Carbon and nitrogen mineralisation in sediments underlying an upwelling region: The Iberian continental margin

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Abstract

Benthic carbon mineralisation was investigated along two continental margin transects off the western Iberian Peninsula. A tentative evaluation of the pore water profiles of oxygen, nitrate and ammonium reveals that both transects are characterised by intense anoxic mineralisation processes on the upper shelf and slope stations, while stations located below 1800 m water depth are dominated by oxic mineralisation. Benthic nitrogen cycling was characterised by nitrate influxes at several stations above 300 m water depth, underlining the importance of the overlying water as a source of nitrate for denitrification.

The comparison of stations located at similar water depths on the northern and the southern transect suggests that benthic mineralisation rates are higher on the southern transect. This may indicate a significant transport of particulate organic matter northward, probably facilitated by Mediterranean deep water. Cross-shelf transport towards the deeper slope appeared to be more pronounced on southern transect, where sub- and anoxic processes were reported down to 1760 m water depth.

A preliminary comparison of the results reported for the Goban Spur area (Omex I) and the present investigation area clearly indicates that benthic mineralisation rates on the shelf are substantially higher along the Iberian shelf. Additionally, it appears that the contribution of anoxic mineralisation processes extends to larger water depths than at Goban Spur.

Introduction

The investigation of benthic carbon cycling along two contrasting continental margins represents a primary goal within the OMEX programme. Previous investigations carried out during OMEX I showed that the benthic carbon cycle along the Goban Spur transect was dominated by the mineralisation of refractory compounds. This conclusion was drawn from the absence of seasonality in benthic mineralisation rates as well as from the low first-order degradation constants of decaying organic matter (Lohse et al 1998). Additionally, the decrease of benthic mineralisation with increasing water depth indicated that there was no carbon depocenter present along this part of the north-western European continental margin.

The Iberian margin represents a geologically and hydrographically substantially different continental shelf-slope system. This area is characterised by a narrow shelf area which transits with steep slopes into the north-Atlantic abyssal plains. High primary production in coastal areas is supported by upwelling North Atlantic deep water. It is hypothesised that a part of this primary production is exported from the shelf-area by so-called filaments, which transport water masses and particulate organic matter into north-western direction towards the Galician Bank.

The principal goal of our project is to investigate the degradation and burial of organic matter along several transects along the Iberian margin. Pore water modelling and sediment-water incubations, carried out in-situ and shipboard, are used to calculate benthic mineralisation rates. In the second phase of OMEX II, biomarker studies and kinetic considerations of the organic matter degradation will allow us to ascertain the origin and the age of the organic material undergoing decomposition. In combination with results from other OMEX II partners we will to try to link our benthic investigations with processes taking place in the upper water column. In this annual report we document initial results obtained from a cruise carried out in July/August 1997.

Material and Methods

Sampling stations were located along two off-shelf transects (Fig. 1 and Table 1). While CTD profiling could be carried out at all visited stations, bad weather conditions and/or bottom topography prevented sediment sampling covering water depths between 200 and 1700 m.
Bottom water concentrations of oxygen and nutrients, which are essential for the determination of interfacial nutrient and oxygen gradients were obtained from deepest CTD bottles, and the overlying water of the box- and the multicorer.
Sediment cores were obtained by multicoring. The corer retrieves four 10 cm (i.d.) cores and eight 6.5 cm (i. d.) core. The sediment structure prevented the collection of sediment samples by multi coring at stations PE109-3, PE109-6 (both coarse, permeable sands) and PE109-10 (consolidated clay).

Pore water compounds and solid phase bulk parameter

Pore water extraction was performed by extruding the sediment from the multi-corers and slicing them into the following intervals:

Sediment intervals to collect (mm)			
0.0-2.5	10.0-15.0	30.0-40.0	70.0-90.0
2.5-5.0	15.0-20.0	40.0-50.0	90.0-110.0
5.0-7.5	20.0-25.0	50.0-60.0	110.0-130.0
7.5-10.0	25.0-30.0	60.0-70.0	130.0-150.0

Slices from identical depths from 4 multicorers were then homogenised and centrifuged at 3000 rpm for 10 min. The separated pore water was filtered and analysed for the depth distribution of ammonium, nitrate, nitrite, phosphate, silicate, urea and $\sum CO_2$ within 24 h shipboard using TRAACS 800+ auto-analysers. Sulphate and dissolved manganese and iron will be analysed at the shore based laboratory.
Additional sediment samples have been taken for the determination of the diffusional characteristics of the sediment (porosity, resistivity) as well as for the solid phase of organic carbon, total nitrogen, solid iron and manganese.

