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Biogenic magnetite, detrital hematite, and relative paleointensity in Quaternary sediments from the Southwest Iberian Margin

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ABSTRACT

Magnetic properties of late Quaternary sediments on the SW Iberian Margin are dominated by bacterial magnetite, observed by transmission electron microscopy (TEM), with contributions from detrital titanomagnetite and hematite. Reactive hematite, together with low organic matter concentrations and the lack of sulfate reduction, lead to dissimilatory iron reduction and availability of Fe(II) for abundant magnetotactic bacteria. Magnetite grain-size proxies (κ_{ARM}/κ and ARM/IRM) and S-ratios (sensitive to hematite) vary on stadial/interstadial timescales, contain orbital power, and mimic planktic $\delta^{18}O$. The detrital/biogenic magnetite ratio and hematite concentration are greater during stadials and glacial isotopic stages, reflecting increased detrital (magnetite) input during times of lowered sea level, coinciding with atmospheric conditions favoring hematitic dust supply. Magnetic susceptibility, on the other hand, has a very different response being sensitive to coarse detrital multidomain (MD) magnetite associated with ice-rafted debris (IRD). High susceptibility and/or magnetic grain-size coarsening, mark Heinrich stadials (HS), particularly HS2, HS3, HS4, HS5, HS6 and HS7, as well as older Heinrich-like detrital layers, indicating the sensitivity of this region to fluctuations in the position of the polar front. Relative paleointensity (RPI) records have well-constrained age models based on planktic $\delta^{18}O$ correlation to ice-core chronologies, however, they differ from reference records (e.g. PISO) particularly in the vicinity of glacial maxima, mainly due to inefficient normalization of RPI records in intervals of enhanced hematite input.

1. Introduction

A series of sediment cores retrieved from the SW Iberian Margin by the R/V *Marion Dufresne* in 1995, 1999 and 2001 contain important archives not only of North Atlantic climate (e.g., Martrat et al., 2007) but also continental climate through marine pollen records (Tzedakis et al., 2009; Margari et al., 2010). Evidence for linkages between northern and southern hemisphere climate have been documented in this region from planktic and benthic $\delta^{18}O$ that record Greenland and Antarctic signals, respectively (Shackleton et al., 2000, 2004), and confirm inter-hemispheric phasing of millennial-scale climate change during marine isotope stage (MIS) 3 inferred by methane synchronization of Greenland and Antarctic ice cores (Blunier and Brook, 2001; EPICA Community Members, 2006). Because of the northern (Greenland) and southern (Antarctic) influence on surface and deep water, respectively (see Skinner et al., 2003, 2007), the planktic $\delta^{18}O$ records from the SW Iberian Margin mimic stadial–interstadial oscillations from Greenland ice (Shackleton et al., 2000, 2004) whereas the benthic $\delta^{18}O$ signal resembles Antarctic temperature variations. Within MIS 3, Antarctic warm events occur during the longest, coldest stadials in Greenland, and are followed by abrupt warming in Greenland as Antarctica began to cool. This pattern has been referred to as the "bipolar seesaw" (e.g., Broecker, 1998) and is explained by changes in heat transport related to large-scale thermohaline circulation (Atlantic Meridional Overturning Circulation). In addition, the Iberian Margin cores exhibit concentrations of coarse (> 90 μm) lithic grains, marked by peaks in magnetic susceptibility, that are associated with ice-rafted debris (IRD) deposited during Heinrich stadials (HS)1, HS2, HS3, HS4, HS5 and HS6 (Thouveny et al., 2000; Moreno et al., 2002; Skinner et al., 2003; Vautravers and Shackleton, 2006; Voelker and de Abreu, 2011).

