Recent sediment transport and accumulation on the western Iberian Margin

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NIOZ (5a) is involved in the following tasks and subtasks described under WP III:

Task III.1. Particle transport, settling, accumulation, mixing and burial fluxes. Temporal and spatial variability

Task III.1.1 Amount, character, distribution and composition of suspended particulates in nepheloid and clear water layers

Task III.1.2 Spatial and temporal variability of the benthic boundary layer dynamics

Task III.1.3 Particle fluxes to the seabed, accumulation and mixing rates

Task III.1.4 Sediment distribution, properties and composition along selected transects

Task III.1.5 Dominant sediment transport processes at contrasting margins

Task III.2. Sediment/water exchange processes and early diagenesis

Task III.2.2 Organic matter diagenesis and burial

1. Introduction and methods

During 3 cruises to the NW Iberian Margin in the period June 1997 - June 1999, we collected samples and data at 46 stations using the RV *Pelagia* of NIOZ. Five of these stations were repeatedly sampled during successive cruises. The stations were made along 5 transects perpendicular to the western Iberian margin, at depths between 101 and 4939 m (Fig. 1). CTD profiles and water column samples were collected at 31 stations, box cores at 37 stations and piston cores at 17 stations. In Fig.1 the sample stations are identified by year of collection (98-05), while in all subsequent figures the stations are identified according to cruise and station number. The stations of *Pelagia* cruise 1997 are indicated with prefix *PE109*, 1998 stations are *PE121* and 1999 stations are identified as *PE138*.

CTD profiling was done with a Seabird CTD and Rosette sampler, equipped in addition to T, S and O_2 sensors with a 25-cm beam SeaTech Transmissometer, a Chelsea Mark III fluorometer and a Seapoint Optical Back Scatter (OBS) instrument. In 1999 a Wetlabs AC3 meter was also included. In 1998 only few CTD data were collected because of cable failure. SPM samples were obtained by filtration of fixed volumes of water from Intermediate (INL) or Bottom Nepheloid Layers (BNL), and from clear water layers as reference.

Lander BOBO I was deployed for long term measurements of near bed dynamics at 2152 m depth near IfM sediment trap IM3. After recovery of BOBO I in 1998, BOBO II was deployed nearby for a one week test period and then redeployed until May 1999.

3.5 kHz penetrating echosounder profiling was done along all transects of cruises *PE109*, *PE121* and *PE138*, preceding sediment sampling.

Sediment samples (box- and piston-cores) were collected along all transects, at depths between 101 and 4939 m (Fig. 1) for the definition of sediment transport processes, particle fluxes and accumulation and mixing rates. Downcore measurements were made of ^{210}Pb, organic carbon, carbonate, grain size and dry bulk density (DBD). Sediment dating was done by biostratigraphy, complemented with ^{14}C AMS dating. Oxygen isotope determinations were made of selected cores (for *PE109-05* see also Reyss *et al.*, this report) and an age model based on ^{14}C AMS dating, magnetic susceptibility peaks and isotope determinations is in preparation.

