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ASSESSMENT OF THE IMPORTANCE OF THE CARBONATE PUMP IN SURFACE WATERS OF THE BAY OF BISCAY

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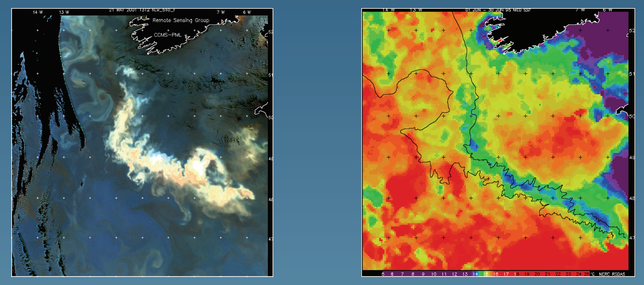
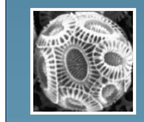
INTRODUTION

During the *Belgica* BG02/11 cruise (22 April - 11 May 2002) in the northern Bay of Biscay, a slope survey covering transects across the continental margin from the La Chapelle Bank to the Goban Spur area were conducted. The sampling campaign was assisted in addition by remote sensed data from SeaWiFS to locate the coccolithophore blooms, as characterised by white, highly reflective regions as shown by ocean colour imagery (lower left fig.). Experiments of ^{14}C incorporation were carried out to determine the production rate of both organic and inorganic particulate carbon.



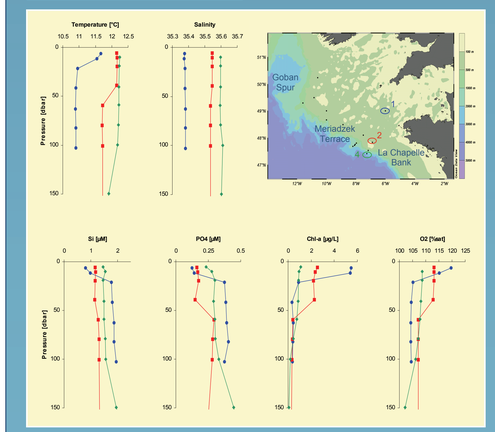
SeaWiFS (left) and AVHRR (right) data received at the NERC Dundee University Receiving Station and processed by the Remote Sensing Group of the Plymouth Marine Laboratory.



Coccolithophorides, among which *Emiliania huxleyi* is the most widespread species in the world's oceans, are the dominant calcifying phytoplankton in the area of investigation. Their importance in biogeochemical cycling is supported not only by their capacity for organic matter production *via* **photosynthesis**, the **biological pump**, but also by their ability to produce **coccoliths**, the **carbonate pump**, which represents a major contribution to the particulate carbon flux to the deep ocean.

In the photic zone, the **biological pump** removes inorganic carbon from the surface ocean, while the **carbonate pump**, according to the equation $Ca^{2+} + 2HCO_3^- \Leftrightarrow CaCO_3 + H_2O + CO_2\uparrow$ releases CO_2 and consumes Total Alkalinity to produce biogenic calcium carbonate. It is generally accepted that the overall effect of photosynthesis and calcification constitutes a net sink of carbon from the atmosphere. There remains still large uncertaintices in the production and fate of biogenic calcium carbonate in the oceanic carbon cycle.

HYDROGRAPHY



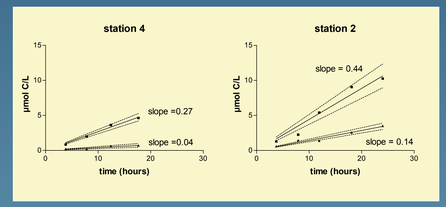
Vertical profiles of temperature confirm the intensive mixing conditions near the slope (st. 4) as evidenced by the sea surface temperature satellite image (top upper right fig.) showing a cold band of water along the shelf break. Chlorophyll-a concentrations increase in surface waters from 1 to 5.5 µg.l^{-1} as one goes from offshore towards the continental plateau, producing an oversaturation in oxygen and a depletion in nutrients at station 1. Sample examination by SEM revealed the presence of diatoms presence at station 1 and mainly coccolithophores at stations 2 and 4.

PRIMARY PRODUCTION AND CALCIFICATION

Samples taken at various depths were spiked with $NaH^{14}CO_3$ and incubated under various light conditions. After incubation, the sample was split and filtered onto two separate GF/F (Whatman®) filters. One filter was counted for total radioactivity while the other was acidified with acetic acid (0.01N) prior to counting. By difference in radioactivity between the two filters, it was possible to estimate simultaneously the amount of ^{14}C incorporated either in the organic matter or in the calcium carbonate phase and thus Primary Production and Calcification rate.

1. Kinetics of ^{14}C assimilation under constant light conditions

Samples were incubated for a 24-hour period under saturating light (200 µmol quanta m^{-2} s^{-1}). In the absence of ^{14}C recycling, initial slope is a proxy for the gross primary production expressed in µmol C l^{-1} h^{-1}. During the present study, linear kinetics was observed up to 18 hours and our incubation experiments were always limited to 4-6 hours.