Oxygen profiling

Oxygen profiles were made in-situ with a free falling instrument (TROL, Temperature Resistivity Oxygen Lander). TROL is equipped with 5 mono-cathodic oxygen micro-electrodes and a resistivity probe. For details of TROL characteristics see Epping and Helder (1997). The oxygen profiles made with TROL were compared with those made shipboard to be able to assess eventually possible artefacts associated with decompression of (deep)-sea sediment samples
Shipboard oxygen profiles were obtained by using Clarke type oxygen microelectrodes. The profiles were made with a vertical resolution of 100 to 500 um using a computerised micromanipulator. All measurements were carried out in 10 cm (i..d.) multicores with a stirred water column.

Sediment-water fluxes

Sediment-water fluxes were estimated in by monitoring the concentration of solutes in the overlying water of 3 10cm (i.d.) multicores. In order to preserve the sediment-water interface, the overlying water of the cores was not replaced by filtered bottom water. Instead, the bottom water reservoir was monitored for concentration changes.
All incubations were performed under gas-tight conditions, which allowed the simultaneous determination of nutrients, oxygen and total inorganic carbon. The cores were stirred with a central

clockwise-anticlockwise rotating magnet. The diffusive boundary layer created by this way of stirring ranged between 200 and 500 µm in thickness, depending on the sediment microtopography.

Results and discussion

Water column

Plotting the oxygen concentrations versus water depth reveals a nearly identical depth-depending pattern at all visited stations (Fig.2). The oxygen minimum zone was located between 750 and 1050 m water depth, where the oxygen concentrations were undersaturated 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 (not shown). Bottom waters are undersaturated between 17 and 31 %. Apart from station 6 (1129 m), no stations were sampled in water depths intersecting with the oxygen minimum zone.

The accurate determination of bottom water oxygen and nutrient concentration is crucial for the calculation of sediment-water fluxes of solutes. Deviation between values estimated from the deepest CTD bottle (5 m above sea floor) on the one hand and multicorer and boxcorer on the other hand gives some clues on the potential disturbance introduced by both coring devices.

Figure 3 exemplifies the nutrient concentrations in the bottom water as measured in the CTD bottles and in the overlying water of the box/multicorers. Lowest values were consistently measured in CTD bottles, highest in the box core overlying water. While it is obvious that the retrieval of sediment cores with overlying water leads to some physical disturbance, our data indicate that the multicorer retrieves sediment cores with less disturbance than the box-corer. This is also confirmed by visual inspection of retrieved sediment from multi coring which usually shows the uppermost sediment layer to be intact. A further advantage of the multi-corer is that the sediment-cores can be processed without further subcoring, as would be necessary during boxcoring.

Sediment-water fluxes and pore water profiles of oxygen, nitrate and ammonium

An representative set of oxygen pore water profiles in Fig. 4. Oxygen penetration depths ranged from ~10 mm at station 2 to ~55 mm at stations 5 on the northern transect and from ~12 mm at station 11 to ~30 mm at station 14 on the southern transect. The penetration depths and the curvature of the profiles suggests that carbon mineralisation at stations located on the southern transect is enhanced compared to stations along the northern transect. For instance, oxygen penetrates down to ~ 40 mm into the sediment at station 8 (north). At station 13, located on comparable water depth (1760 m) on the southern transect, oxygen penetrates only ~ 20 mm into the sediment. The exponential-like curvature of the profile indicates consumption of oxygen throughout the oxic zone, while the rather linear gradient found at station 8 suggests only a modest oxygen consumption at the oxic/anoxic interface. It should be noted that the apparent high oxygen consumption at station 13 is characterised by high sediment mass accumulation rates, which are one order of magnitude higher than all other investigated stations (see contribution van Weering et al). These findings are in line with the comparatively high organic carbon concentration (1.1 wt %, results of M. Belzunce Segarra, CSIC Vigo).

