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Contourites of the Gulf of Cadiz: A high-resolution record of the paleocirculation of the Mediterranean outflow water during the last 50,000 years

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Abstract

The Mediterranean outflow water (MOW) paleocirculation during the last 50,000 years has been inferred from the grain-size distribution of contourite beds in core MD99-2341 from the Gulf of Cadiz (Southern Iberian Margin–Atlantic Ocean). Three main contourite facies are described. Their vertical succession defines two contourite sequences that reveal past variations of the MOW bottom-current velocity. A comparison of contourite sequences and the planktonic $\delta^{18}O$ record of core MD99-2341 with the $\delta^{18}O$ record from Greenland Ice Core GISP2 show a close correlation of sea-surface water conditions and deep-sea contouritic sedimentation in the Gulf of Cadiz with Northern Hemisphere climate variability on millennial timescales. A high MOW velocity prevailed during Dansgaard-Oeschger stadials, Heinrich events and the Younger Dryas cold climatic interval. The MOW velocity was comparatively low during the warm Dansgaard-Oeschger interstadials, Bølling-Allerød and the Early Holocene. Rapid sea-level fluctuations on the order of 35 m during Marine Oxygen Isotope Stage 3 are considered to have exerted limiting controls on the MOW volume transport and thus positively modulated the MOW behaviour during the last 50 kyr.

Keywords: Gulf of Cadiz; Contourites; Mediterranean outflow water; Paleoclimate changes; Sea-level fluctuations; Paleocirculation

1. Introduction

The last glacial period was marked by rapid climatic oscillations described in the records of Greenland ice cores (Dansgaard et al., 1993; Grootes et al., 1993). These Northern Hemisphere climatic oscillations, named Dansgaard-Oeschger (D-O) stadials and interstadials (cold and warm phases, respectively) are also recorded in ocean sediments (Bond et al., 1993). During some of the coldest stadials, the deposition of ice-rafted detritus indicates that massive iceberg discharges (Heinrich events – HE) occurred in the North Atlantic (Heinrich, 1988; Bond et al., 1992). These 'Heinrich layers' have been recognized as far south as the Portuguese margin (Schönfeld, 1993; Lebreiro et al., 1996; Baas et al., 1997; Bard et al., 2000; Schönfeld and Zahn, 2000; de Abreu et al., 2003) and in the Gulf of Cadiz (Reguera, 2001; Llave et al., 2006; Voelker et al., 2006). Meltwater

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discharge associated with these ice surges induced rapid changes in North Atlantic thermohaline circulation (Broecker et al., 1990; Rasmussen et al., 1997; Elliot et al., 2002). The atmospheric imprint of associated climatic oscillations modified the water-mass exchanges between Atlantic Ocean and Mediterranean Sea (Sierro et al., 2005).

The Gulf of Cadiz is located in the eastern Atlantic Ocean, west of Gibraltar Strait (Fig. 1). Present-day circulation is dominated there by antagonistic currents: at the sea surface, the North Atlantic Surface Water and the North Atlantic Central Water (NACW) flow into the Mediterranean Sea while a deep undercurrent, named the Mediterranean outflow water (MOW) flows out of the Mediterranean Sea (Ambar and Howe, 1979; Ambar, 1983). The MOW is a warm (13 °C) and saline (38‰) water mass and its dynamics are controlled by the integrated evaporative balance of the Mediterranean Sea (Bryden and Stommel, 1982) and more precisely by the interannual to decadal variability of its two sources (Astraldi et al., 2002): The Levantine Intermediate Water (LIW) is formed near Rhodes, and the Western Mediterranean Deep Water (WMDW) which is formed in the Gulf of Lions (South of France), especially during cold and windy winters (Lacombe et al., 1985; Rohling et al., 1998). The WMDW contributes only 10% to the MOW flow today (Kinder and Parilla, 1987). However, Voelker et al. (2006) consider the WMDW as a substantial part of the MOW during the last glacial period. They argued that buoyancy loss of glacial LIW could have reduced the density gradient between Mediterranean intermediate and deep waters and thus led to an increased contribution of WMDW to the MOW (Bryden and Stommel, 1984; Voelker et al., 2006). After exiting Gibraltar Strait, the MOW mixes with NACW in the Gulf of Cadiz (Baringer and Price, 1999) and moves northwest along the western Iberian Margin. The MOW divides into two major core layers: the Mediterranean Upper Water (MU, Fig.1) and the Mediterranean Lower Water (ML, Fig.1). The MU is centred between 400 and 600 m. The density of this core layer is in disequilibrium with the ambient NACW, and it is held at that shallow depth only by the Coriolis force induced by its high flow velocity. The slightly more saline and slower-moving