2. P *vs.* E and C *vs.* E Curves

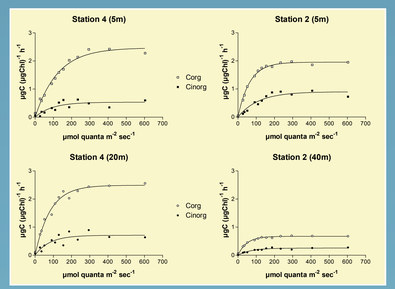
Photosynthesis *vs.* light intensity experiments have allowed the characterisation of the photosynthetic properties of the phytoplankton based on the classical Platt equation:

$$P^B = P^B_{max} [1-\exp(-\alpha E / P^B_{max})] \exp(-\beta E / P^B_{max})$$

where P^B is the photosythetic rate, P^B_{max} the maximum photosynthesis rate, α the maximum light utilization coefficient, β the photoinhibition parameter and E the photosynthetically avalaible radiation (PAR). The light adaptation parameter E_k can also be defined by P^B_{max}/α.

The results compared to the theoretical curves show that, in general, the plankton at depth exhibit a higher photosynthetic efficiency but is not affected by photoinhibition, which can be neglected in the present study. Interestingly enough, the rate of calcification follows a similar trend to the P *vs.* E curve and rate parameters of the Platt equation can be calculated accordingly.

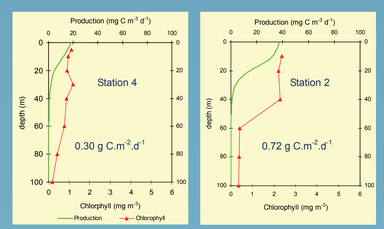
The parallelism of the two curves indicates that photosynthesis and calcification are intimately coupled.



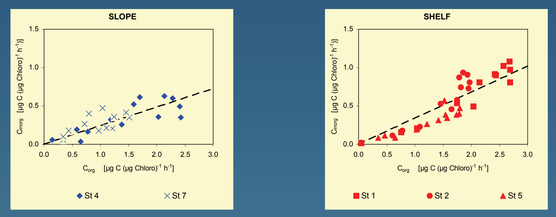
Station	Depth (m)	Chl-a (µg.L^{-1})	P^B_{max}	α_{photo}	E_k	C^B_{max}	α_{calcif}	E_k
2	5m	2.53	1.95	0.0304	64	0.90	0.0080	113
	40m	2.28	0.67	0.0139	48	0.26	0.0036	72
4	5m	1.12	2.47	0.0200	123	0.53	0.0058	91
	20m	0.91	2.49	0.0302	82	0.71	0.0090	79

P^B_{max}, C^B_{max} µg C (µg Ch a)$^{-1}$ h^{-1}
α µg C (µg Ch a)$^{-1}$ (µmol quanta m^{-2} s^{-1})$^{-1}$ h^{-1}
E_k µmol quanta m^{-2} s^{-1}

Daily primary production was evaluated at each station based on photosynthetic parameters, vertical distribution of chlorophyll-a concentration and light penetra tion profile. The daily irradiance used in the calculation was that obtained from the meteorological forcing.



3. Variations in the C_{inorg} : C_{org} ratios



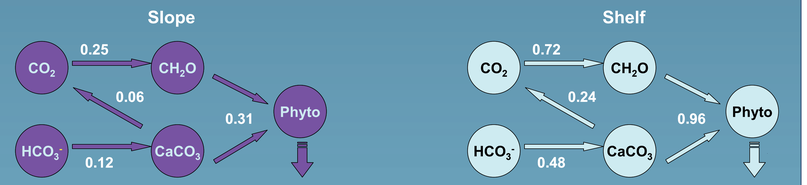
The uptake ratios C_{inorg} : C_{org} determined from the P-E curves are compared for the continental shelf the slope stations. They are respectively equal to : C_{inorg}/C_{org} = 0.34 for continental shelf; C_{inorg}/C_{org} = 0.24 for slope.

The higher ratio observed for the continental shelf is most likely induced by the higher primary production.

CARBON FLUXES IN THE PHOTIC ZONE

stations	C_{org} [gC.m^{-2}.d^{-1}]	C_{inorg} [gC.m^{-2}.d^{-1}]
1	0.80	0.27
2	0.72	0.24
5	0.64	0.22
4	0.30	0.07
7	0.20	0.05

In order to assess the importance of the carbonate pump, tentative carbon fluxes in gC m^{-2} d^{-1} have been calculated by integrating the daily primary production and the associated calcification rate obtained by the C_{inorg}/C_{org} ratios over the photic depth.



The primary production observed during our field survey was mainly associated with the coccolithophorides. The total transfer of dissolved inorganic carbon to the particulate phase in the northern Bay of Biscay area is estimated to be 0.96 gC m^{-2} d^{-1} for the shelf break and 0.31 gC m^{-2} d^{-1} for the slope region. Of this carbon, approximately 20 to 25% is associated with the inorganic carbonate phase. The organic carbon produced is rapidly remineralised in the water column during settling, while the calcium carbonate resists much better to dissolution. Consequently, the carbon deposited and preserved in the sediments is mainly present as calcium carbonate and inorganic carbon flux becomes therefore significant at a global marine scale.

Recent investigations have shown that calcium carbonate could dissolve even in shallow and intermediate waters where this mineral phase is over-saturated. It is therefore important to understand the mechanisms associated with this process. This aspect constitutes the follow-up of the present research.

AKNOWLEDGMENTS

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Project Internet Site: http://www.ulb.ac.be/sciences/dste/ocean/carbonate/frame.html