Nitrate (Fig. 5) and ammonium (Fig. 6) pore water profiles, generally indicative for the presence of sub- and anoxic mineralisation processes, confirm the first impression that the southern transect is diagenetically more active than the northern transect. This conclusion is evidenced by the downward nitrate gradients, which penetrate less deep at stations on the southern transect compared to stations located at similar water depths along the northern transect. Identical to the previously visited Goban Spur area, nitrate pore water profiles at stations > 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 denitrification (Lohse et al 1996). At stations 8 and 9, nitrate reaches asymptotic values between 4 and 10 cm sediment depth. As a consequence, sampling strategies during coming cruises will include sampling from depths > 20 cm in order to estimate the depth-integrated denitrification rate accurately.

At stations located < 350 m water depth, nitrate concentrations just below the sediment-water interface approximate those in the overlying water, implying that the sediments may act as a sink for nitrate. This situation has been reported for other upwellling regions along the eastern North American continental shelf, where the combination of very high nitrate concentrations in the overlying water (30-40 μM) is accompanied by a pronounced oxygen minimum intersecting with the seafloor. In that area, high rates of denitrification are supported by the diffusion of nitrate from the overlying water through the nitrification zone (Devol and Christensen 1993). Shipboard incubations of sediment-water enclosures indeed confirm an nitrate uptake of the sediments at station 11 on the southern transect (Fig. 7).
Ammonium pore water profiles indicate the presence of anoxic mineralisation rates on the shallow stations on both transects (Fig. 6). Corroborating to the oxygen and the nitrate pore water profiles it is obvious that anoxic mineralisation is more important along the southern transect. This is most evident at station 13, where despite a water depth of 1760 m more a substantial ammonium accumulation below the oxic zone could be noticed. The results are in line with the release of ammonium from the sediment, indicating that nitrification in the oxic surface does not convert upward diffusing ammonium quantitatively into nitrate. If this tentative conclusion will be confirmed in further investigations, it becomes clear that the benthic nitrogen cycle at Iberian margin differs substantially to the one reported at the Goban Spur area.

References

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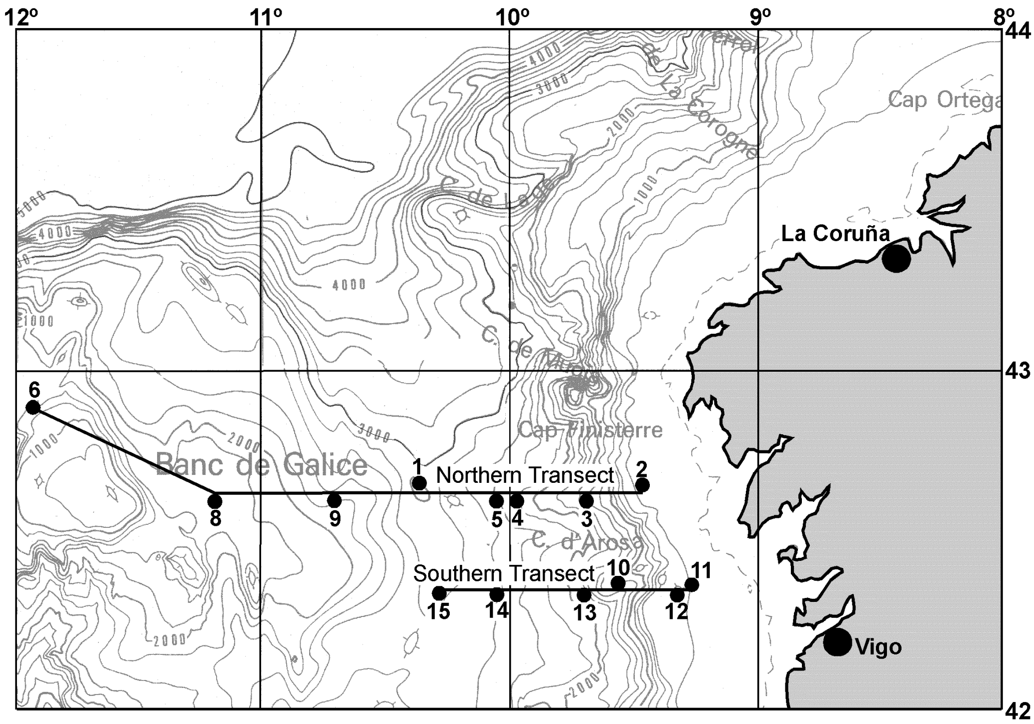