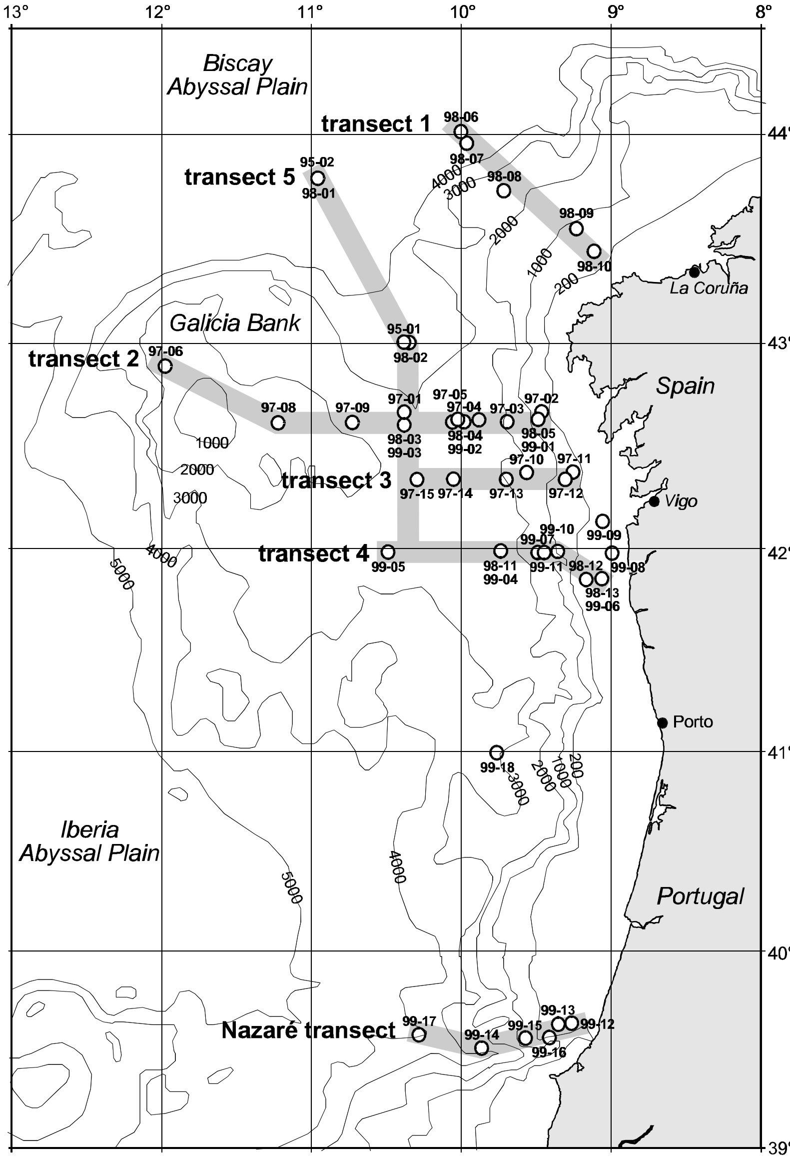

Figure 1. Location of study area showing transects studied and stations made during cruises PE109 *(1997),* PE121 *(1998) and* PE138 *(1999).*

2. Results

2.1. Amount, character and distribution of suspended particles in the water column

Surface nepheloid layers (SNL) are present over the entire study area, varying in thickness between 40-100 m at the shelf and shelf edge, to more than 200 m further to the West. Usually a maximum in turbidity in the SNL is observed at 50-100 m depth, coinciding with a distinct subsurface chlorophyll maximum. The latter is found at the basis of a surficial layer of slightly reduced salinity. A possibly related, two-stepped transmission profile is sometimes observed in the SNL.

Intermediate nepheloid layers (INL) were only occasionally observed, notably off the shelf edge. The INLs at the shelf edge and upper slope have a very limited lateral extent, and appear to form the extension of BNLs present on the shelf.

Distinct bottom nepheloid layers (BNL) of 40-100 m thick are present on the shelf edge. BNLs increase in thickness and become less clearly distinctive with increasing water depth.

In contrast to the above, very distinct INLs and BNLs of up to 1000 m thick were observed in the Nazaré Canyon (Fig. 2). Bottom nepheloid layers on stations directly adjacent to the canyon extend as INL in the canyon. With increasing canyon depth, however, INLs disappear and BNLs become less distinct. At canyon station *PE138-17* the turbidity profile is indistinguishable from other slope profiles observed outside of the canyon.

