Work Package III

Fluxes and Processes in Nepheloid Layers and Surface Sediments

Management Report

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1. Coordination, workshops and meetings

During year 1 of OMEX II, the WP III leader did not attend the first steering committee meeting nor WP I / II workshops. A first and successful WP III workshop and meeting, attended by WP III and a number of WP II partners was held April 4-8, 1998 in Faro, Portugal. A total of 17 presentations was given and interactions and future intergration of data discussed during the last day. Exchange of data has started. International participation in specific national cruises is increasing. Sea going programmes 1998/1999 were discussed.

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

Partners involved: 2, 5a, 5c, 5d, 7, 8a, 8b, 14b, 15a, 24b, 25, 26, 27.

1.1 Amount, character, distribution and composition of suspended particles in nepheloid and clear water layers (Partners: 5a, 8b,14b, 24b, 25, 26, 27)

The water column was sampled with CTD equipped with transmissometer, and/or fluoro-meter with OBS along transects across the Iberian Margin during Charles Darwin cruises105 and 110, Pelagia 109, Corvet 96 and Clima 97, covering the Iberian shelf and margin area between. 41.20 and 43°N. Transmission profiles were used for determination of SPM distribution in the water column. Subsequently water samples were collected from the intermediate (SNL) and bottom nepheloid layers (BNL) and filtered to study the amount and composition of SPM in the BNL.

The study of SPM in the northern Portuguese margin shows distinct differences between winter and summer, allowing assessment of the inter-annual variability. The adjoining shelf and upper slope margin off Vigo were intensely studied during CD 105 and 110 cruises, which indicated intense intermediate nepheloid layers (INL) in the North Atlantic Central Water, underlain by relatively clear Mediterranean Water. Within the North Atlantic Deep Water low typically clear water minimum particle concentrations were found, with locally patches of INL. Along transect plotting of attenuation suggests an important role for canyons and chutes in the export of particulate material to the deep ocean.

Sediment stability and characteristics of resuspended aggregates were experimentally determined on sediment cores by means of an erosion chamber augmented by image analysis. Under tidal flow conditions typical for continental margin conditions a thin surface layer erodes as aggregates which can be subsequently transported in a number of tide related resuspension-deposition loops over long distances (partner 24).

Large volumes of sea water in intermediate and nepheloid layers were sampled (partner 27) for determination of short lived isotopes attached to SPM. Filtration and radiochemical purification was conducted on board the ship and measurements will be completed in Gif.

Deliverables month 12: met by all partners

1.2 Spatial and temporal variability of the benthic boundary layer dynamics (Partners: 2, 5a, 7, 24b)

Lander STABLE (partner 2) was shortly deployed in shallow water (202 m depth) at the shelf edge to obtain short term turbulence and sediment resuspension measurements near the bed. The lander BOBO was deployed for long term (12 months) measurements of currents, salinity, temperature and

time-lapse seabed photography near IfM sediment trap IM 3 (2152 m depth). On selected stations critical shear velocities were measured (24b)during Pelagia cruise PE 109.
Deliverables: n.a (Month 24)

1.3 Particle fluxes to the seabed, accumulation and mixing rates (Partners: 5a, 5c, 25, 26, 27)
To measure these, sediment samples (box, kasten and pistoncores) were taken (partners 5a, 26, 8b) along transects perpendicular to the margin and at the shelf during Charles Darwin cruises105 and 110, Pelagia 109, Corvet 96 and Clima 97.

Sediment distribution, properties and composition along selected transects of the Iberian shelf and margin was studied, showing that mass accumulation rates are relatively high at the shelf edge, while local no sedimentation takes place at the upper slope. Rates range from ~6 to about 3,5 g/cm^2/1000yr. Locally an exceptional high mass accumulation rate of 11.43 g/cm^2/1000yr was measured at the lower continental slope off Vigo. The eastern margin of Galicia bank appeared strongly influenced by local current scour, resulting in lowest accumulation rates between 1.09-2.06 g/cm^2/1000yr.

The ^{210}Pb distribution in the sediments shows strongly different mixing of the surface sediments along the transects; mixing is down to 10 cm at the shelf edge stations and less at the slope stations.
Deliverables: n.a.(Month 24)

1.4 Sediment distribution, properties and composition along selected transects (Partners: 5a, 5c, 8b, 25, 26, 27)
Multibeam and penetrating echosounder swath bathymetry and profiles were collected from the Iberian margin during cruises 105 and 110 by "Charles Darwin" and during cruise Pelagia 109. Processed swath bathymetry data yielded a detailed bathymetric map and other contour plots of the margin, used for plotting sediment mooring and lander deployment stations.

