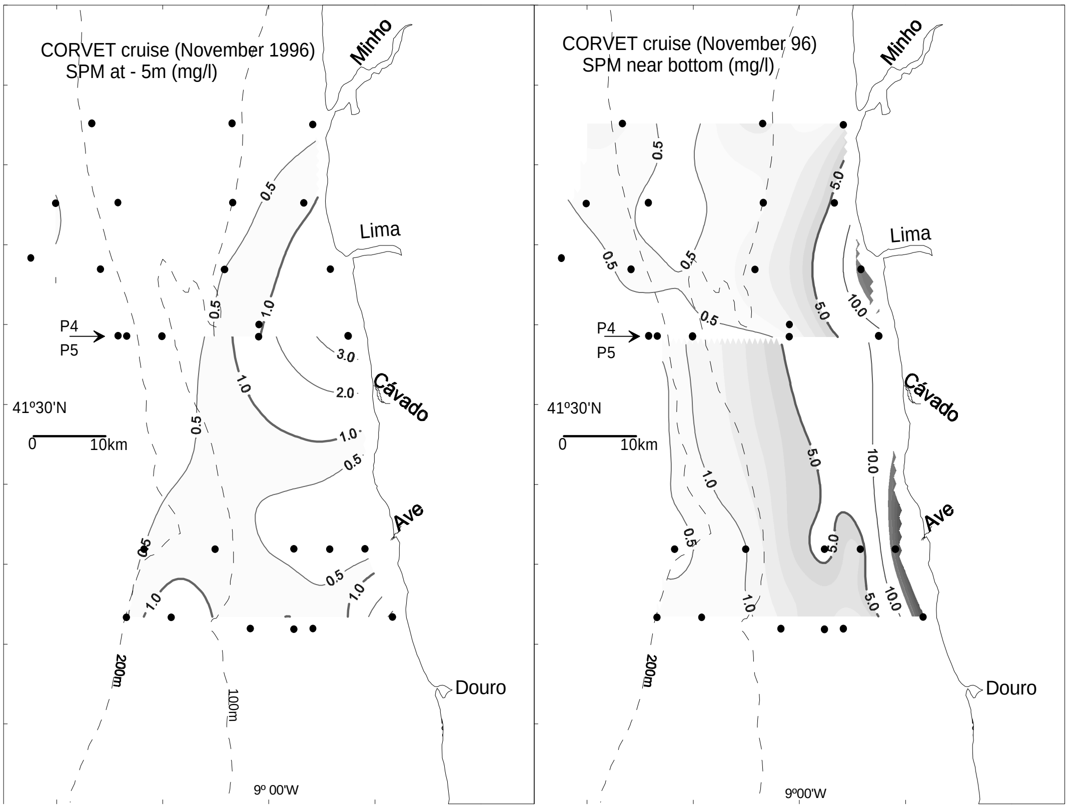
6. References

Dias, J.M.A. (1987). "*Dinâmica Sedimentar e Evolução Recente da Plataforma Continental Portuguesa Setentrional*". Dissertação de Doutoramento, Universidade de Lisboa. 384 pp. (*unpublished).*

Magalhães, F. (1993). "*A cobertura sedimentar da plataforma e da vertente continental superior a norte de Espinho*" Dissertação de mestrado, Univ. Lisboa. 191 pp. (*unpublished*).

Rodrigues, A.; Magalhães, F.; Dias, J.M.A. (1991). "Evolution of the north Portuguese coast in the last 18,000 years". *Quaternary International*, 9:67-74.

a)



