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Late Holocene climate variability in the Tagus prodelta, Portugal: benthic foraminiferal perspective

H. B. B. Jónsdóttir[a,b,1], K. L. Knudsen[a], F. Abrantes[b], J. Eiríksson[c], A. Ferreira[b], I. M. Gil[b], S. Lebreiro[b] & T. Rodrigues[b]

a - University of Aarhus, Department of Earth Sciences, DK-8000 Aarhus C, Denmark
b - Instituto Geologico e Mineiro, Department of Marine Geology, PT-2720 Alfragide, Portugal
c - University of Iceland, Science Institute, IS-101 Reykjavík, Iceland
1 – helga.bara@igm.pt

ABSTRACT
Keywords: Paleoenvironment; Western Iberian Margin; benthic foraminifera; upwelling; Medieval Warm Period; Little Ice Age.

A sediment core (D13902) from the Tagus Prodelta has been studied to reconstruct the paleoenvironment on the Western Iberian Margin during the last 2000 years which covers the historical time and the time period when antrophogenic forcing has became significant. The benthic foraminiferal assemblage was investigated as well as the isotopic composition of benthic foraminifera (*Uvigerina* sp. 221). The most common benthic foraminifera species are *Bulimina marginata*, *Bolivina pacifica, Cassidulina laevigata*, *Nonion asterizans* and *Bolivina dilatata*. Other abundant species were *Ammonia beccarii* and species of the genus *Elphidium*. Considerable environmental fluctuations since 2000 cal. yr BP (BP=before present) are indicated by both the faunal distribution and the isotopic composition. An indication of increased productivity is observed in the time interval from 2000 cal. yr BP until 600/650 cal. yr BP. A period of less productivity occurred between 1600 and 1350 cal. yr BP, which corresponds to the end of Western Roman Empire (AD 500-800). During the Medieval Warm Period (c. 950 – 600/650 cal. yr BP) upwelling conditions prevailed in the Tagus Prodelta with high productivity, while a freshwater input from the river Tagus influenced the area during the Little Ice Age (after 600/650 cal. yr BP).

RESUMO
Palavras-chave: Paleoambiente; Margem Ibérica Oeste; afloramento costeiro; foraminíferos bentícos; Período Quente Medieval; Pequena Idade do Gelo

O “core” sedimentar (D13902) do Prodelta do Tejo tem sido estudado para reconstruir o paleoambiente da Margem Ibérica Oeste durante os últimos 2000 anos, este período para além de ter um registo histórico, as forças antropogénicas têm se tornado muito significativas. Foi investigada a abundância dos foraminíferos benticos e a composiçao isotópica de um foraminíferos bentíco (*Uvigerina* sp. 221). As espécies dominantes dos foraminíferos benticos são a *Bulimina marginata*, *Bolivina pacifica, Cassidulina laevigata*, *Nonion asterizans* e a *Bolivina dilatata*. Outras espécies igualmente abundantes são a espécie *Ammonia beccarii* e as espécies do genero *Elphidium*. Consideraveis flutuações ambientais têm-se verificado desde os 2000 anos calibrados para idades BP (BP=before present) como está registado na distribuição faunística e pela composição isotópica. O aumento de produtuvidade é observado no intervalo de tempo de 2000 anos calibrados para idades BP até 600/650 anos calibrados para idades BP. O período de menor produtividade ocorre entre 1600 a 1350 anos calibrados para idades BP, que correspondem ao fim do Império Romano do Oeste (AD 500-800). Durante o Período Medieval Quente (por volta dos 950 - 600/650 anos calibrados para idades BP) as condições do afloramento costeiro prevaleceram no Prodelta do Tejo como se pode observar pela alta produtividade, enquanto que o “input” da água do rio Tejo influenciou a área em estudo durante a Pequena Idade do Gelo (depois dos 600/650 anos calibrados para idades BP).