On the Spanish Iberian margin the shelf and shelf break are characterized by a strong slightly diffuse reflector with a lack of well defined layers below (Type 1 reflector). The upper and middle continental slope show strong irregular hyperbolic reflectors (Type 2), indicating local outcrops of indurated rocks and lack of an appreciable sediment cover. The lower continental slope and part of the channel floor between Galicia Bank and the NW Spanish margin is characterized by well-layered, continuous reflectors (Type 3), formed by alternations of transparent and strongly reflective beds. In the deepest part of the channel irregular, discontinuous reflectors with strong reflectivity at the surface and little penetration or diffuse character (Type 4) are occasionally found. The eastern slope to the Galicia Bank shows a characteristic pattern of well-layered and subsequently truncated layers (Type 5) evidencing current scouring of the margin.

At the northern Portuguese margin grain size was shown to be strongly affected by sediment resuspension due to wave action and tidal currents in shallow waters. Surface sediments here show a clear increase to somewhat coarser particles over the outer shelf. In the inner shelf lower POC values result from resuspension and redistribution of bottom sediments, resulting in a westward increase in POC. Sediments from mud patches on the Portuguese shelf do not indicate distinct differences of sedimentation and mixing rates in their down-core ^{210}Pb distribution. A marked homogeneity in the first ten centimeters of the sediment column may be explained as mixing caused by either bioturbation or by storm events. A further evaluation of either process will be made on the basis of core material to be collected in July 1998.

The sediment dynamics and distribution of amino acids, carbon and nitrogen in surface sediments of the northern Portuguese shelf and margin were studied showing that Si concentrations over the shelf are highly variable and decrease with increasing distance from the coast. Quartz and carbonate contents of the Douro and Minho mud patches show also some variability. Organic carbon concentrations range from 0.55- 2.11% (wt).
Deliverables: met (Month 12)

1.5 Dominant sediment transport processes and fluxes at contrasting margins (Partners: 2, 5a, 7, 8b, 14b, 24b, 26, 27)
This subtask is an integration of work done under OMEX II by the various partners and has started by exchange of data and results as presented in the Faro Workshop of Workpackage III partners. Ongoing cooperation and exchange between partners to achieve this goal takes place.
Deliverables: n.a (Month 36)

1.6 Modeling near bed-transport and budgets (Partner: 2)
Comparison of the 2-D model of bottom boundary layer mixing with the results of a 1-D model showed the importance of the coastal boundary condition and the variation of the slope between continental shelf and slope. Up- or down-welling bottom flow modifies the density which in turn modifies the along-slope current above the boundary layer significantly, effects omitted in 1D.

The internal tide enhances the bottom stress which in turn has a significant effect on the resuspension of bottom sediment and sediment transport over the shelf and slope with the critical shear velocity value used (corresponding to fine non-cohesive material).
Deliverables: n.a (Month 18)

1.7 Long term change (Partners: 5a, 26, 27)
The Magnetic susceptibility (MS) and weight corrected magnetic susceptibility of four Kastencores collected from the Portuguese and Spanish upper slope has been studied and downcore organic carbon and carbonate contents measured. Samples were taken for downcore studies of oxygen isotopes and grainsize. An initial interpretation defines the most prominent MS peaks as turbidites and Heinrich layers.

An additional set of four pistoncores in waterdepths from 1200 to 3000m showed prominent MS peaks in sediments along 42.20°N indicative for the presence of Heinrich layers. These data likely will allow correlation of the cores and thus aspects of long term change over a large part of the NW Iberian margin.

Diatom studies of surface sediments to establish the relationship between present day oceanographic conditions and the contemporary sedimentary record, indicated an overall poor diatom diversity and an offshore increase in diatom contents.
Deliverables: (Month 18)

Task III.2: Sediment /water exchange processes and early diagenesis
Partners involved: 5a, 5c, 15a, 28

2.1 Sediment-water exchange processes (Partners: 5c, 28)
A comparison between nutrient concentrations in the bottom water (measured in the CTD bottles) and in the water overlying the box/multicorer samples shows that lowest values were consistently measured in CTD bottles, highest in the box core overlying water.

Vertical profiles of phosphate, iron, manganese, acid volatile sulphide (AVS) and trace metals have been determined in pore water and solid phase of sediment cores collected off Porto. The results indicate that the peak of phosphate production appear below the layers of higher iron and manganese production. The flux of phosphate from the pore water to the water column has also been evaluated. Total trace metals (Cd, Cu, Pb) concentrations normalised with respect to aluminium content did not show remarkable variations.