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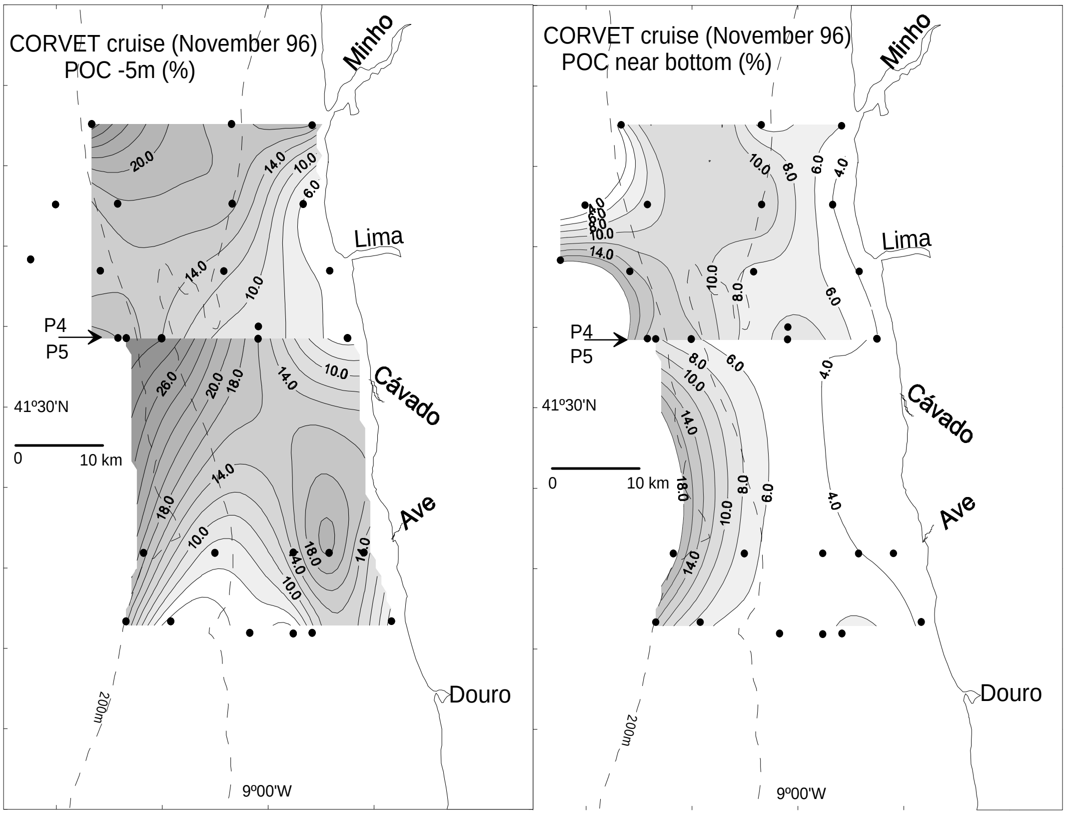

Fig. 1. *CORVET96* – a) SPM distribution in the surface nepheloid layer (-5 m) and in the bottom nepheloid layer. b) POC distribution. Dots are the location of stations.