Fig 1: Investigated area showing northern and southern transect. Numbers refer to sampling locations as indicated in Table 1

R.V.'Pelagia'
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	station	Lat N	Long W	water depth (m)	deployments
northern transect	2	42.39	09.29	186	CTD MC BC TROL
	3	42.39	09.42	1425	CTD BC
	4	42.37	09.59	2145	CTD MC BC TROL
	5	42.38	10.09	2570	CTD MC TROL
	6	42.52	11.52	1129	CTD
	8	42.38	11.11	1681	CTD MC BC TROL
	9	42.37	10.42	2209	CTD MC BC TROL
southern transect	10	42.21	09.34	1144	CTD
	11	42.20	09.15	197	CTD MC BC TROL
	12	42.23	09.20	329	CTD MC BC TROL
	13	42.19	41.05	1760	CTD MC BC TROL
	14	42.20	10.03	2600	CTD MC BC TROL
	15	42.19	10.17	2781	CTD BC

Table 1: Position of sampling stations, water depth, and deployments

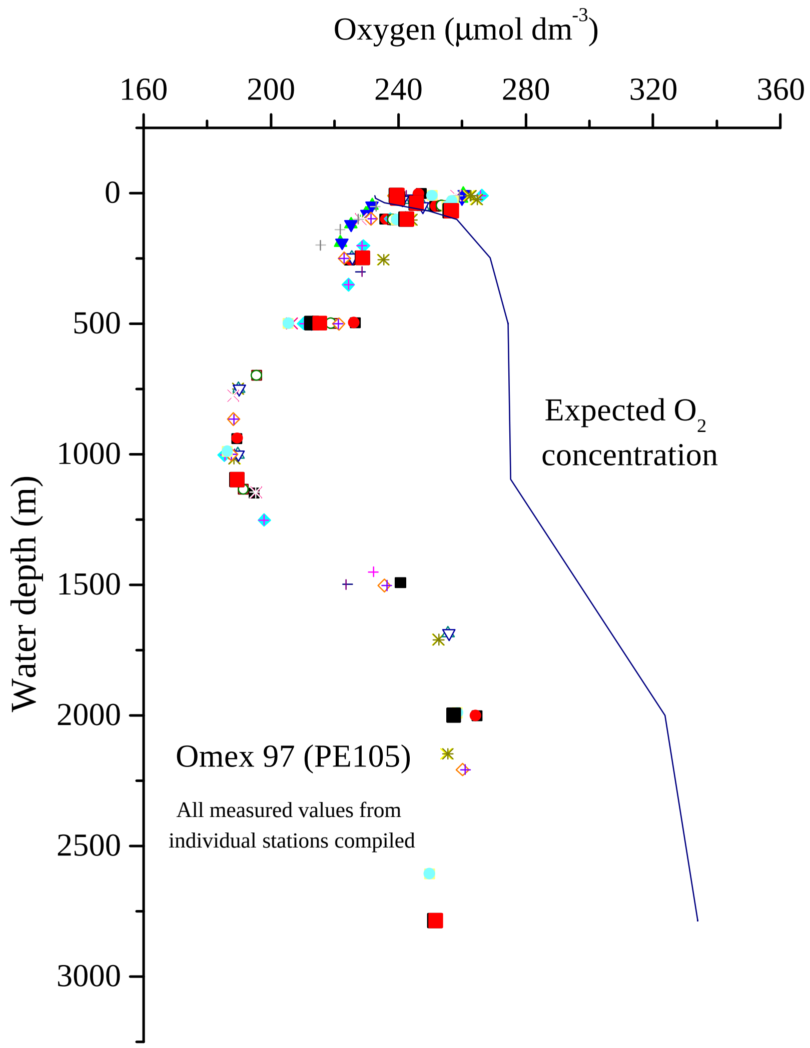
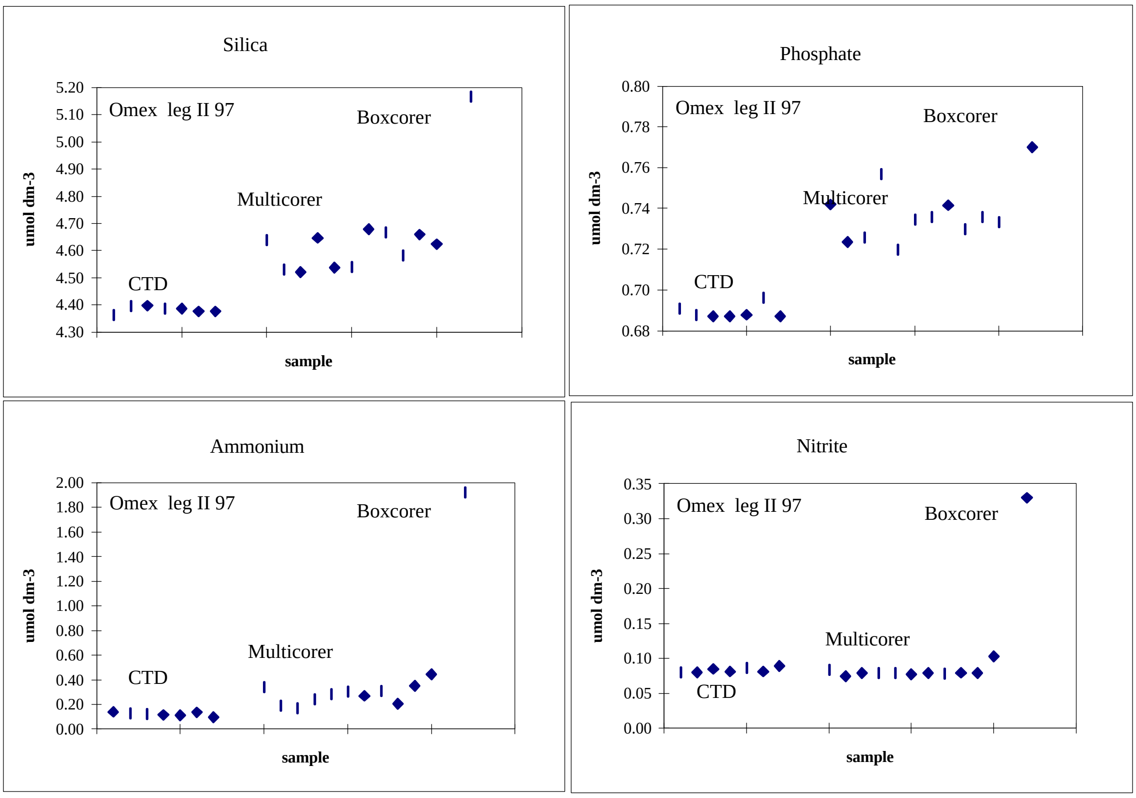


