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Tracing the late Holocene evolution of the NW Iberian upwelling system

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Abstract

This work analyses data from the OMEX core KSGX 40 (164-cm long) collected in the Galicia Mud Deposit, from the NW Iberian outer continental shelf, off the Ria de Vigo (North Spain). Sediment grain-size and benthic foraminifera distribution patterns indicate a number of substantial changes in sedimentation and also food/oxygen availability to the benthic ecosystem during the last ~4.8 ka cal BP. Cluster analysis (Q-mode and R-mode) based on the most abundant *taxa* was used to recognize similarities within the data set. Three main clusters were established by Q-mode cluster analysis. The species distribution pattern of two of these three clusters is clearly related with changes in texture of the sediments. Textural data and benthic foraminifera proxies suggest that between ~4.8 and 2.2 ka cal BP there was a period of higher hydrodynamism, with more energetic oceanic currents associated with shelf mixed waters. The period since ~2.2 ka cal BP until present was characterized by generally lower bottom energetic conditions and by a supply of finer sediment, which was richer in organic matter leading to more eutrophic conditions in the benthic environment, mainly between ~2.2 and 1.2 ka cal BP and since ~0.5 ka cal BP until the present. Eutrophication was probably determined by strong water column stratified conditions and by coastal upwelling-dominated depositional intervals and/or by higher lateral flux of organic carbon. Since the upwelling increasing periods are in general due the intensification of northerly winds, both most productive upwelling-dominated periods may be attributed to climatic/oceanographic induced changes during the Sub-Atlantic climate. Small sea levels oscillations also should contribute to these results. Eutrophication since the end of Little Ice Age may be related to human influence in coastal areas.

Keywords: Holocene; NW Iberian upwelling system; stratification; productivity benthic foraminifera proxies

1. Introduction

1.1. Benthic foraminifera as a proxy of productivity

Foraminifera are abundant and ubiquitous inhabitants of the marine benthos. The variability of the organic carbon flux to the sea floor has an important environmental influence on the benthic foraminifera (e.g., Altenbach and Sarnthein, 1989; Loubere and Fariduddin, 1999), because surface-derived organic matter is the primary energy source for most of the benthic foraminifera (Wollenburg and Mackensen, 1998). Some benthic foraminifera species react rapidly to the input of organic matter from primary production, exhibiting an increase in population size after

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phytodetritus deposition (Murray, 1991). The flux of organic matter to the sea floor is the main parameter that controls bathymetrically the density and the composition of benthic foraminiferal faunas (Fontanier et al., 2002). The organic flux is also the main parameter controlling the foraminiferal distribution in sediments (microhabitat) since the supply of metabolisable organic matter controls the oxygen consumption in the sediment and the localization of the successive redox fronts (Jorissen et al., 1998; Fontanier et al., 2002). Several benthic foraminifera are known to inhabit oxygen-depleted environments (e.g., Jannink et al., 1998; Fontanier et al., 2002). Anoxic conditions do not have a direct lethal effect for many species (e.g., Jannink et al., 1998; Fontanier et al., 2002). The flux of organic matter to the sea floor is controlled mainly by surface-water productivity, lateral supply of C_{org} and hydrodynamic conditions. These variables show considerable geographic variation and reflect global climate processes, i.e., ocean–atmosphere control of primary production (Loubere, 1996).

1.2. Regional oceanography

The NW Iberian coast is the northern limit of the Eastern North Atlantic upwelling system which is dominated by the Portugal Current System (Ambar and Fiúza, 1994). During summer, the Portugal Coastal Current (PCC) is 30–40 km wide, 50–100 m deep and flows southward in the vicinity of the shelf break, being driven by upwelling-favourable northerly winds. PCC transports recently upwelled, cold and nutrient-rich Eastern North Atlantic Central Water (Fiúza et al., 1982; Fiúza, 1984; Ríos et al., 1992; Pérez et al., 1993). Under upwelling conditions there are also equatorward flows on the shelf surface circulation, originated by the predominance of northerly winds (e.g., Frouin et al., 1990; Huthnance, 1995). On the contrary, a poleward flowing slope undercurrent centred at depths of 150–300 m is primarily forced by large-scale geopotential gradients and topography (e.g., Frouin et al., 1990; Huthnance, 1995).

The strength and position of the atmospheric pressure cells that rule the North Atlantic climatology, the Azores High and the Iceland Low pressure centres show seasonal variations, forcing the along–shore winds responsible for the upwelling processes in the Western Iberian Margin (Wooster et al., 1976; Blanton et al., 1984; Fiúza, 1984). The predominance of northeasterly winds from March/April to September/October is the main cause of upwelling, although the coastline orientation and the properties of subsurface waters also influence the upwelling phenomena (Wooster et al., 1976; Blanton et al., 1984; Fiúza, 1984). During winter, the strong winds from S–SW lead to the establishment of a downwelling regime over the shelf, characterized by persistent poleward flow (Vitorino et al., 2002).

One of the most characteristic features of the NW Iberian upwelling system is a recurrent topography-intensified upwelling centre off Cape Finisterre (43°3′N, 93°W; Fig. 1) (e.g., Haynes et al., 1993; Castro et al., 2000) and the formation of upwelling filaments at the beginning of the upwelling season (Haynes et al., 1993). The upwelling filaments reach their maximum offshore extent in late September, but have usually disappeared by late October (Álvarez-Salgado et al., 2001a; Haynes et al., 1993). During the upwelling period, primary production is enhanced in shelf areas (Tenore et al., 1995) and inside the Rias Baixas (Hanson et al., 1986; Tilstone et al., 1999) and dissolved organic carbon accumulates in surface layers (Álvarez-Salgado et al., 2001b). According to Abrantes and Moita (1999), during the upwelling regime phytoplankton biomass at the surface is ten times higher than during the non-upwelling period. Diatoms and coccolithophorid abundance distribution patterns in the sediments preserve much of their original biological spatial variability and reflect the original proportions of production generated by the occurrence of upwelling, independently of lithology and/or the relative importance of several geological processes acting on the West Iberian Shelf.

Under upwelling conditions, the existence of well developed upwelling filaments, such as the one regularly observed south of Cape Finisterre (Haynes et al., 1993), can promote horizontal transport of both particulate and dissolved matter produced during upwelling events from the shelf area into oceanic waters (Álvarez-Salgado et al., 2001a; Smyth et al., 2001). Although during this season sedimentary transfers by the Galicia shelf-waters are predominantly southwards (Jouanneau et al., 2002). In this region the organic carbon flux depends not only on oceanic productivity but also on detritus outwelling from the Rias Baixas, which are recognized to be high productive systems (López-Jamar et al., 1992). The organic carbon flux also probably depends on significant amounts of refractory terrestrial organic carbon released by coastal erosion and transported into the studied area. Thus sediments are supplied by several sources of organic matter to the Galician continental margin.

The aims of this study are to search for changes in the organic carbon flux to the Galicia Mud Deposit and infer about some conditioning factors acting on the outer shelf off the Ria de Vigo, during the last ~4.8 ka cal BP.