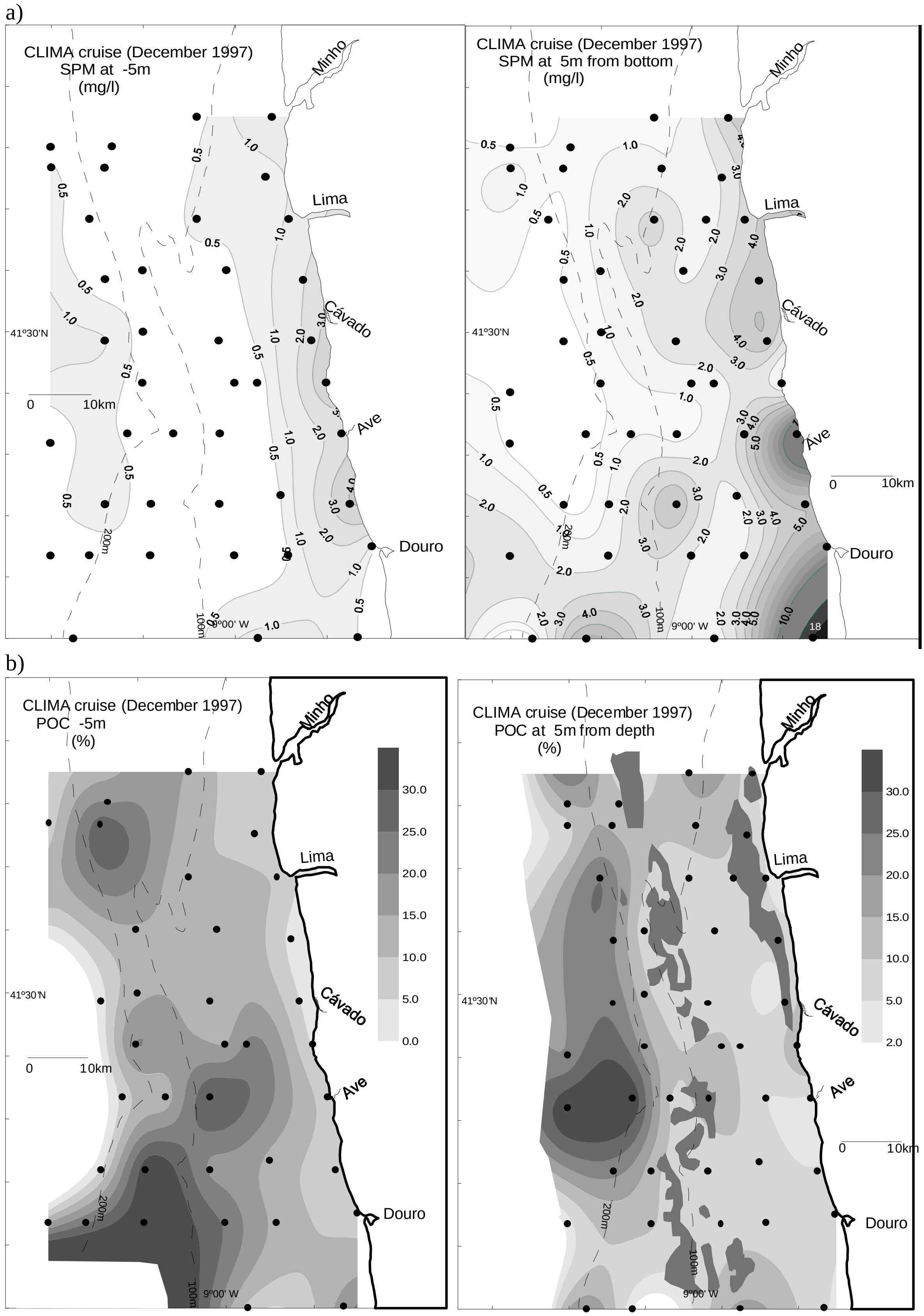

Fig.2. *CLIMA97* cruise a) SPM distribution in the surface nepheloid layer (-5 m) and in the bottom nepheloid layer. b) POC distribution.

