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Relative paleointensity (RPI) in the latest Pleistocene (10–45 ka) and implications for deglacial atmospheric radiocarbon

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A B S T R A C T

We report magnetic properties and relative paleointensity (RPI) proxies from a suite of 10 conventional piston cores and Kasten cores from the SW Iberian Margin collected during cruise JC089 of the RSS *James Cook* in August 2013. Mean sedimentation rates are in the 10–20 cm/kyr range. Age models were acquired by correlation of Ca/Ti and Zr/Sr XRF core-scanning data to L* reflectance from the Cariaco Basin that is, in turn, tied to the Greenland ice-core chronology. The natural remanent magnetization (NRM) is represented by a single magnetization component carried by a low-coercivity mineral (magnetite), although reflectance and bulk magnetic properties indicate the presence of a high-coercivity (hematitic) magnetic phase, possibly from eolian dust. The presence of fine-grained hematite means that the sediments are not ideal for RPI studies, however the detrital hematite does not appear to contribute to the NRM or anhysteretic remanent magnetization (ARM). In order to test the usefulness of the RPI data, we construct a stack of 12 RPI records from the SW Iberian Margin for the 0–45 ka interval and compare it with a stack of 12 globally distributed marine and lake records, chosen on the basis of mean sedimentation rates (>15 cm/kyr) and superior age models. The two stacks are similar, but different from published RPI stacks, particularly for the 10–30 ka interval, and imply a virtual axial dipole moment (VADM) high at ~15–18 ka followed by a drop in field strength from ~15 to 13 ka. A revised VADM estimate calculated from Greenland ^{10}Be ice-core flux using a contemporary age model is remarkably consistent with the new overall RPI stack, based on Iberian Margin and global RPI records. The elevated atmospheric ^{14}C levels of the last ice age cannot, however, be fully explained by this RPI stack although relative changes such as the long-term drop in atmospheric ^{14}C from 30 to 15 ka are reproduced, supporting the hypothesis of a combined influence of production rate and ocean ventilation on ^{14}C during the last ice age.

1. Introduction

Consistent correlation of sedimentary relative paleointensity (RPI) proxies to oxygen isotope data over the last 1–2 Myrs (e.g., Channell et al., 2009; Xuan et al., 2016) has shown that RPI proxies in sediments can reflect the Earth's axial dipole (AD) field and therefore provide a signal suitable for global stratigraphic correlation. This conclusion is supported by the consistent picture of dipole field strength from RPI and from sedimentary ^{10}Be/^{9}Be ratios back to 850 ka (e.g., Simon et al., 2016). Because the strength of the AD field is an important control on atmospheric cosmogenic isotope production, RPI records have implications for the calibration of radiocarbon dates and for the carbon cycle including the apparent drop in atmospheric Δ^{14}C in the "mystery interval" at 17.5–14.5 kyr (Broecker and Barker, 2007).

The Holocene (0–11.5 ka) record of paleointensity has been modeled from archeomagnetic and lava-flow data (Korte et al., 2009, 2011; Pavon-Carrasco et al., 2014) indicating a pattern of AD field intensity changes characterized by a broad high in intensity at ~1–3 ka, preceded by a broad low in the 5–7 ka interval (Fig. 1b). Beyond the range of archeomagnetic data, latest Pleistocene (11.5–45 ka) sedimentary RPI data have been compiled into regional and global stacks (Laj et al., 2000, 2004; Stoner et al., 2002; Valet et al., 2005; Channell et al., 2009; Ziegler et al., 2011), but with