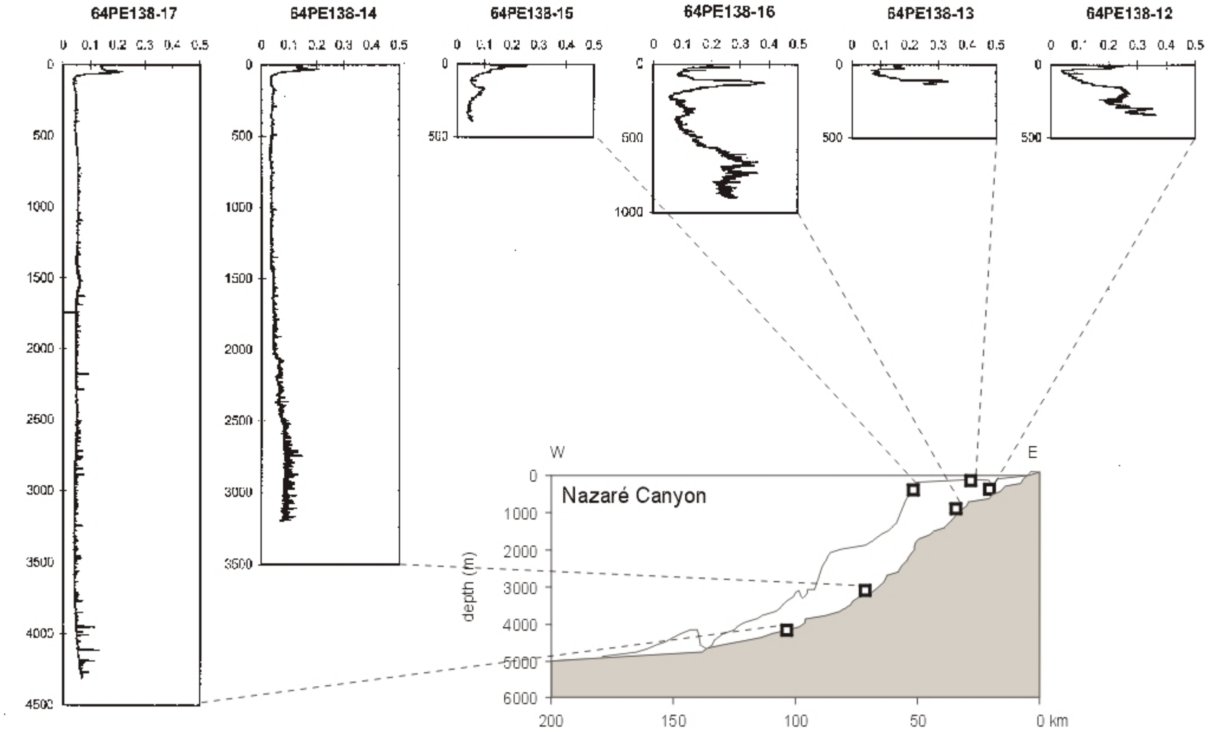

Figure 2. Light attenuation profiles of Nazaré canyon stations. The stations are projected on the profile in the lower right of the panel. Stations PE138-13 and 138-15 are from the shelf and upper slope directly to the north of the canyon (see also Fig.1)

2.2. Regional sediment distribution, properties and composition

The regional sediment distribution appears strongly affected by bottom currents and reworking at the shelf and shelf edge, and is apparently influenced by the stepped, very irregular topography and morphology of the upper part of the middle slope. 3.5 kHz reflectors described previously (van Weering and de Stigter, 1998) could also be distinguished along the transects studied in 1998 and 1999.

The shelf and shelf break are characterized by a strong slightly diffuse reflector representing the seabed, with a lack of well-defined layers below. Patches of finer grained sediment of a more transparent character, fill local depressions. Strong irregular hyperbolic reflectors demonstrate local outcrops of indurated rocks and lack of an appreciable sediment cover on the upper and middle continental slope. On the lower slope a thick sediment drape is present, with laterally extending, well-stratified continuous reflectors. At the base of the slope, truncated reflectors indicate local current scour. South of about 42°40N, the well-bedded sediment cover draping the lower Galician slope continues into the depression between the Galicia margin and Galicia Bank. North of 42°40N, a strong surface reflector representing turbidite beds characterizes the seabed in the depression. Occasionally, irregular, discontinuous reflectors, with strong reflectivity at the surface and little penetration or diffuse character, probably slumped deposits, are found. The eastern slope to the Galicia Bank shows a characteristic pattern of well-layered, truncated layers, with local sediment fill of current-eroded depressions.