Introduction

Remote sensing techniques have been used to study the present oceanic system off Portugal. It has been shown that during summertime there is an increase in upwelling along the coast associated with increased northerly winds and westerly winds. This intense upwelling was observed to be connected with an intensification of the Azores anti-cyclone (Fiúza, 1983). During a positive NAO index, strong westerlies induce more intense upwelling along the Iberian margin, increasing the nutrient supply. Offshore, the coastal surface waters are replaced by water from deeper bathymetric levels belonging to the Eastern North Atlantic Central Water, which is characteristically colder and enriched in nutrients compared to the coastal surface waters (Fiúza *et al*., 1982). During a negative NAO index, however, the atmospheric system totally changes, bringing warmer winters to the northern latitudes and more rain to the southern latitudes of Europe. Consequently, the discharge from the rivers in Portugal increases during winter and during negative NAO index in Portugal. The Tagus river is the largest river and it is highly influencing the Portuguese margin (Abrantes, 1988).

Results and discussion

A total of 92 benthic foraminiferal taxa have been identified, consisting of 72 calcareous and 20 agglutinated taxa. Inner shelf to bathyal faunal types were dominant (*Bulimina*, *Cassidulina*, *Bolivina*, *Hyalinea*), and less

abundant were faunas inhabiting brackish to hyporsaline lagoons or shelves (*Ammonia*, *Elphidium*). The shell structure of the dominant species, thin-walled, cylindrical or ovate shaped, is characteristic in regions of low-oxic waters and/or high flux rates of organic matter (Harman, 1964; Schönfeld, 2001).

Considerable changes in the environment have occurred on the Iberian margin during the last 2000 years. This is reflected by variations in the faunal composition, as well as by the percentage distribution of individual species. Other parameters such as stable oxygen and carbon isotopes, diatom distribution, magnetic susceptibility, grain size, organic carbon content and C/N ration and Fe content in the sediment support this view (Abrantes, F. *et al*., 2003).

Species tolerant for increased organic carbon and oxygen depletion generally increase in abundance upwards in the core (*Hyalinea balthica* and *Bulimina marginata*). The interpretation is also supported by an increase in the oxygen isotope composition of *Uvigerina* sp.221 (Figure 1). This indicates an increased productivity in the area, since 2000 cal. yr BP, continuing until approximately 600/650 cal. yr BP, as reflected in the foraminiferal composition. However, fluctuations were observed, and during the time interval 1600 to 1350 cal. yr BP, the species tolerant for low oxygen environment (*Bolivina dilatata*, *Bolivina striatula*, *Hyalinea balthica* and *Bulimina marginata*) decrease in concentration. The diatom abundance is relatively high during this period, an influence from near-coastal areas. The C/N ratio, which is a measure for the degree of oceanographic conditions (Matos, 1974) support this observation. Organic carbon and nitrogen content of the sediment reveal higher ratio (C/N) in the lower part of the core, indicating a high terrestrial input during deposition. Terrestrial plants have relatively high C/N ratios of about 20-200, whereas marine phytoplankton have C/N ratios of about 5-10 (Leithold and Hope, 1999).