The *Marion Dufresne* (MD) cores collected in 1995 from the SW Iberian Margin (MD95-2039, -2040 and -2042) have been used to determine records of relative paleointensity (RPI) of the geomagnetic field, leading to the construction of a Portuguese Margin RPI stack (Thouveny et al., 2004). The RPI studies were carried out in conjunction with studies of $^{10}Be/^{9}Be$ in sediments from

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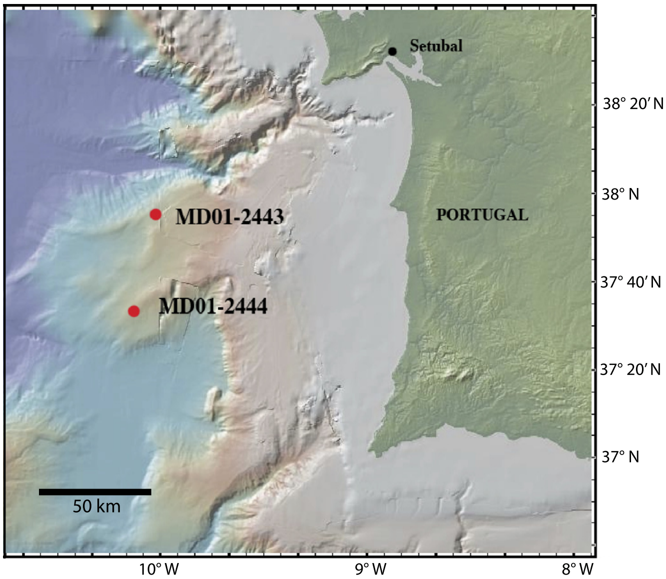

Fig. 1. Location of Cores MD01-2443 and MD01-2444 (from GeoMapApp™).

the same cores, which can be related to ^{10}Be flux in ice cores, atmospheric ^{10}Be production, and hence to RPI (Carcaillet et al., 2003, 2004a, 2004b; Ménabréaz et al., 2011). Magnetic parameters have indicated finer magnetite grain sizes during interglacials, when sortable-silt grain sizes imply stronger bottom current flow, and according to Moreno et al. (2002), magnetic grain-size parameters reflect varying detrital sources whereas physical sortable-silt grain size is controlled by local bottom-current strength.

Here we describe magnetic properties and RPI records from two MD piston cores collected in 2001 from the SW Iberian Margin (Fig. 1). Core MD01-2443 (37°52.85′N, 10°10.57′W, 2925 m water depth) and Core MD01-2444 (37°33.68′N, 10°8.53′W, 2637 m water depth) are 27 m and 29.5 m in length and extend into marine isotope stage (MIS) 11 and MIS 6, respectively.

The centennial timescales associated with non-axial dipole (NAD) components of the geomagnetic field (e.g., Lhuillier et al., 2011) implies that RPI, when measured in sediments with sedimentation rates less than a few decimeters/kyr, are largely devoid of NAD components are therefore useful for global correlation at millennial or multi-millennial timescales (see Channell et al., 2009). This study of cores from the SW Iberian Margin was prompted by the need for high-resolution RPI records to augment the existing reference template, by the availability of high-quality age control at this location through δ^{18}O (Shackleton et al., 2004), and by the apparent suitability of magnetic properties for RPI studies (Thouveny et al., 2004). In November 2011, Integrated Ocean Drilling Program (IODP) Expedition 339 occupied IODP Site U1385 (37°34.29′N, 10°7.56′W), located close to Core MD01-2444 (see Stow et al., 2012).