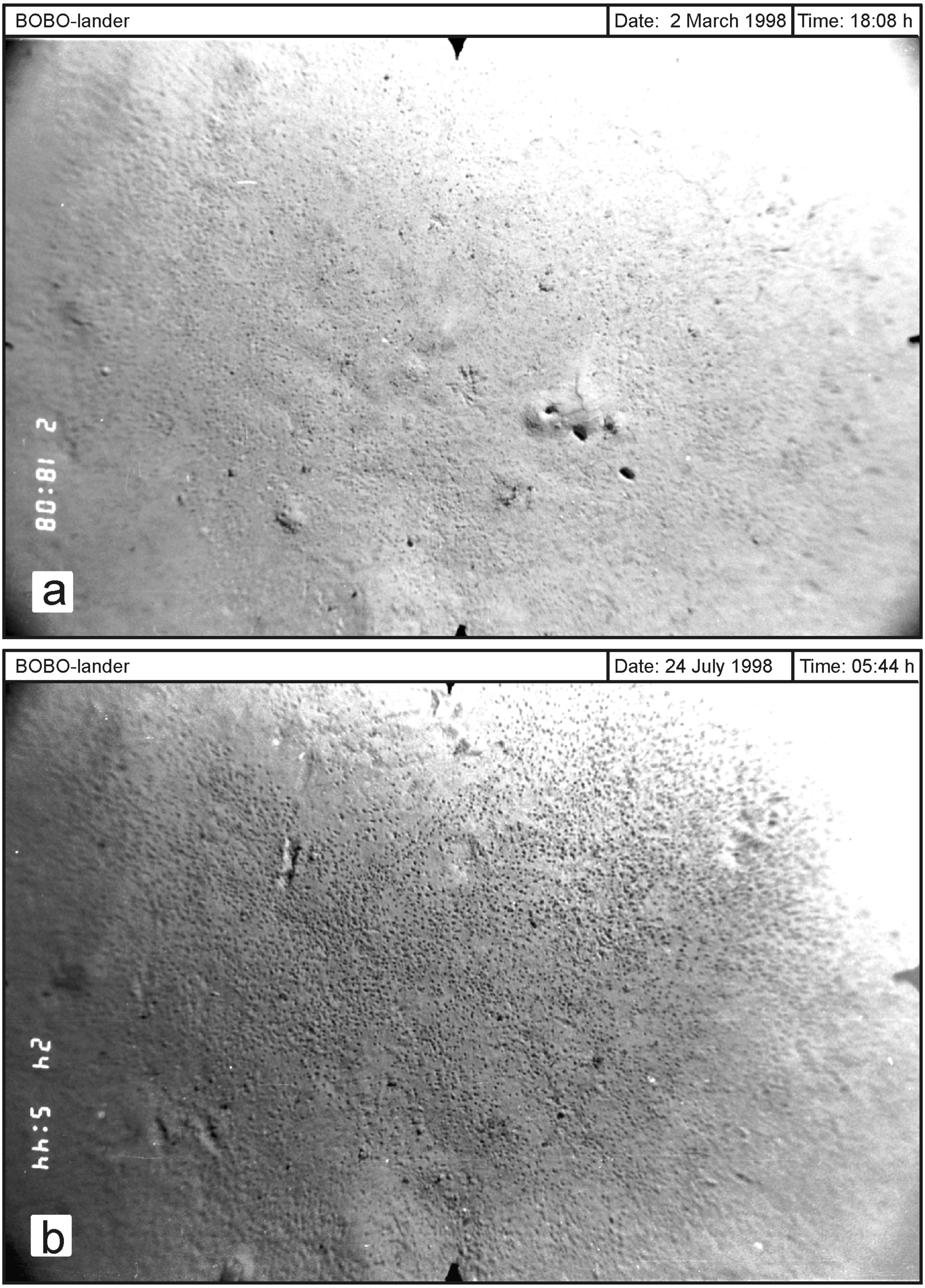

Figure 3. Seabed below BOBO lander at 2152 m water depth on the Iberian Margin. Length of photographed surface approximately 2 m. a: March 2nd, 1998, showing little biogenic activity and minor micro seabed morphology; b: July 24th, 1998, showing strongly increased biogenic activity and burrowing of the surface sediment, with minor micro relief.

The upper Nazaré Canyon, extending from the shore of Nazaré to about 4000-m depth, has a narrow, meandering bed, and steep walls. The canyon walls produce irregular, hyperbolic reflections, indicating a rough topography with a rocky bottom with little or no recent sediment cover. The canyon bed is usually barely visible due to side-echoes from the walls, however, locally well-stratified sediment accumulations appear at the bottom of the canyon. Sediment sampling here indicates soft silty clays with abundant mica and plant debris, of several meters thickness. The lower course of the canyon, about 4000 to 5000 m depth, is weakly sinuous and has a broad flat bed of several kilometers wide, incised by shallow braided channels. The canyon bed is characterized by strong surface reflections, masking any deeper structures. Box cores retrieved from the canyon bed show coarse massive quartz sands, with a thin surface layer of soft silty clay.

2.3 Near-bed sediment dynamics

Initial results of the current meter measurements made by the ADCP during the short term test deployment in summer 1998 show maximum tidal current velocities ranging between 15-25 cm s^{-1}, directed parallel to the slope. Simultaneous measurements of averaged ADCP backscatter over the lowermost 2 m of the water column shows irregular peaks of backscatter, confirmed by simultaneous recorded OBS backscatter at 1 and 3 mab (meter above bed). Backscatter intensity peaks are highest for the OBS at 1 m and slightly lower at 3 mab. Peaks occur associated with highest recorded current velocities. Associated with the changes in tidal current velocity is a bottom water temperature variability of 0.2-0.3°C.

Seabed photographs were made at 12-hour intervals over the period June 1997-August 1998. These show considerable changes in seabed micro-morphology, caused by seasonally, strongly variable presence of benthic animals grazing at the seabed. Also a response of the seabed to seasonally changing dynamic conditions is shown by the development of small ripple fields in autumn, which disappear after some 48 hours. Examples are shown in Fig. 3.

2.4. ^{210}Pb distribution

On the shelf, ^{210}Pb profiles (Fig. 4) show a well-mixed surface layer of at maximum 15-cm thickness. Below this level, the ^{210}Pb activity decreases exponentially to background values. Recent sediments are absent over large parts of the upper slope, whereas ^{210}Pb profiles of the middle and lower slope indicate recent sedimentation. These sediments lack a surface mixed layer and show a continuous decline of activity to background values. Subsurface mixing, indicated by local subsurface maxima at some depth below the surface are commonly observed in almost all profiles.

^{210}Pb profiles of shelf sediments were used, in addition to determine ^{210}Pb excess flux and sediment mixing, for the calculation of sedimentation rates. Sedimentation rates were converted to mass accumulation rates using dry bulk density determinations. Fluxes of ^{210}Pb decrease exponentially with increasing distance from the shore.

