

Biostratigraphy of the Holocene and of the Main Cold Events of the Late Quaternary in the Gulf of Cadiz

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Abstract The Gulf of Cadiz, west of the Strait of Gibraltar, is the site of water exchange between the Atlantic Ocean and the Mediterranean where many palaeoceanographic studies have taken place over the last several decades. Based on 21 cores from three cruises, oxygen isotope curves, 139 radiocarbon dates, and microfaunal analyses, this work presents and discusses the main bioevents used as detailed biostratigraphic points in this area for the late Quaternary. Those bioevents, such as well-known cold events (Younger Dryas, Heinrich events) or bioevents occurring during the Holocene, are essentially based on planktonic foraminifer species and/or coiling ratio and the point occurrences of pteropod species. The large and extensive data set allows us to discuss ages and the spatial validity of such bioevents.

Keywords Biostratigraphy · Planktonic foraminifera · Pteropods · Gulf of Cadiz · Late Quaternary

Introduction

Biostratigraphy based on events can be an interesting tool in high-accumulation environments such as contourite deposits, because it requires relatively few specimens compared to, for example, radiocarbon dating. For the North Atlantic Ocean, percentages of *Neogloboquadrina pachyderma* sinistral, a polar species of

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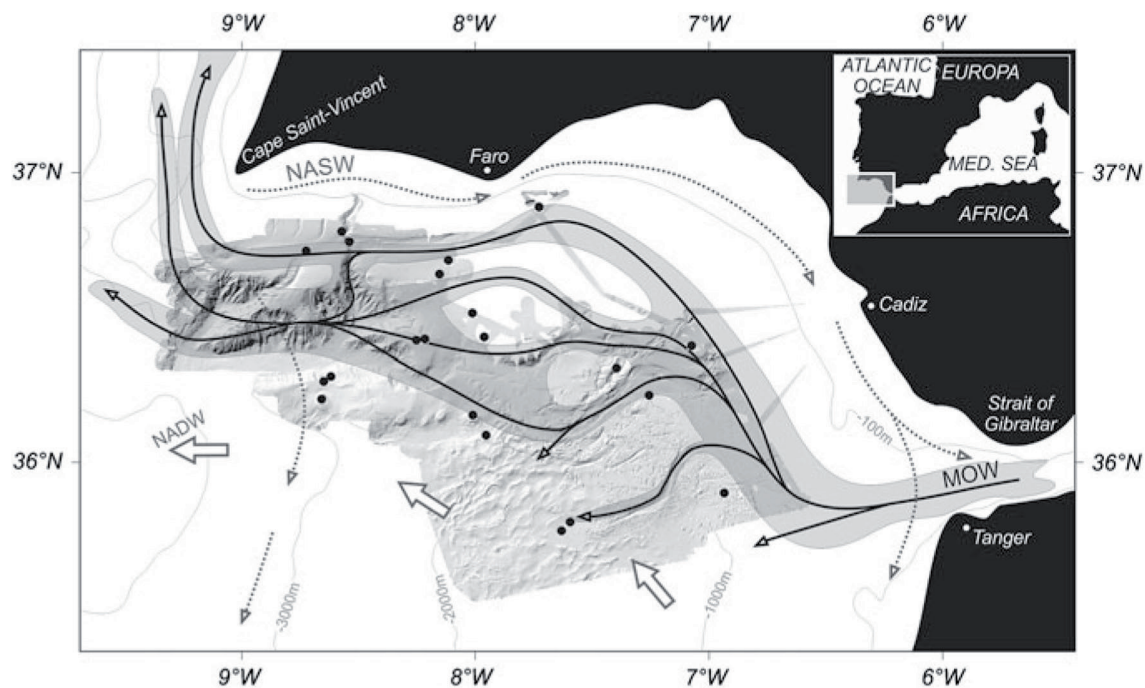


Fig. 1 General map of the Gulf of Cadiz showing the general circulation of the *MOW* and location of cores used for this study. *NASW* North Atlantic Surficial Water; *NADW* North Atlantic Deep Water; *MOW* Mediterranean Outflow Water

planktonic foraminifer, are often presented to characterize brief, cold climatic phases such as the Heinrich events (Eynaud et al. 2009) in spite of their low abundance at mid/low latitudes. Their sudden appearances coincide with phases of sea-surface cooling. In this study, we want to show that other species offer the same kind of precision for periods described as relatively homogeneous, such as the Holocene. Those bioevents allow rapid correlations between sedimentary cores to be made on a regional scale.

This study aims to describe the main bioevents recognized during the last 40,000 yr in the Gulf of Cadiz, to discuss their ages based on several oxygen isotope curves and a comprehensive data set of radiocarbon ages, and to evaluate the regional validity of such a biostratigraphic approach.

Study Area

The Gulf of Cadiz is located in the southwest of the Iberian Peninsula, west of the Strait of Gibraltar (Fig. 1). It is the site of water exchanges between the Atlantic Ocean and the Mediterranean. Whereas the fresher Atlantic water enters the Mediterranean at the surface as an antiestuarine circulation, the dense and saline water from the Mediterranean flows westward to form the Mediterranean Outflow Water (*MOW*) from 500 to 1500 m depth (Rogerson et al. 2005). The interaction of the *MOW* and the slope generates deposition of large contourite drifts and locally any

gravity flows. Those contourite drifts provide a record of temporal variations in MOW intensity or MOW migration (Rogerson et al. 2005; Llave et al. 2006).

Materials and Methods

This study is based on 21 piston cores collected in the Gulf of Cadiz (Fig. 1). Among those cores, five were chosen for isotopic analyses. Radiocarbon dating was performed on 139 samples from the 21 cores and determined via accelerator mass spectrometry (AMS) at the LMC14-Saclay (Paris) under the French Artemis program.