Fig.2 Measured and expected oxygen concentration at all visited stations (see Table 1)



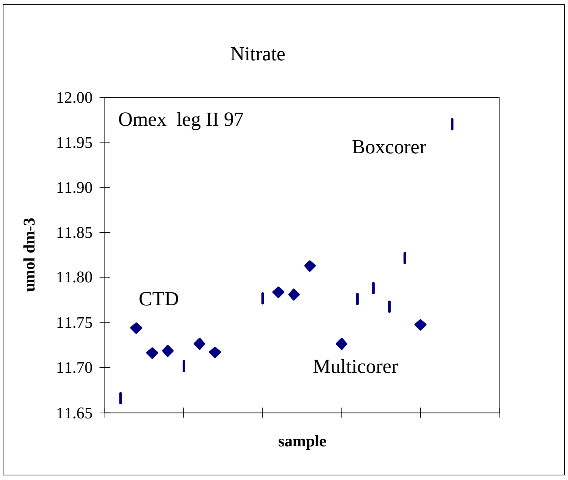
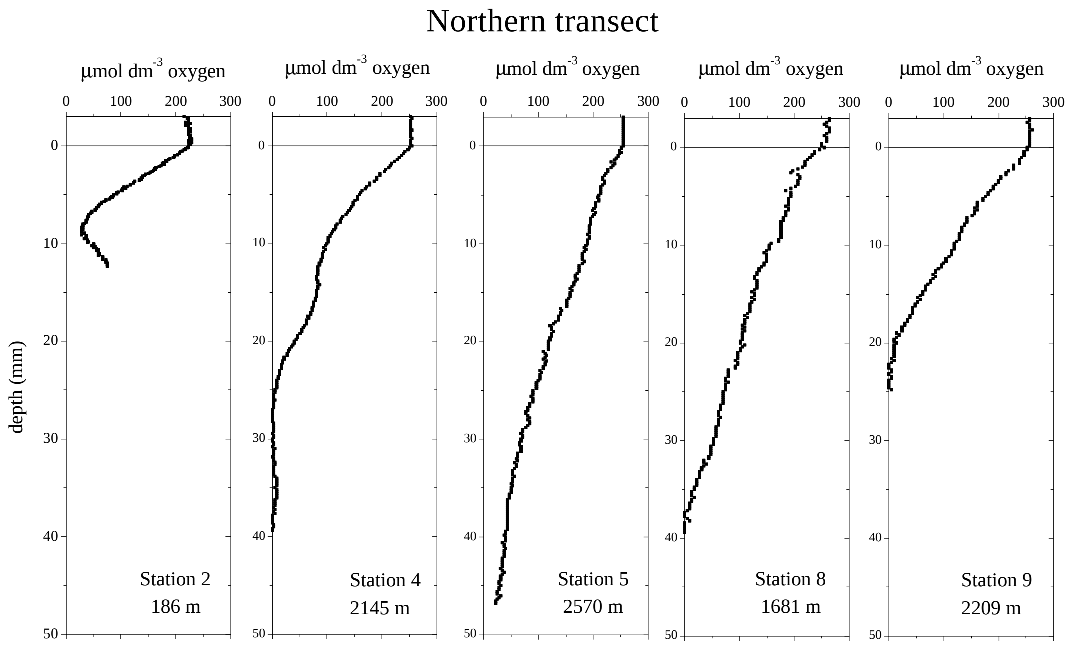


Fig. 3

Bottom water nutrient concentrations
as determined from
the deepest CTD bottle and the overlying water of
the multicorer and the boxcorer
at station PE109-11



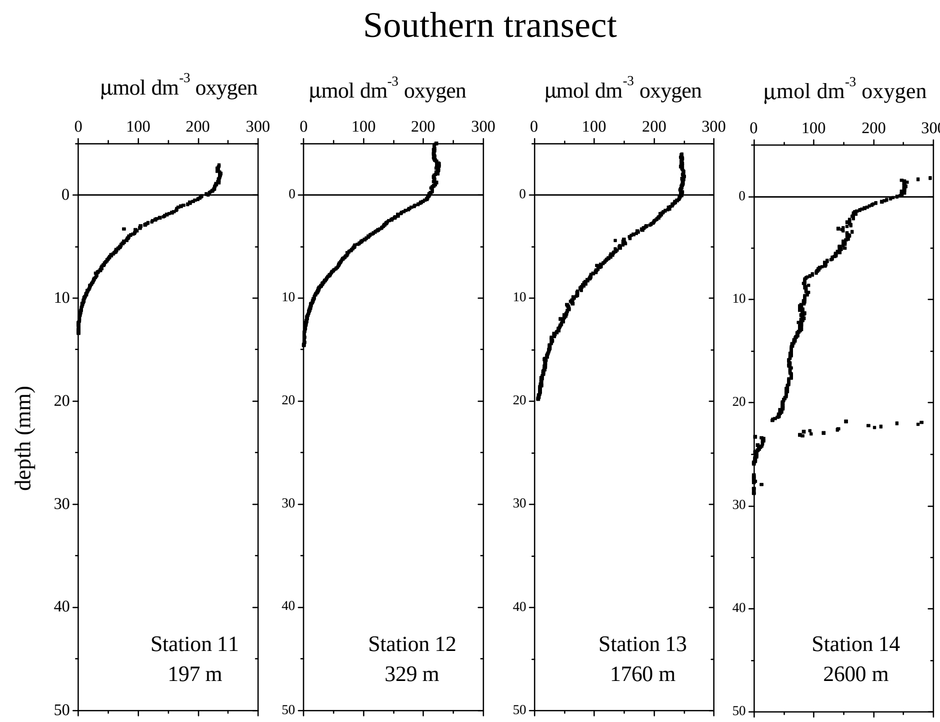


Fig. 4 Representative oxygen profiles obtained by shipboard profiling at the northern (upper panel) and the southern transect (lower panel).