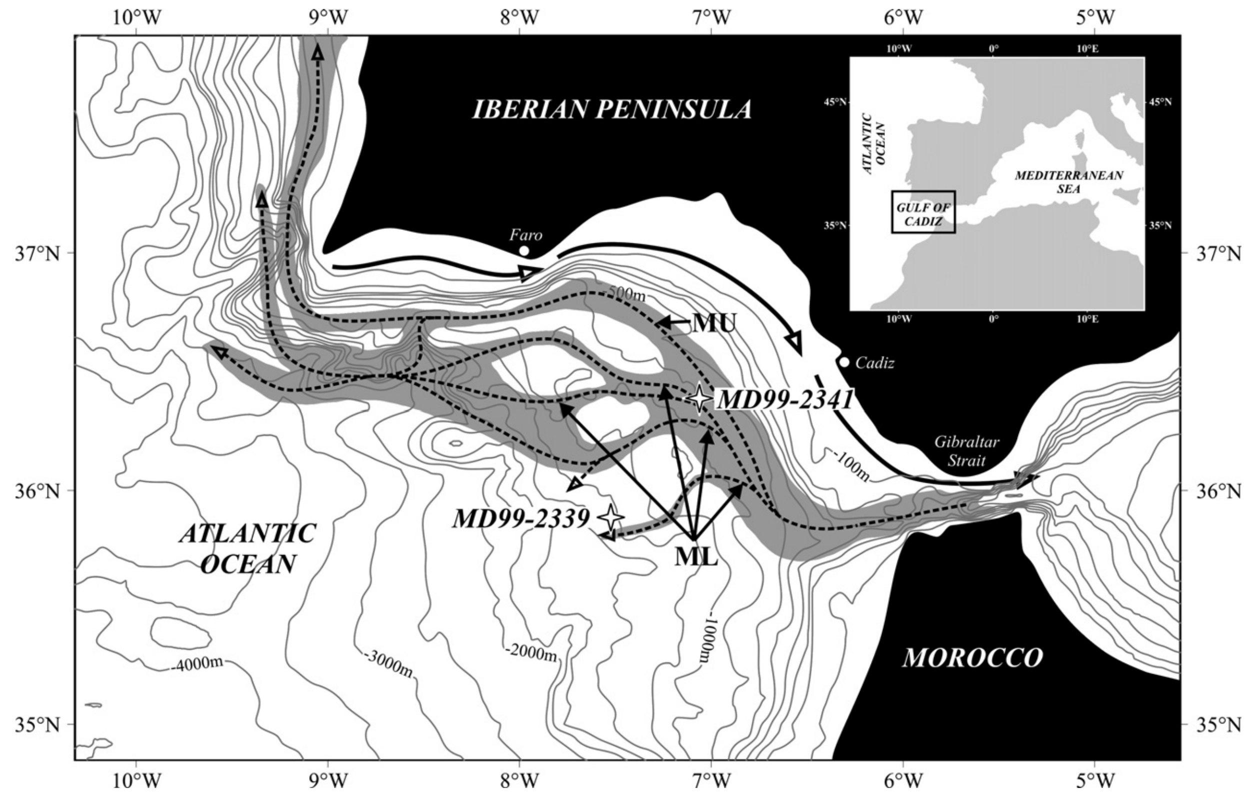

Fig. 1. General map of the Gulf of Cadiz showing the general circulation of the MOW and location of cores MD99-2341 (this study) and MD99-2339 (Voelker et al., 2006). Dotted arrows represent the Mediterranean outflow water (MOW) pathway, composed of the Mediterranean Upper Water (MU) and the Mediterranean Lower Water (ML). Continuous arrows in the northern part of the Gulf of Cadiz represent the Atlantic inflow pathway.