Faunal analyses were performed on the 21 cores. The >150- μm fraction was split into aliquots of at least 300 specimens of planktonic foraminifera for identification, according to the taxonomy of Hemleben et al. (1989). Particular species considered were *N. pachyderma* sinistral (s), *Globorotalia truncatulinoides*, *G. ruber*, *Globigerinoides conglobatus*, *Globorotalia crassaformis*, and *Globigerinoides sacculifer*. Pteropod species considered were *Limacina retroversa* and *Limacina inflata*. The faunal data are given as percentages of total numbers of planktonic foraminifera, as percentages of coiling ratio, or as presence/occurrence, depending on the most appropriate use.

Chronological Framework of the Gulf of Cadiz Reference Cores for the Last 40 kyr

Planktonic foraminiferal $\delta^{18}\text{O}$ data, radiocarbon dates, and biostratigraphic data for the 21 cores show a series of 11 events recognized in both the planktonic foraminiferal assemblage records and the $\delta^{18}\text{O}$ curves.

The data of *N. pachyderma* (s) are given as percentages of the total number of planktonic foraminifera. This arctic to subarctic species is typically used in temperate latitudes to identify cold climatic episodes such as Heinrich events or the Younger Dryas (Darling et al. 2006; Eynaud et al. 2009; Voelker and de Abreu 2011). Their percentages vary from one event to another, in some cases associated with the pteropod *L. retroversa*.

G. ruber, *G. conglobatus*, *G. crassaformis*, and *G. sacculifer* are summer subtropical species and are typical of warm periods such as the Holocene and the Bölling-Allerød (B-A). Their presence or absence is used to indicate Holocene and B-A limits (de Abreu et al. 2003; Rogerson et al. 2005) and can be associated with the pteropod *L. inflata*.

G. truncatulinoides is also a summer subtropical species, typical of warm periods, and can be dextral or sinistral. The data of *G. truncatulinoides* are given as percentages of coiling ratio, with the following formula: $\%TS = TS * 100 / (TS +$

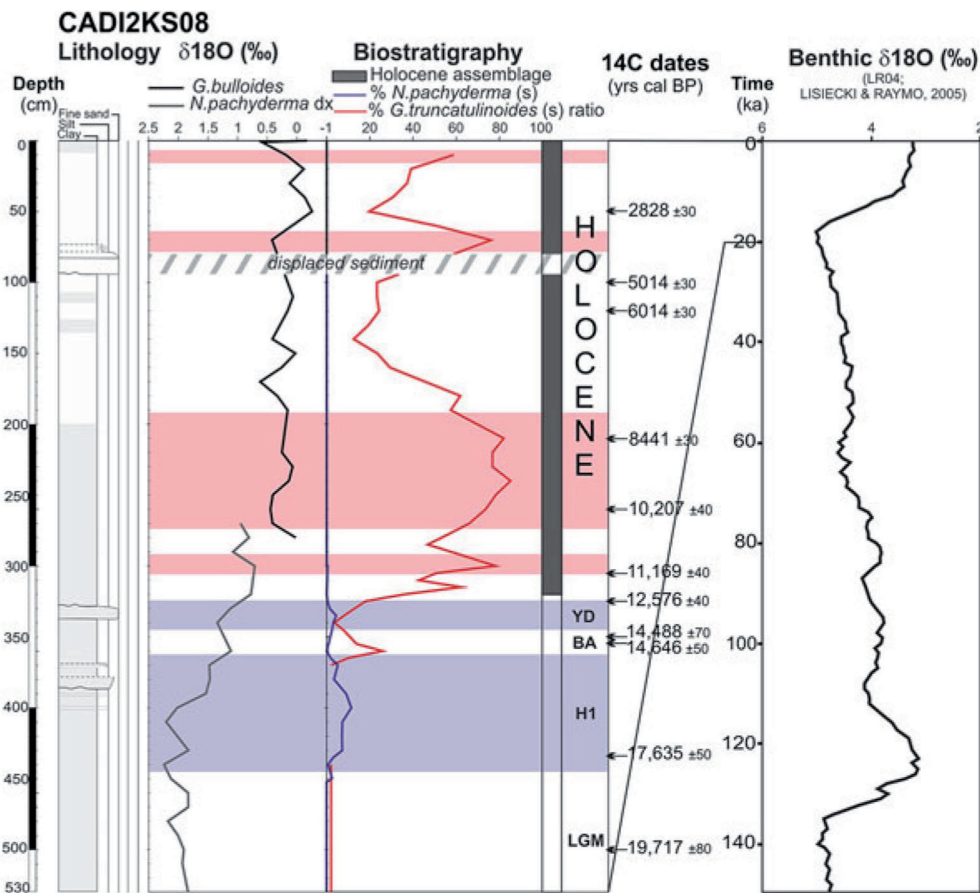


Fig. 2 Example of biostratigraphic events in core CADI2KS08 with planktonic oxygen isotope curve and radiocarbon dates, compared to the standard curve from Lisiecki and Raymo (2005). YD Younger Dryas; BA Bölling-Allerød; H1 Heinrich event 1; LGM Last Glacial Maximum

TD) where TS is the number of specimens of *G. truncatulinoides* sinistral and TD the number of specimens of *G. truncatulinoides* dextral. High values of %TS are recognized at least three times during the Holocene and between particular Heinrich events.

A synthesis of the age range of these bioevents is proposed and compared with data from the literature, especially for well-known events such as the Younger Dryas, Bölling-Allerød, and Heinrich events 1–4 (Fig. 2).

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