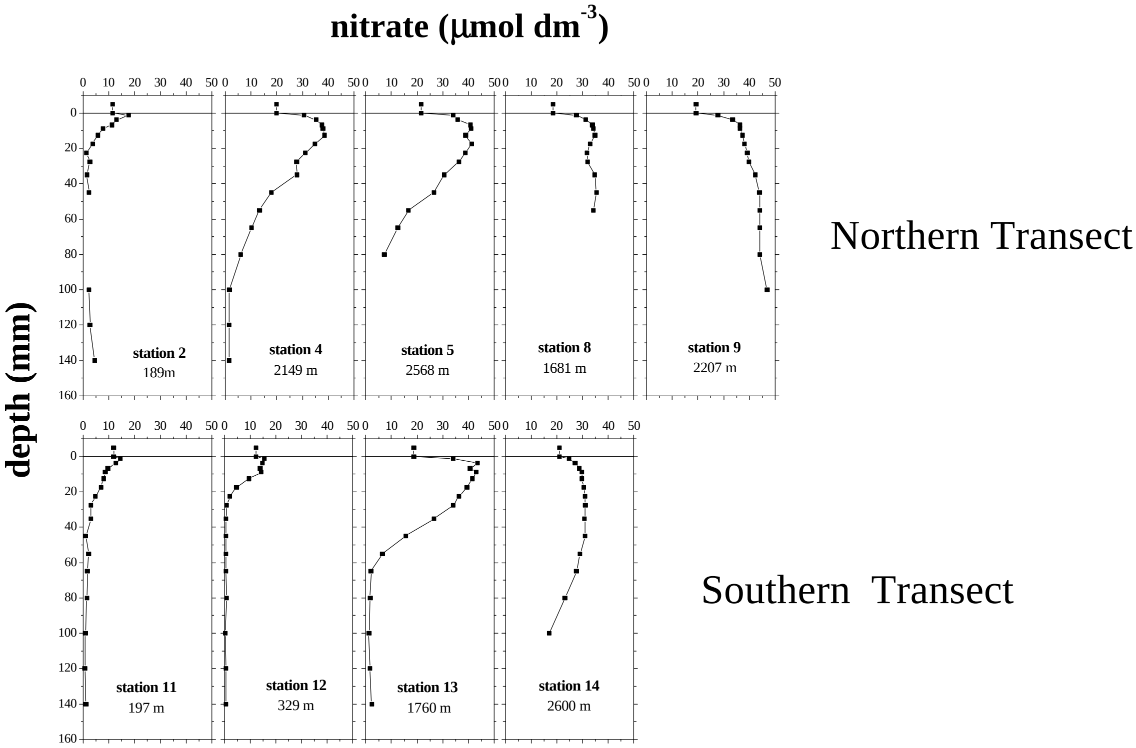


Fig. 5 Nitrate pore water profiles at all visited stations

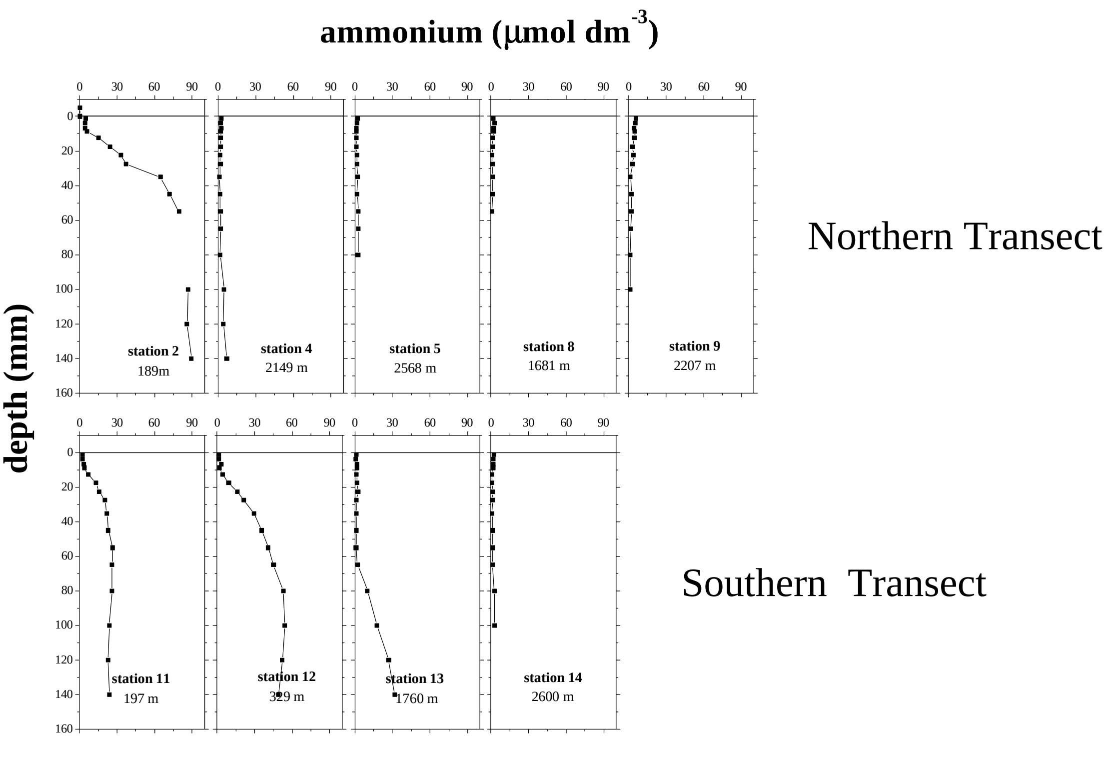


Fig. 6 Ammonium pore water profiles at all visited stations

