Sedimentary labile organic carbon and redox control on species distribution of benthic foraminifera: A case study from Lisbon-Setúbal Canyon

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Introduction

The relationship between labile organic matter, redox zonation and microhabitat of benthic foraminifera was described by Jorissen et al. (1995) in terms of the conceptual TROX (TRophic OXygen) model. According to this model, in food-limited and well-oxygenated environments, the foraminiferal community is restricted to the surficial sediments due to low food supply, and consists of epifaunal taxa specialised to live in oligotrophic regions. On the contrary, in eutrophic environments, where food is plentiful and the pore water oxygen content is often reduced, the foraminiferal assemblage is dominated by infaunal taxa. In these environments, the depth distribution is controlled by the sediment redox zonation. In this study we propose to evaluate and begin to quantify the TROX concept by investigating the distribution of benthic foraminifera, using pore water nitrate profiles as an indicator of redox zonation and sedimentary CPE (chloroplastic pigment equivalents) content as a measure of the labile organic matter availability. In addition, the sedimentary organic carbon content was measured and compared against the pigment content.

With this aim, 11 stations (7 in the Lisbon-Setúbal submarine canyon and 4 on the adjacent continental slope) were sampled for living benthic foraminifera during two cruises (Oct 2003 and May 2004). Sediment and pore water geochemistry, and pigments were analysed only from sediments sampled in May 2004.

Methods

Foraminifera: Multi-cores (Ø 6cm) were sliced (the top 2 cm was cut in slices of 0.5 cm and the remaining sediment in 1 cm slices) and stored in a solution of rose Bengal in 96% ethanol (1 g/L). Well-stained foraminifera (>150 µm fraction) were picked, counted and taxonomically identified from the top 5 cm of the sediment. Total standing stocks (TSS) were converted to densities by standardising the number of individuals to 50 cm^3.

Pore water geochemistry: The geochemical analyses were performed on material collected in May 2004. To obtain pore water profiles of dissolved nitrate (NO_3^-) in the sediment, the cores were immediately sectioned upon arrival on board (top cm into 0.25 cm slices, from 1 to 3 cm the slices were 0.5 cm, from 3 to 7 cm the slices were 1.0 cm, below 7 cm slices were 2 cm). The sediment was centrifuged at 3000 rpm for 10 minutes. The supernatant was filtered (0.45 µm, Acrodisc filters) and analysed on board using TRAACS-800+ autoanalyser.

Bulk sediment analyses:
-*Organic carbon:* measured using a Thermo Finnigan flash element analyser. Organic carbon was quantified after removal of $CaCO_3$ with 1 M HCl.
-*Pigments*: The concentrations of sediment-bound chlorophyll *a* (chl *a*) and phaeopigment (degradation product of chl *a*) were quantified following Yentsch and Menzel (1963). In this study, we report only the sum of the total pigmenst, or CPEs (chloroplastic pigment equivalents = chl *a* + phaeopigments).

Figure 1. Station location map, the Iberian continental margin. Stations names indicate water depth (C=canyon, S=slope).

Results

Geochemistry: Sedimentary organic matter and pigment content, and relation to pore water nitrate

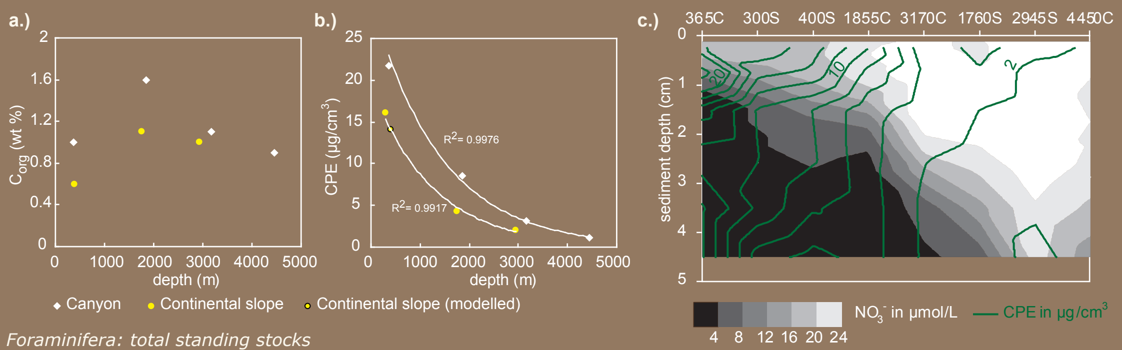

Figure 2. Geochemistry
a.) Organic carbon (Corg) vs. water depth. No clear trend was observed between these parameters.
b.) CPE vs. water depth. In Contrast to C_{org}, a clear exponential decline was seen between CPE and water depth, both along the open slope and in the canyon.
c.) Map of variation of CPE (µg/cm³) and pore water nitrate (µmol/L) along a gradient of decreasing CPE inventory in top 5 cm of sediment. Note a clear inverse trend between the two parameters.