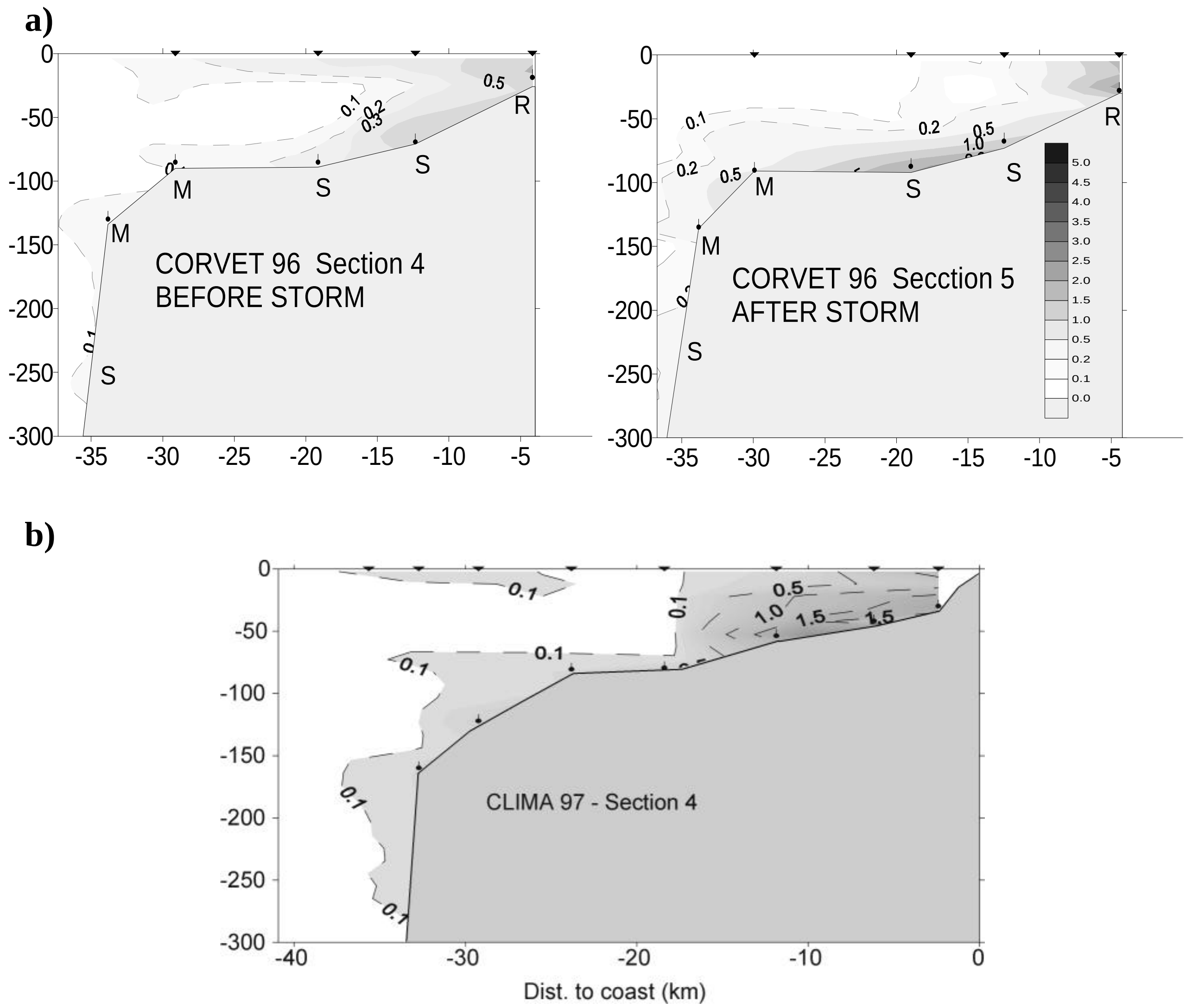

Fig. 3. Cross shelf nephelometric profiles (in f.t.u. units, 1 f.t.u.≈ 1.6 mg l^{-1}) a) *CORVET96* before and after the 19 November storm. (S-sand; M-mud; R-rock). b) *CLIMA97*

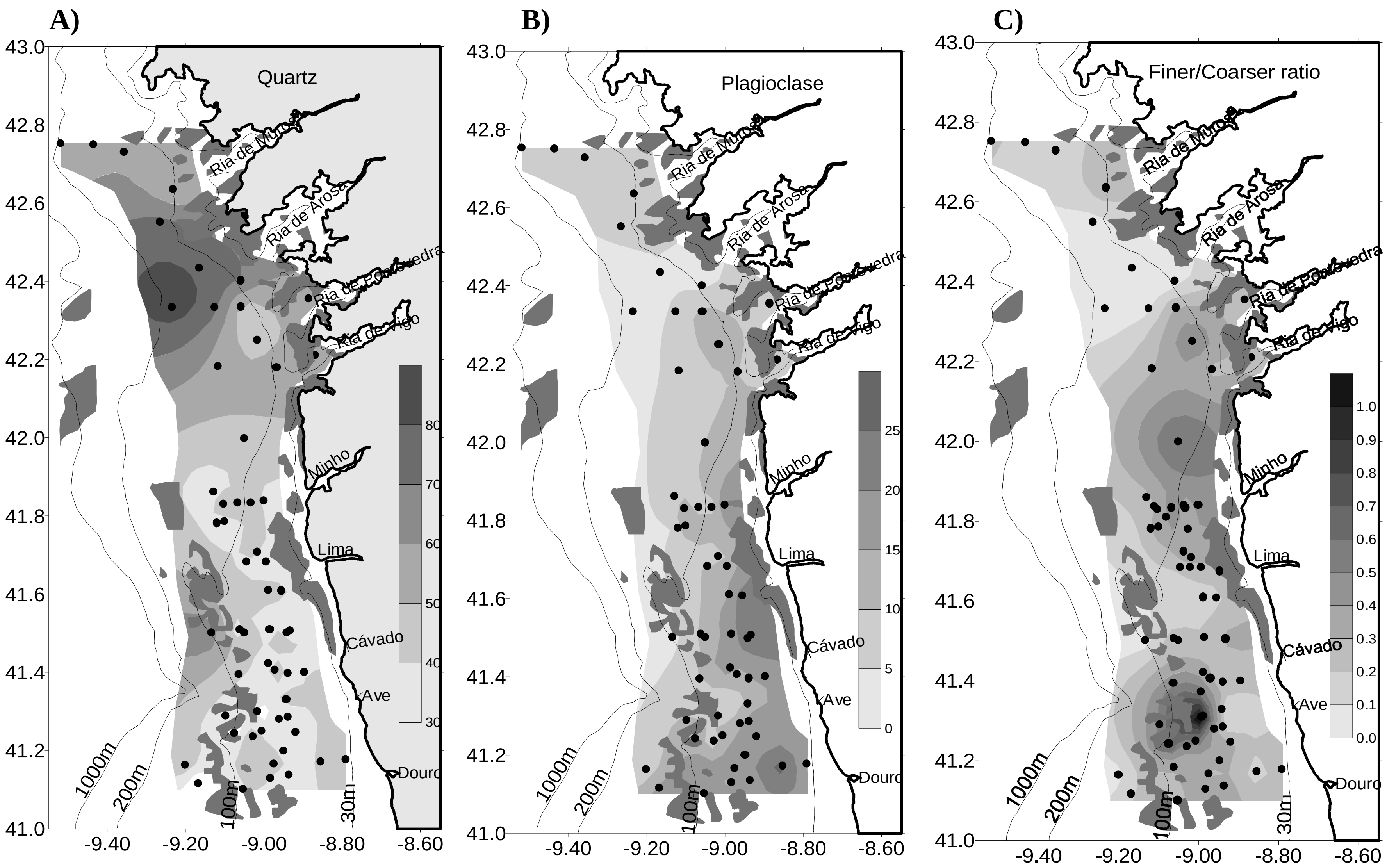

Fig. 4. Composition of the bottom sediments (1st centimetre). A. Distribution pattern of Quartz. B. Distribution of Plagioclase (fraction <63 µm). C. Finer (mica+chl+kaul.)/coarser (qz+feldsp+plag.) ratio.