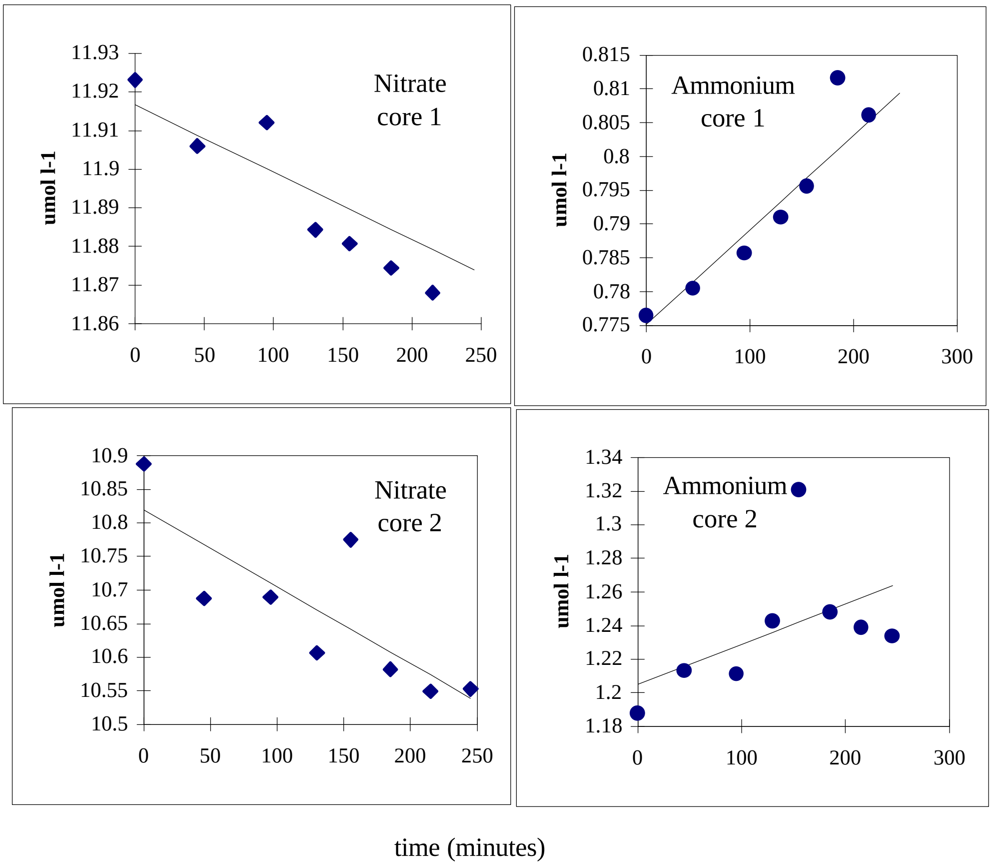


Fig. 7 Nitrate and ammonium concentrations in the overlying water of sediment cores versus with proceeding incubation time at station PE109-11.