2.5. Organic carbon distribution

Core top C_{org} values on the slope show a clear decrease with increasing distance to shore, from 1.1% in station PE109-13 on the middle slope to 0.2% in station PE109-06 on Galicia Bank. Downcore values of C_{org} on the slope are markedly lower, but show a similar trend (Fig.5). On the shelf, a maximum C_{org} content of 1.3% is found in muddy sediments at station PE121-13, whereas low values ranging between 0.2 to 0.4% characterize sandy shelf sediments.

2.6. Mass accumulation and organic carbon burial rates

Sedimentation rates were estimated on the basis of ^{210}Pb distribution profiles (shelf stations only), and ^{14}C AMS calibrated biostratigraphy (Fig. 6). Sediment accumulation rates on the shelf are very high, at least when compared to the adjacent slope, ranging between 394 up to 3379 g m^{-2} y^{-1}. On the steep upper slope, recent sedimentation is practically negligible, whereas on the middle and lower slope accumulation rates of 31.5 to 108.6 g m^{-2} y^{-1} are found.

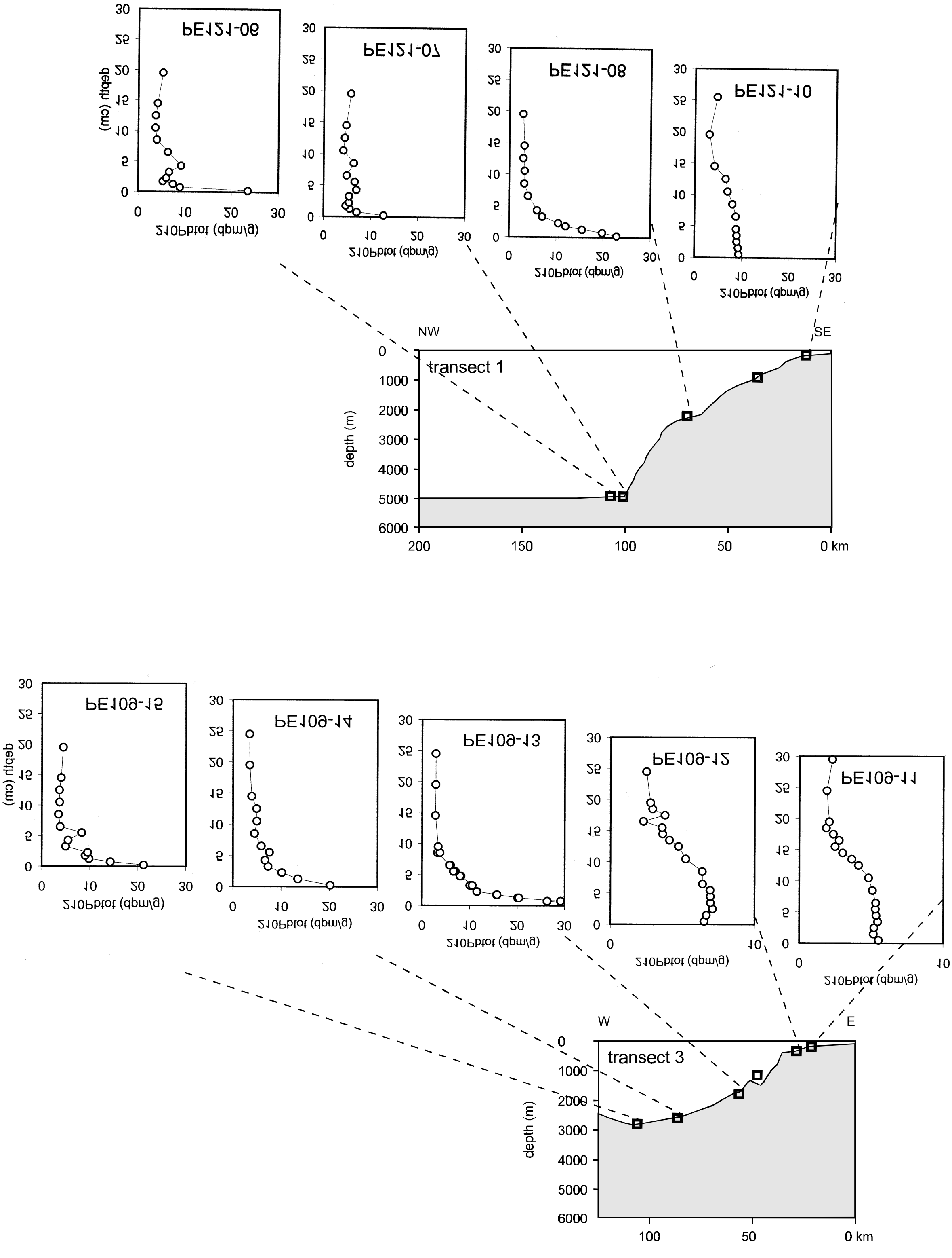

Figure 4. Examples of characteristic ^{210}Pb profiles of surface sediments along the Galician margin transect off La Coruña (transect 1) and off Vigo (transect 3), illustrating the changes in recent sedimentation and mixing in shelf and slope sediments. For location of stations see Fig.1