Foraminifera: total standing stocks

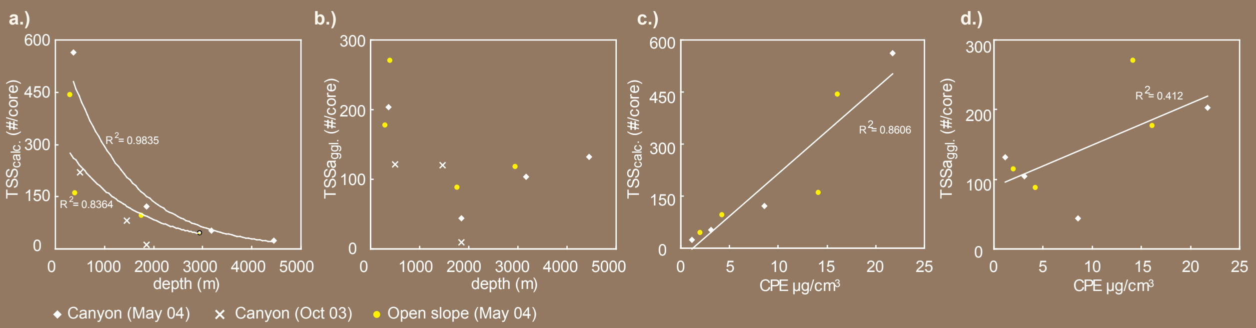

Figure 3. Total standing stocks (TSS)
a.) An exponential decline was seen between the TSS of calcareous foraminifera and water depth both in the canyon and open slope (Oct 03 stations not included in the regression).
b.) TSS of agglutinated foraminifera did not show a correlation with water depth.
c.) TSS of calcareous foraminifera showed a strong correlation with the sedimentary CPE content.
d.) TSS of agglutinated foraminifera showed only a very weak correlation to sedimentary CPE content.

Foraminifera: species distribution in sediment and relation to pore water nitrate and sedimentary CPE content

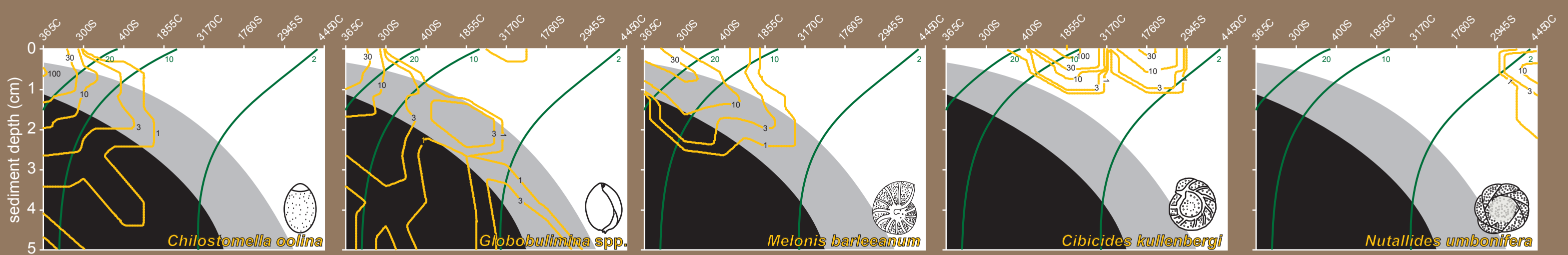

Figure 4. Contour plot of foraminiferal distribution in sediment relative to schematised pore water nitrate and sedimentary CPE content (after Figure 2c). White area represents oxic sediment. Light grey area represents dysoxic sediment where nitrate declines from 20 to 2 µmol/L. Black area represents anoxic sediment below the nitrate reduction zone. Stations arranged in order of declining CPE inventory in top 5 cm.

Conclusions

-Water depth controls sedimentary phytopigment content, but not the total organic carbon. The implication is that sedimentary C_{org} content alone is not a good measure for benthic food availability but should be used with care and preferentially replaced by other indexes such as phytopigments
-Calcareous foraminiferal abundance correlated with the sedimentary phytopigment content, thus suggesting that the abundance of calcareous taxa is primarily controlled by the availability of labile organic matter. This relationship was less clear with the agglutinated foraminifera.
-The foraminiferal species distribution changed with water depth, reflecting changes in NO_3^- penetration depth and the sedimentary phytopigment content. For instance, some infaunal taxa, e.g. *Melonis barleeanum*, *Chilostomella oolina* and *Globobulimina* spp., appeared to track redox fronts, as their in-sediment profile covaried with the pore water NO_3^- content. Other species, such as *Nutallides umbonifera* were only found in the most oligotrophic sites.

References
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Yentsch C.S., Menzel D.W., 1963. A method for the determination of phytoplankton chlorophyll and phaeophytin by fluorescence. *Deep-Sea Research*, 10, 221–231