2. Age model

The close similarity of the planktic δ^{18}O records from the SW Iberian Margin and δ^{18}O of Greenland ice cores over the last glacial cycle (Shackleton et al., 2000, 2004; Skinner et al., 2003) allows Greenland age models to be adopted for SW Iberian Margin sediments. The age model for Core MD01-2444 for the last glacial cycle was constructed by correlation of the MD01-2444 planktic δ^{18}O record to the Greenland ice-core record, using the revised Greenland chronology of Shackleton et al. (2004). For Cores MD01-2443 and MD01-2444, beyond the last glacial cycle, we use an age model derived by correlating millennial variability in the δ^{18}O records to a synthetic Greenland δ^{18}O record produced using the EPICA Dome C (EDC) ice core and a thermal bipolar seesaw model (Barker et al., 2011; Hodell et al., 2013). The synthetic Greenland δ^{18}O record was placed on an absolute 'Speleo-Age' timescale by correlating cold events in the synthetic Greenland record with 'weak monsoon events' in the detrended speleothem record (Barker et al., 2011). Planktic δ^{18}O (Fig. 2b) and benthic δ^{18}O (Fig. 2c) data for MD01-2443 are available from marine isotope stage (MIS) 5 to the base of the section in MIS 11 (De Abreu et al., 2005; Tzedakis et al., 2004, 2009; Voelker and de Abreu, 2011). For Core MD01-2444 (0-200 ka), planktic oxygen isotope data (Fig. 2b) have been published in various studies (De Abreu et al., 2005; Vautravers and Shackleton, 2006; Skinner et al., 2007; Margari et al., 2010). For the last glacial cycle, back to 200 ka, the age model for Core MD01-2443 was constructed by correlation of the Ca/Ti ratio, determined by X-ray fluorescence (XRF) core scanning (Fig. 2d), between Cores MD01-2444 and MD01-2443 (see Hodell et al., 2013), and hence transfer of the Greenland chronology from Core MD01-2444 to MD01-2443. The resulting age models imply sedimentation rates in the 5–20 cm/kyr range and the 10–40 cm/kyr range for Cores MD01-2443 and MD01-2444, respectively (Fig. 2e).

3. Natural remanent magnetization (NRM)

Continuous u-channel samples (2 × 2 × 150 cm^3 samples encased in plastic with a clip-on lid constituting one of the sides) were collected from the archive halves of each 1.5 m section of Cores MD01-2443 and MD01-2444. Measurements of natural remanent magnetization (NRM) of u-channel samples were made at 1 cm intervals, with a 10 cm leader and trailer at the top and base of each u-channel sample, using a 2 G Enterprises pass-through magnetometer at the University of Florida designed for the measurement of u-channel samples (Weeks et al., 1993; Guyodo et al., 2002). After initial NRM measurement of u-channel samples, stepwise AF demagnetization was carried out in 5 mT increments in the 10–60 mT peak field interval, and in 10 mT increments in the 60–100 mT interval, using tracking speeds of 10 cm/s. Component magnetizations were computed each 1 cm for a uniform 20–80 mT demagnetization interval (see Supplementary Fig. S1) using the standard least-squares method (Kirschvink, 1980) without anchoring to the origin of the orthogonal projections, using UPmag software (Xuan and Channell, 2009). Supplementary materials related to this article can be found on-line at http://dx.doi.org/10.1016/j.epsl.2013.06.026. The maximum angular deviation (MAD) values are generally below 5° (see Supplementary Fig. S1), indicating well-defined magnetization components although the NRM is not fully demagnetized at peak fields of 100 mT, indicating that the NRM is partially carried by high-coercivity magnetic minerals. Component declinations (see Supplementary Fig. S1) were adjusted for vertical-axis core rotation by uniform rotation of the entire core such that the mean core declination is oriented North. Top-core twisting of sediment is apparent in the declination of Core MD01-2443 where the top 13 m of sediment (back to 110 ka) is affected (see Supplementary Fig. S1). For Core MD01-2444, the top 13 m (back to ∼ 50 ka) is also twisted although less so than core MD01-2443. Component inclinations are negative over about 10 cm of core at 13.5 ka (2.4 m depth) in Core MD01-2444 (see Supplementary Fig. S1), however, further investigations are required before these component directions can be attributed to the geomagnetic field. As has been often noted, the top ∼ 10–15 m of *Marion Dufresne* (MD) cores retrieved with the Calypso corer are usually "oversampled" (stretched) during recovery by ∼ 30–40% (see Szérémeta et al., 2004), possibly account-