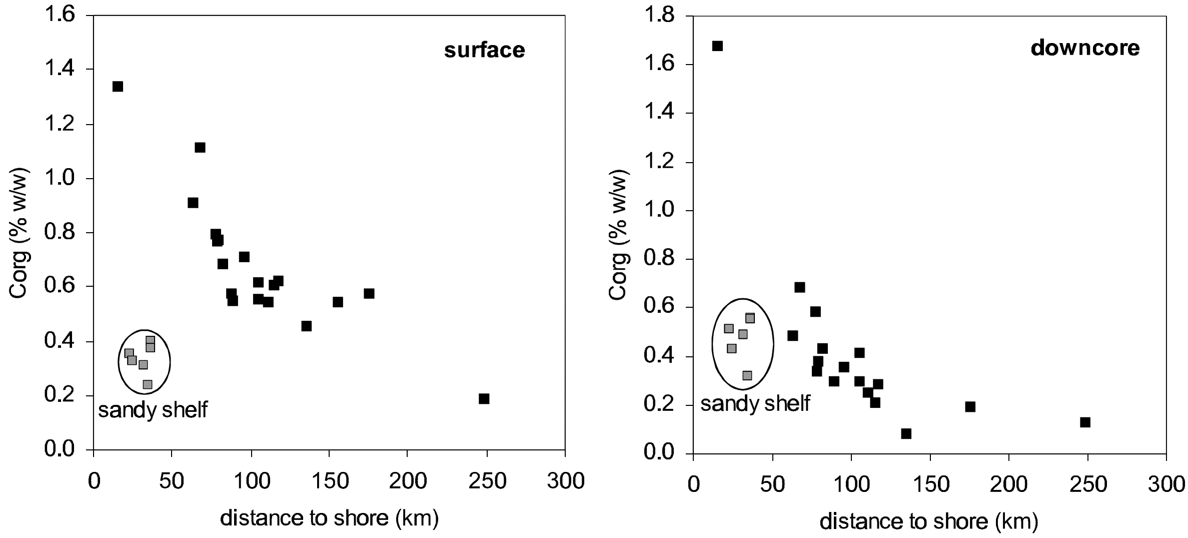

Figure 5. Organic carbon contents of surface sediments (left panel) and downcore (right panel), illustrating the strong decrease of organic carbon with increasing distance to shore of the sample stations, and the low carbon contents in the (sandy) shelf sediments.

Accumulation rates on the middle and lower slope accord well with mass fluxes recorded in sediment traps by Antia, ranging from 31.0 to 98.2 g m^{-2} y^{-1}. A maximum value of 139.1 g m^{-2} y^{-1} is found on the Biscay Abyssal Plain immediately adjacent to the base of the Galician continental slope. Sediment accumulation rates are low on the Galician Bank.

Organic carbon burial fluxes are strongly correlated with mass accumulation rate. On the shelf, burial fluxes range from 2.03 to 18.68 g m^{-2} y^{-1}, whereas on the slope values range from 0 to 0.74 g m^{-2} y^{-1} (Fig. 7).

3. Conclusions

Surface nepheloid layers (SNL), with increased turbidity and beam attenuation caused by higher particle densities extended over the entire study area during all cruises. A turbidity peak at about 50-100 m depth coincides with a distinct subsurface chlorophyll maximum. INLs at the shelf edge and upper slope have a very limited lateral extent, and appear to form the extension of shelf derived BNLs with a patchy spatial distribution. Very distinctive bottom nepheloid layers are present on the shelf edge. BNLs increase in thickness and become less distinct with increasing water depth, and distance from shore.

In the upper and middle part of Nazaré Canyon distinct INLs and BNLs of up to 1000 m thick occur. Bottom nepheloid layers directly adjacent to the canyon extend as INL in the canyon. With increasing canyon depth, INLs disappear and BNLs become less distinct.

Long term BOBO backscatter measurements illustrate irregular near bed beam attenuation in the lower 3 m of the water column, often but not always related to tidal currents. BOBO current meter measurements at the seabed directly below sediment trap station IM2 show maximum tidal current velocities between 15-25 cm s^{-1}, directed parallel to the slope. The BOBO lander seabed photographs confirm that current velocities are higher during short periods in autumn, indicating considerable interannual variability of bottom stress, and thus of sediment reworking and winnowing over a part of the annual cycle.