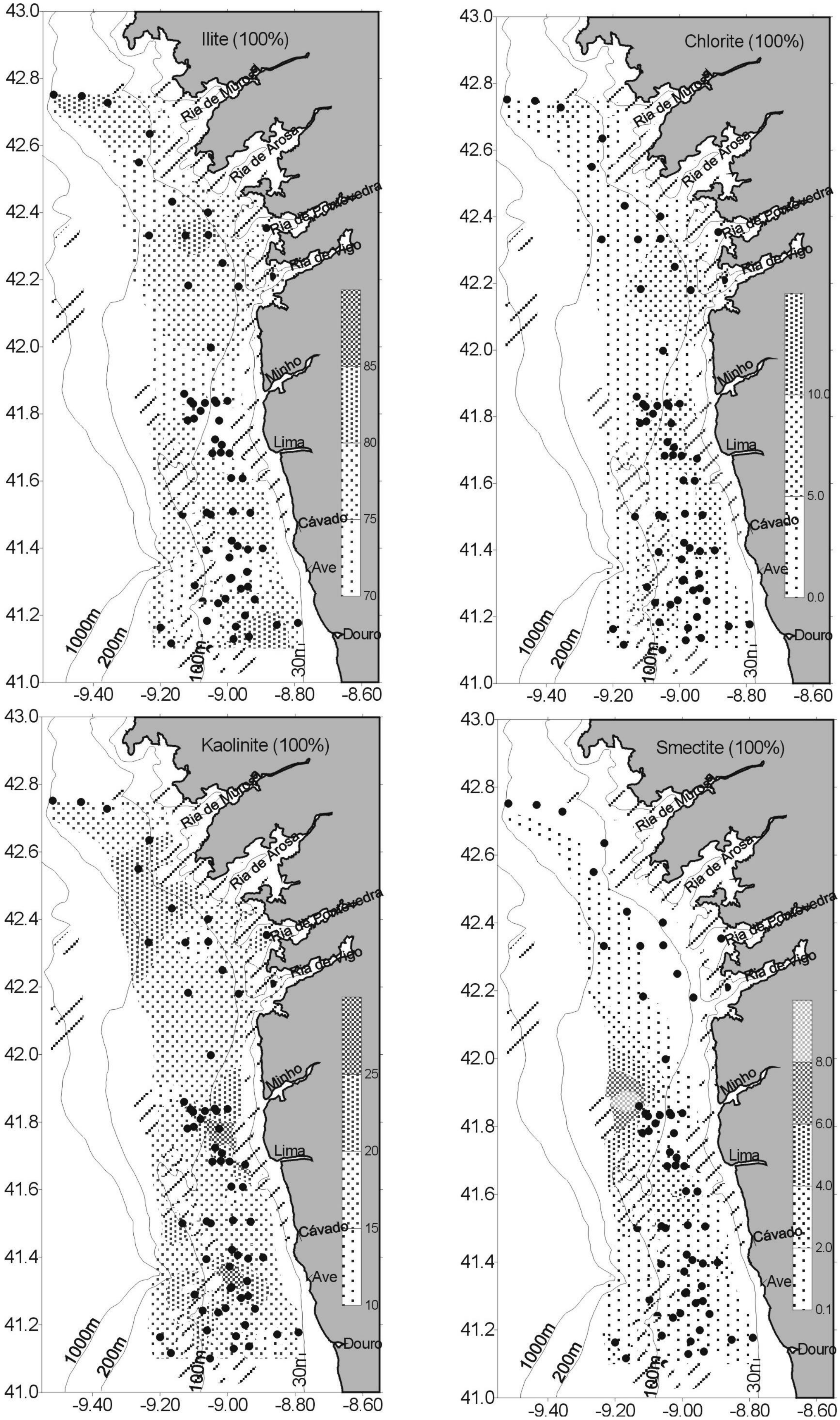

Fig. 5. Composition of the bottom sediments (1st centimetre): Clay mineralogy (fraction <2 μm).