Variations in the Mediterranean thermohaline circulation during the Last Glacial/Interglacial transition (20 Ka PB), based on a dinocyst record of the Alboran Sea

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ABSTRACT

The dinoflagellate cyst assemblages in a core from the Western Alboran Sea, in the upwelling domain off Malaga, show a record of marine environmental change for the Late Glacial and Holocene periods. The dinocysts are good indicators for changes in sea surface productivity. Productivity changes, in the Western Alboran Sea, relate to upwelling intensity. The environmental change based on this record allowed to link and time the responses of the oceanic circulation to climate.
Results indicate that upwelling was present over the last 20 ky. It was weakened during brief periods suggesting a weaker thermohaline circulation and a lowered E-P budget. Enhanced upwelling occurred between 14.5-12.6 ky BP, suggesting an intensification of the thermohaline circulation and pointing to the conclusion that on a long term, the main forcing of the Mediterranean circulation was thermohaline, not relative sea-level changes.

RESUMEN

Las asociaciones de cistes de algas dinoflageladas, presentes en un testigo obtenido en el afloramiento de la cuenca occidental del mar de Alborán, registran los cambios climáticos y ambientales que tuvieron lugar en el Mediterráneo durante la última deglaciación. Este registro, permite relacionar la respuesta de la circulación termohalina, a través del Estrecho de Gibraltar, con los cambios climáticos. Los resultados obtenidos indican que, el afloramiento de Alborán, ha sido activo durante los últimos 20 mil años; con breves periodos de menor intensidad y un periodo más intenso. Los primeros, sugieren una circulación termohalina más débil y valores más bajos del balance hídrico (E-P) de la cuenca mediterránea. El segundo, permite concluir que el control más importante de la circulacion Mediterránea durante los últimos 20 ka fue el balance hídrico de la cuenca, y no, los cambios relativos del nivel del mar.

Palabras clave: *Paleoceanografía, cambios ambientales, última transición Glacial/Interglacial, cistes de dinoflagelados, Mar de Alborán*

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Introduction

The Mediterranean Sea is a marginal basin connected to the Atlantic Ocean by the narrow Strait of Gibraltar (GS). Now, in the basin Evaporation-Precipitation (E-P) is positive [1]. This results in the development of a two-layered flow through the sill of Gibraltar, a surface inflow of less saline North Atlantic Water(NAW) and a subsurface outflow of cooler and more saline Mediterranean Water (MOW)[1]. The rates of flow through the sill are determined by changes in the basin's E-P budget[2]. Therefore, the system is very sensitive to climate changes and related environmental parameters [1,2]. A key site to monitor the Atlantic-Mediterranean water exchange is the GS [3] and by extension in its adjacent basin, the Alboran Sea (AS). The oceanography of the AS is complex but well-established, mainly through modeling, ship data and satellite imagery studies [4,5,6]. The geometry of the GS drives the NAW inflow toward the Spanish coast. Depending on its velocity, an anticyclonic gyre develops over the western AS [7]. Along the northern edge of this gyre, offshore Malaga, upwelling of nutrient-rich waters occurs [5]. Long-term variations in the upwelling intensity and its productivity, are caused by fluctuations in the inflow velocity. These fluctuations can be related either to changes in the Mediterranean E-P budget, deep water production [8], or to sea-level change in the Atlantic. Therefore, the AS is an ideal setting to study the climate changes and related ocean responses.

In this study, dinoflagellate cysts are used to estimate the paleoproductivity history of the AS upwelling. This yields a better understanding of the Mediterranean thermohaline circulation and its response to the climate change that occurred during the Last Glacial/Interglacial transition. The results obtained have implications for modeling the circulation changes of a marginal basin facing climatic changes.

Methods

Core Tg-5 was obtained in the upwelling domain(Fig., 1). Age framework in the core is based on AMS ^{14}C on four selected samples. Coredepths 14, 72, 163, and 202 cm gave the following ages: 1830 ±50, 7390 ±70, 15,380 ±130 and