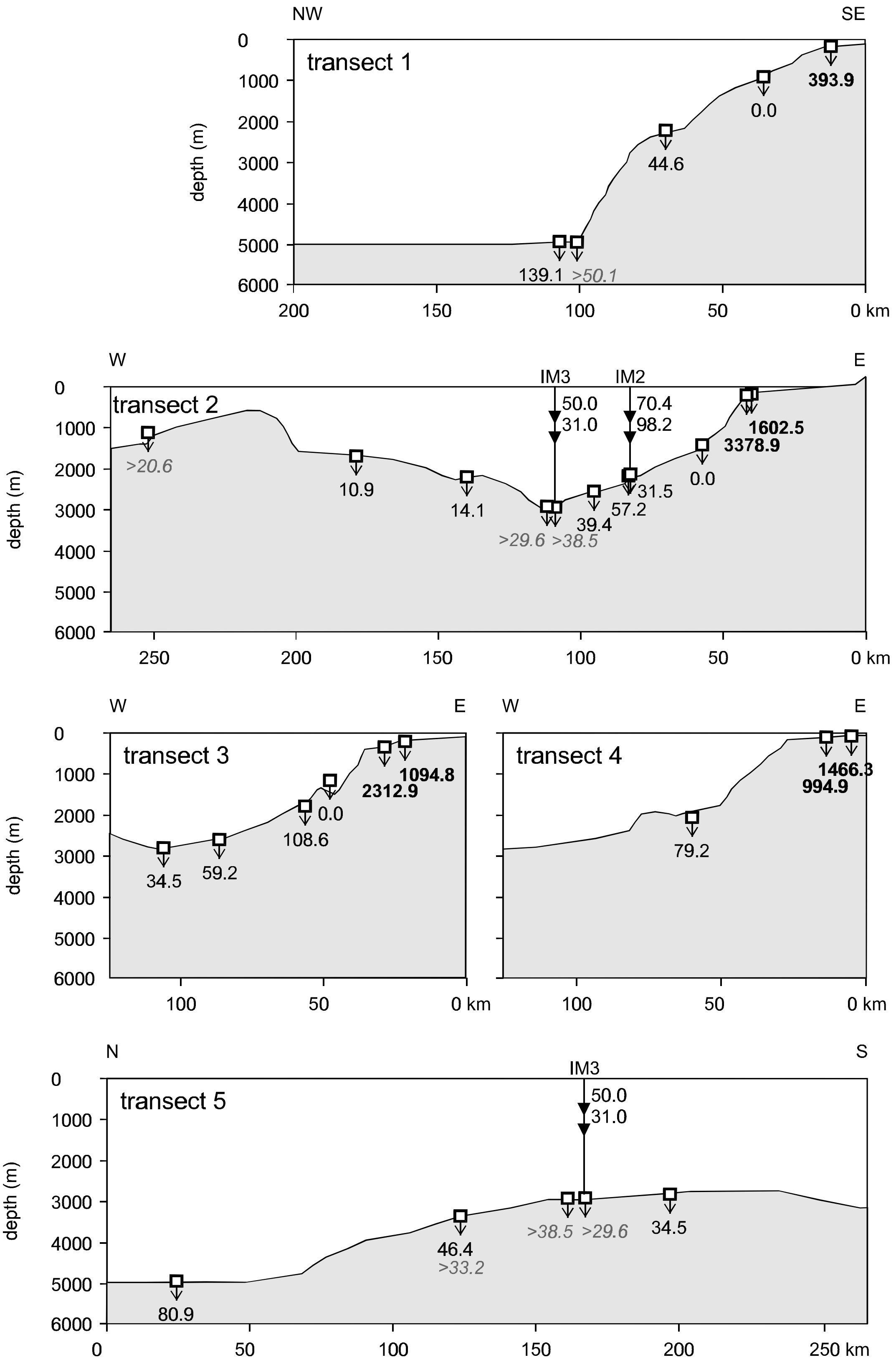

Figure 6. Total sediment flux along the transects sampled across the Iberian margin (1997-1998 data, for location of transects see Fig. 1). Values in bold print are based on ^{210}Pb analysis; all other values are based on biostratigraphy; values in italic are minimum estimates. Highest values occur at the shelf and shelf edge with considerable lower values on the middle and lower slopes. Arrows in the watercolumn in transects 2 and 5 are values from sediment trap measurements by Antia et al (pers.comm.). These illustrate influx by INL into trap IM2 and reduced settling at the station directly below.