A plot of oxygen concentrations versus water depth reveals a nearly identical depth-depending pattern at the Iberian margin. The oxygen minimum zone is located between 750 and 1050 m water depth, where the oxygen concentrations were under saturated by nearly 35%. This depth interval coincides with the outflow of Mediterranean deep water flowing northwards, as seen in the increased salinities at this water depth. Bottom waters are under saturated between 17 and 31 %.

Deliverables: n.a (Month 18)

2.2 Organic matter diagenesis and burial (Partners: 5a, 5c, 8b,14b, 25, 26, 27)
Oxygen penetration depths range from ~10 mm at the shelf edge to ~55 mm at the deepest station on a transect to Galicia Bank, and from ~12 mm to ~30 mm along a transect off VIGO. The penetration depths and the curvature of the profiles suggests enhanced carbon mineralisation along the southern transect. The exponential-like curvature of the profile indicates consumption of oxygen throughout the oxic zone, while a rather linear gradient suggests an only modest oxygen consumption at the oxic/anoxic interface. A locally high oxygen consumption at the lower slope coincides with observed high sediment mass accumulation rates, one order of magnitude higher than other stations at the NW Iberian margin and with a locally high organic carbon concentration (1.1 wt %) .

Nitrate pore water profiles at stations above 350 m water depth showed a pronounced peak in the upper part of the oxic layer, clearly demonstrating the presence of nitrification as prevailing source of nitrate for de-nitrification (see Lohse et al, this report.).

Below 350 m water depth, nitrate concentrations just below the sediment-water interface imply that the sediments may act as a sink for nitrate, conform observations from other upwelling regions.

Ammonium pore water profiles indicate the presence of anoxic mineralisation rates on the shallow stations on transects along 42.20 and 42.40°N. Corroborating to the oxygen and the nitrate pore water profiles, it is obvious that anoxic mineralisation is more important along the southern transect.
Deliverables: n.a (Month 18)

2.3 Dominant carbon mineralisation mechanisms and factors at contrasting margins (Partners: 5c, 28)
A comparison of pore-water profiles from the Goban Spur with those obtained during OMEX II from the Iberian margin indicates tentatively that the benthic nitrogen cycle at the Iberian Margin differs substantially from the Goban Spur. This aspect will be further studied and defined.
Deliverables: n.a. (Month 36)

2.4 Modeling benthic fluxes (Partner: 15a- See also sub-task 3.6)
Follows in a later stage after sufficient field data have been derived under 2.1-2.3.
Deliverables: (Month 36)

Task III.3: Role and importance of the benthic community
Partners involved: 5d, 15a, 15b, 24b

3.1 Role and importance of bio-entrainment and bio-deposition (Partner: 24b)
Experimental studies in laboratory flumes showed that benthic Foraminifera (*Marsipella* spec.) dominating a mid slope station (1645 m) at the Iberian continental margin can scavenge aggregates transported in the benthic boundary layer. These BBL aggregates occur in concentrations of 0.5 and 5 cm^{-3} at 0.5 cm height above the sea floor, where free stream flow velocities were in the order of 33 and 3 cm s^{-1}. Aggregate encounter rates varied between 1.6 - 9.4 x 10^{-4} and aggregate capture rates from 1.6 - 10 aggregates $ind.^{-1}$ d^{-1}. These low capture rates can still be high enough to balance the carbon demands of the Foraminifera. The estimated POC bio-deposition of the foraminiferal community was 0.22 - 0.67 mg m^{-2} d^{-1}, which is roughly 1 - 4 % of the total carbon deposition needed to feed mid-slope benthic communities.

POC deposition via aggregates was low when compared to the bio-deposition rates estimated for the Goban Spur study site of the OMEX I project.
Deliverables: n.a (Month 18)

3.2 Microbial activity (Partner: 24b)
Studies of particle composition, microbial activities and the genetic structure of the microbial communities of six locations in the Whittard Canyon between 170 to 3700 m water depth were made.