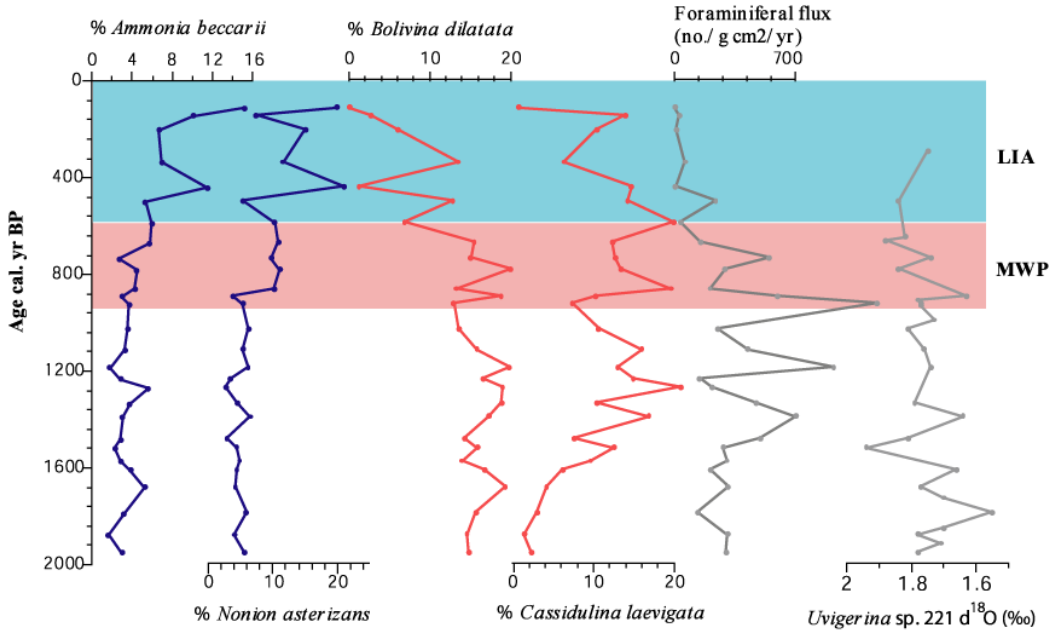

Figure 1 - Percentage distribution of selected species in core D13902.
Foraminiferal flux and oxygen isotopic composition of Uvigerina sp. 221 also shown.

Period of high productivity prevailed during the time interval between ca. 950 and 600/650 cal. yr BP, corresponding to the Medieval Warm Period (MWP; A.D. 800/1000-1350; Lamb, 1969; Hass and Kaminski, 1995). The period of high productivity appears to have been more intense during the later half than the first half of this period. This is reflected in the foraminiferal composition, which is characterised by high abundance of species indicating upwelling, i.e. *Bolivina dilatata*, *Bolivina striatula*, *Bulimina marginata*, *Hyalinea balthica* and *Cassidulina laevigata* (Figure 1). Lower C/N ratios support the interpretation of more oceanic conditions in the area during this later part of the period, i.e. less influence from the Tagus river.

After approximately AD 1350-1400, or during the Little Ice Age (LIA; AD 1350-1900; Hass and Kaminski, 1995), there was a pronounced faunal change in the Tagus prodelta. Species such as *Ammonia beccarii* and *Nonion asterizans* and species of the genus *Elphidium* became more abundant during this period, indicating more freshwater input from the river Tagus to the area (Figure 1). Different species of the genus *Haynesina* have been found in recent material inside the Tagus river. The concentration of this species in the later half of the LIA support the interpretation of an increased freshwater input to the area. The four taxa *Ammonia beccarii*, *Nonion asterizans*, *Elphidium* spp., and *Haynesina* spp. show high correlation to each other.

Oxygenation and organic carbon flux to the seafloor are important factors controlling the foraminiferal distribution (Kaiho, 1999; Sen Gupta, 1999; Van der Zwaan *et al*., 1999; Schönfeld, 2001). In the present core, the foraminiferal productivity increases in the middle part of the core, before and during the MWP, in contrast to the

concentration of organic carbon that shows lower values during this time interval. Therefore, it seems that changes in the productivity is rather related to the oxygen level in the sediment and in ambient bottom water or subsurface pore water. Thus, higher concentration of foraminifera was observed during periods of less organic carbon flux to the sediment and higher oxygen levels. As discussed above, the organic carbon content in the core seems to be mainly of terrigenous origin. The foraminiferal flux is a good indicator of productivity, and a high flux reflects favourable nutrient condition (Altenback and Sarnthein, 1989). Benthic and planktonic foraminiferal fluxes are usually closely connected. Planktonic foraminifera are known to exhibit maximum fluxes during times of increased upwelling (Abrantes, 2001; Wefer and Fisher, 1993). The foraminiferal flux in the present record supports the interpretation of more favourable living conditions for foraminifera during increased upwelling conditions before and during the MWP and less favourable conditions during the LIA.

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