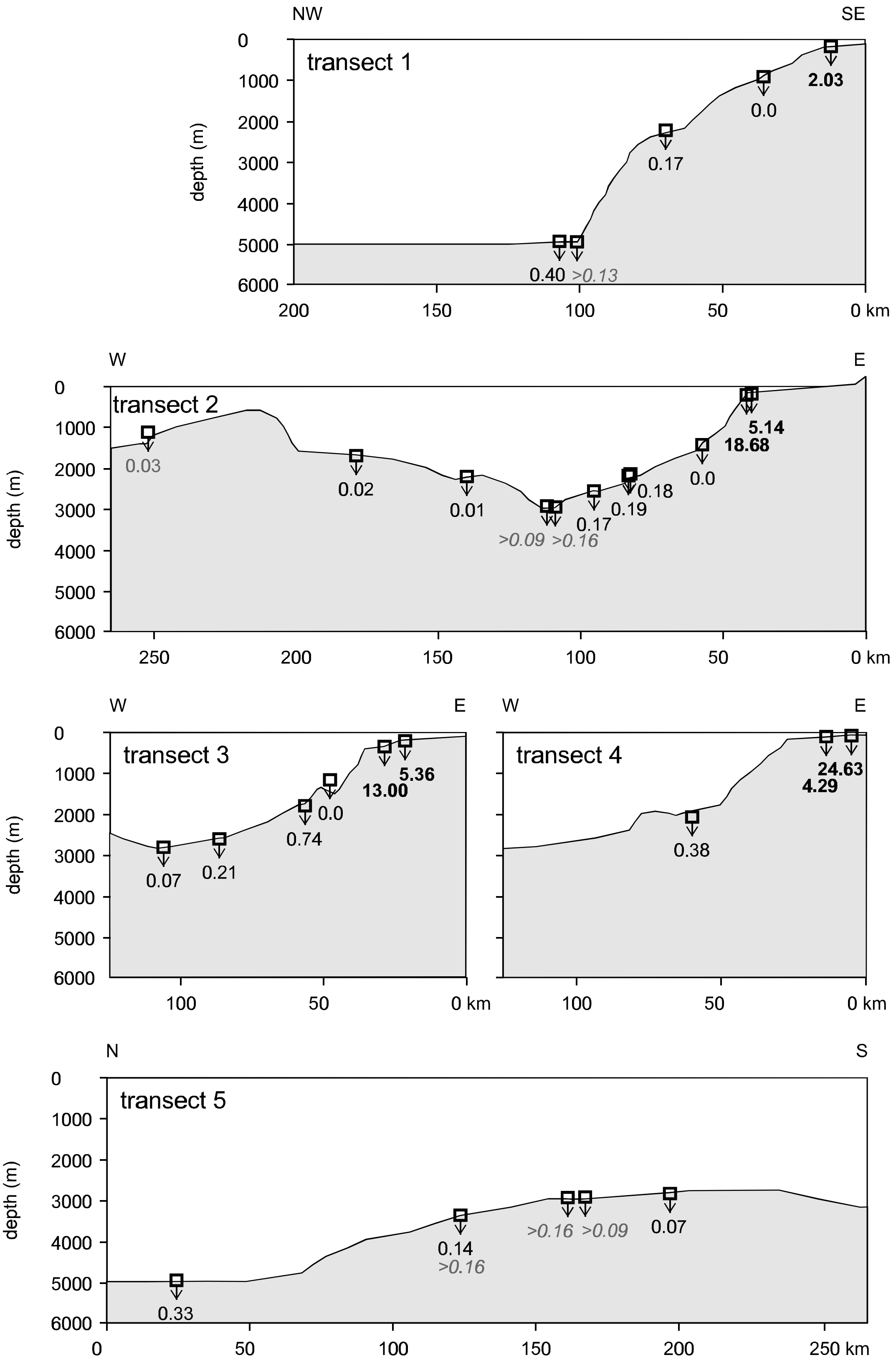

Figure 7. Organic carbon burial fluxes along the same transects (1997-1998 data, for location of transects see Fig. 1). Values in bold print are based on ^{210}Pb analysis; all other values are based on biostratigraphy; values in italic are minimum estimates. Relatively low carbon burial values are found in the north, with a clear increase to the south of the study area. Extremely low burial rates on the flanks of Galicia Bank (transect 2) are considered due to sediment reworking and strong winnowing by currents.

^{210}Pb profiles of shelf surface sediments show a well mixed surface layer of at maximum 15 cm thickness and an exponential decrease to background values below, similar to the observations of Reyss *et al.* (1999). Recent sediments are irregularly distributed and often absent on the upper slope; the middle and lower slope are covered by recent sediments. C_{org} values of surface sediments decrease with increasing distance away from the shelf, from 1.1% on the middle slope to 0.2% on Galicia Bank. Although lower, downcore organic carbon values have the same trend. Sediment accumulation on the shelf is very high, with values between 394-3379 g m^{-2} y^{-1}. On the middle and lower slope accumulation rates of 31.5 to 108.6 g m^{-2} y^{-1} are found. Accumulation rates on the middle and lower slope agree well with mass fluxes observed in sediment traps by Antia (*pers. comm.*).

References:

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