The preliminary results suggest that microbial activities and particle composition in the BBL differ significantly from the intermediate and upper water column. Rates of bacterial production ranged from 0.004 to 1.9 mg C m^{-3} d^{-1}, with highest rates measured in the euphotic zone. However, the median microbial activities in the benthic boundary layer were higher than in the intermediate water column, 0.31 compared to 0.006 mg C m^{-3} d^{-1}, respectively.
Due to significant differences in bacterial abundance between the euphotic zone and the deeper water layers highest cell specific bacterial production rates of 0.36 fg $cell^{-1}d^{-1}$ were observed in the benthic boundary layer.
In the BBL, bacterial production rates were significantly related to the concentrations of particulate organic carbon and chl. Equivalents. In all other samples the microbial activities appeared to be independent of particle composition.
Deliverables: n.a (Month 18)

3.3 Benthic food supply, respiration, and carbon mineralisation (Partners: 5d 15b, 24b)
A transect off La Coruña showed that two stations (C41 and C59) at the lower slope and abyssal plain not only have the highest phaeophorbide concentrations, but also the highest chlorophyll-a concentrations, with a maximum at the abyssal plain station. Off Galicia the low values of phaeophorbides (chlorophyll-a undetectable) in the channel between the continental slope and Galicia Bank are remarkable.
SCOC deck incubations showed values comparable to those measured at the OMEX-I transect over the Goban Spur by Duineveld *et al*, 1997. Outstanding is the high SCOC value at a deep station at the foot of the continental slope (C59, 4900m), of three times the normal NE Atlantic abyssal value.
Deliverables: n.a (Month 18)

3.4 Benthic community structure (Partner 15b, 5d and 24b)
Samples were taken for meio-, meso- (not yet sorted) and macrofauna and for sediment analyses along two transects at the Iberian Margin in June/July 1997. Macrofauna densities were high at the shelf and decreased with increasing water depths. Macrofauna biomass was lower at the shelf and upper part of the slope at the Iberian Margin than at the Goban Spur, whereas density and biomass were more or less similar at the lower part (>2000 m). At the lower part, however, the % of organic carbon and nitrogen were higher at the Iberian Margin than was found at the Goban Spur, whereas the median grain-size was similar. A larger fraction of the organic matter arriving at these depths thus seems to be buried within the sediment at the Iberian Margin compared to the Goban Spur, whereas a similar amount seems to be used by the macrofauna.

Results on the megafauna community study show that meganauna filter feeders form an important feature in the Iberian margin and its biomass is comparable with the Goban Spur values reaching a maximum around 2000m depth. Cold water coral reefs (Lophelia) are present at the slope and at the Galicia Bank. Relative high sediment community oxygen consumption values were found at the deepest stations where there are also the highest phytopigment concentrations.

Sediment stability and characteristics of resuspended aggregates were experimentally determined on recovered cores from different locations of the western European continental margin by means of a benthic erosion chamber augmented by an image analysis system. In conjuction with hydrodynamic details published elsewhere, the experiments demonstrate that under tidal flow conditions typical for continental margins, the interfacial layer erodes as aggregates. Experimental studies in laboratory flumes show that benthic Foraminifera (*Marsipella* spec.) dominating a mid slope station (1645 m) at the Iberian continental margin can scavenge aggregates transported in the benthic boundary layer.

3.5 Variability of benthic community structure and functioning at contrasting margins (Partners: 5d 15b, 24b)
The macro-fauna density was high at the Galician shelf and decreased with increasing water depth and distance from the shore. Macro-fauna densities at the shelf were more or less similar. Also, at the lower slope (>2000 m) densities were more or less similar. Very low densities were found at the mid slope (1522 m) off La Coruna, and at the Galicia Bank at 764 m. At both stations relatively high

numbers of filter-feeding taxa were found, suggesting high flow velocities. The vertical distribution of the macro fauna seems to be depth related, with most fauna concentrated in the upper 1 cm at mid-slope depths (1000-2000 m).
Macro-fauna biomass (without some extreme large individuals) overall decreases with increasing water depth. The shelf (station C0) near La Coruña had a very low biomass compared to the shelf stations at the Galicia Bank and the Goban Spur transects. Extreme low biomass was found at the middle slope(1522 m, station C36), the Galicia Bank had also a low biomass for its depth. The low biomass at these two stations was due to low densities (as discussed above) and not to small size of the animals, whereas at the shelf station C0 animals were very small. At the Galicia Bank mean individual weight was high, as were the mean individual weights at the deep La Coruña stations.
Both transects show a similar pattern of relatively fewer individuals of larger size with increasing distance from the coast. No direct relationship with the % of Corg or nitrogen with either density, biomass or size could be observed. Both percentages, however, show a negative correlation with median grain-size. At the lower part of the slope (>2000 m) biomass and mean individual weight were more or less similar to the values found at the Goban Spur at similar depths.
Deliverables: n.a (Month 24, resp. 36)

3.6 Ecological modeling (Partner:15a)
Deliverables: n.a. (Month 36)