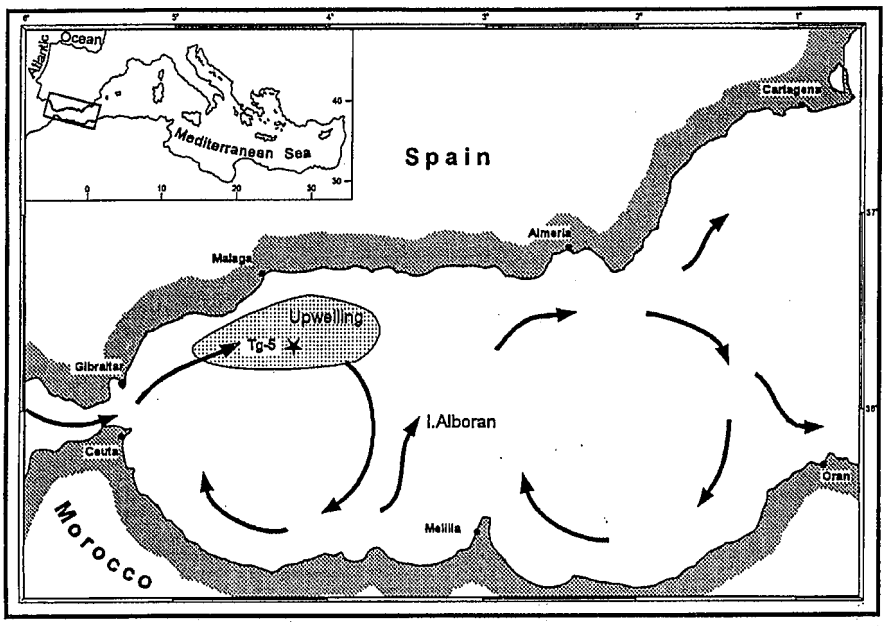

fig. 1.- Surficial circulation of the Alboran Sea, With the upwelling and location of the core.

Fif. 1.- Circulación del Mar de Alborán, con la localización del área de afloramiento y el testigo estudiado.

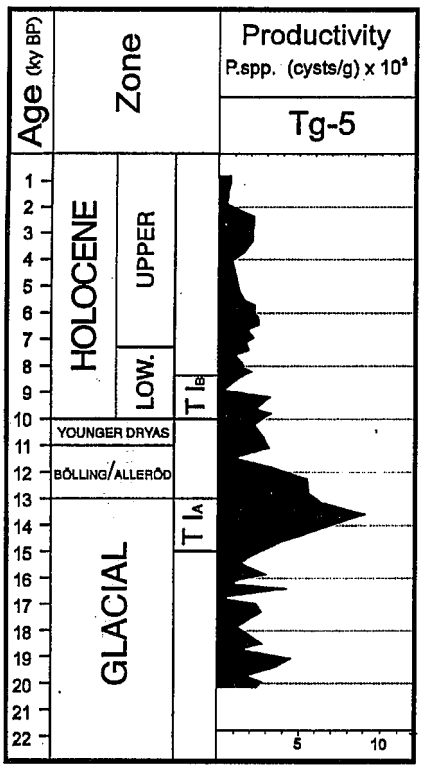

Fig. 2.- Productivity changes based on absolute frecuencies of the dinocists P.spp group.

Fig. 2.- Variaciones de productividad en base a cambios de las frecuencias absolutas del grupo de cistes P.spp.

was reconstructed by using linear interpolation. Sedimentation rates varied between 9.69 and 11.38 cm/ky. The samples represented a time-span of 250 yrs and sampling distance was 300 yrs.

Protoperidinium sppare (P.S pp) is a group of heterotrophic dinoflagellates feeding mainly on diatoms [9]. Since diatoms are the main primary producers of the ocean, and flourish under high nutrient concentrations and intense vertical mixing [10], the abundance of their predators, P.spp group, is expected to increase accordingly. Hence, changes in absolute frequencies in the P.spp group can be used to reconstruct Sea Surface Productivity and the upwelling history of the western AS over the last 20,000 yrs.

Sediment samples (1.5-2 g dry weight) were prepared and dinocysts counted following the procedures described in [11].

Results and conclusions

The cysts of P.ssp were found throughout the core (Fig., 2), suggesting that there was upwelling over the last 20 ky.

To explain the variations in productivity, two factors are important: (1) changes in the basin's E-P budget and (2) changes in the postglacial rate of sea-level rise.

Brief low productivity events were found at 17.9, 17, 16.3, 15.2,11.5, 8.8, 4 and 1.8 ky BP. These, could be related either to lower inflow velocities or to short-term absence of the gyre, <200 yrs. They suggest a weakened thermohaline circulation due lowering in the of the basin E-P.

Enhanced productivity was found between 14.5-12.6 ky BP, centered at 13.5 ky BP. It is related to a higher inflow velocity resulting in the gyre's higher spin and enhanced upwelling. This event was triggered either by an increased E-P budget or by on increase in a postglacial sea-level rise. On the one hand, the pollen spectra are consistent with a vegetation growing under a warm climate with little precipitation [12,13], accounting for the required change in the E/P balance. On the other hand, this was a period with increased rates of sea-level rise [14]accounting for the increased inflow. Nevertheless, the fact that no increased SSPs were found during the second peak of increased sea-level rise rates, centered at 9.5 ky BP, points to the first option. If so, this implies that sea level rises of 3.7 and 2.5 m/100yrs [14] could not enhance the upwelling. Therefore, on a long term, the main forcing of the Mediterranean circulation is thermohaline.

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