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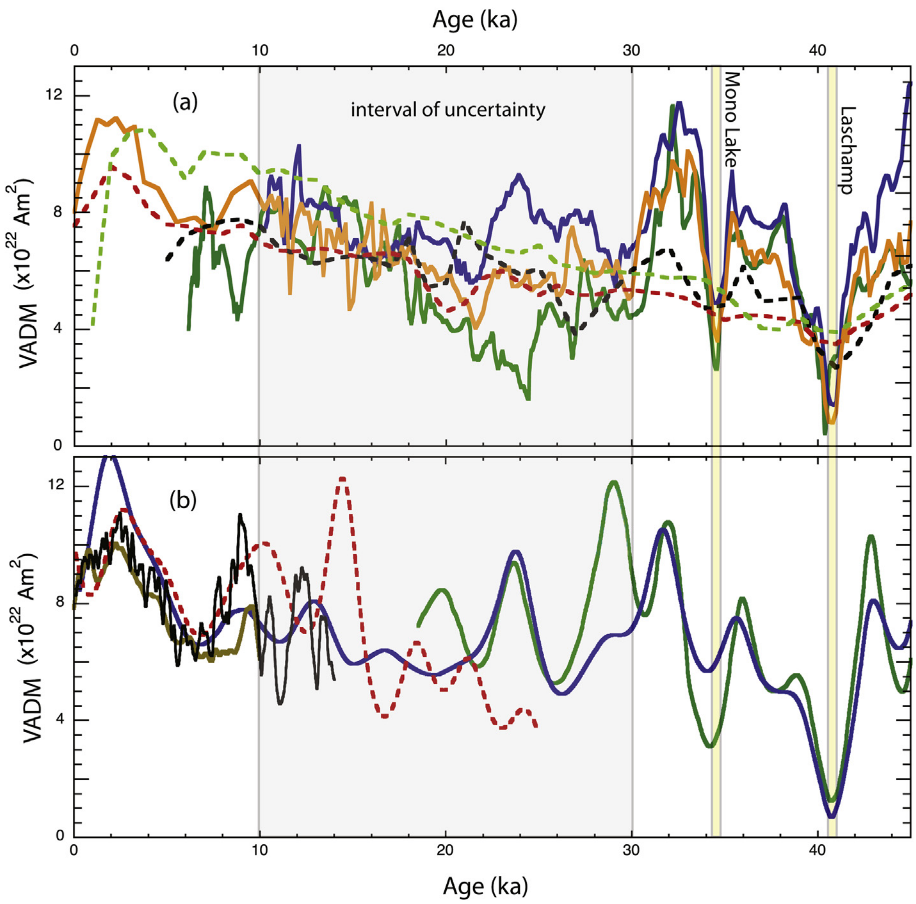

Fig. 1. (A) Relative paleointensity stacks: NAPIS (blue, Laj et al., 2000), GLOPIS (orange, Laj et al., 2004), SAPIS (dark green, Stoner et al., 2003), Sint-2000 (dashed red, Valet et al., 2005), PISO-1500 (dashed black, Channell et al., 2009) and PADM2M (dashed light green, Ziegler et al., 2011). (b) Modeled Holocene axial dipole field intensity (brown, Korte et al., 2011; black, Pavon-Carrasco et al., 2014), virtual axial dipole moment (VADM) determined from ^{10}Be flux (blue) and ^{36}Cl flux (green) in Greenland ice cores (Muscheler et al., 2005), and from Δ^{14}C (red dashed, Muscheler et al., 2005). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

little agreement between stacks, or individual records, for the 10–30 ka interval (Fig. 1a). The poor consistency of sedimentary RPI data since the time of the Mono Lake (~34 ka) and Laschamp (~41 ka) excursions (Fig. 1a) is attributed to drilling disturbance in the uppermost few meters of recovered sediment sequences.

Absolute paleointensity data from volcanics have not contributed significantly to the paleointensity time-series for the 10–30 ka interval for several reasons: lava sequences are plagued by unknown time-gaps between flows, ^{40}Ar/^{39}Ar dating has poor precision for young (<40 ka) ages, scarcity of robust radiocarbon age control, and scatter in absolute paleointensity determinations when plotted versus age particularly for the 10–30 ka interval (e.g., Teanby et al., 2002; Pressling et al., 2006; Genevey et al., 2008; Laj et al., 2014).

Using models of cosmogenic nuclide production (Masarik and Beer, 1999), Muscheler et al. (2005) calculated the virtual axial dipole moment (VADM) corresponding to the flux of cosmogenic isotopes in ice cores for ^{36}Cl (Baumgartner et al., 1998; Wagner et al., 2000) and ^{10}Be (Yiou et al., 1997; Finkel and Nishiizumi, 1997). Estimates of atmospheric ^{14}C activity have been derived from independent age control on radiocarbon ages from stalagmites (Beck et al., 2001; Wang et al., 2001; Southon et al., 2012), corals (Fairbanks et al., 2005), lake varves (Bronk Ramsey et al., 2012) and from the correlation of marine sediment cores to Greenland ice (Hughen et al., 2004; Peterson et al., 2000; Bard et al., 2004). VADM estimates derived from atmospheric ^{14}C (Muscheler et al., 2005) are not consistent with estimates from ^{36}Cl and ^{10}Be from Greenland ice, particularly for 10–30 ka (Fig. 1b). Discrepancies may be due to differing transport pathways for ^{36}Cl and ^{10}Be from the atmosphere to ice, diffusion of ^{36}Cl in firn (not likely in Greenland), and changes in the carbon cycle, particularly changes in ocean ventilation (e.g. Skinner and Shackleton, 2004; Muscheler et al., 2004; Robinson et al., 2005; Skinner et al., 2010; Chen et al., 2015). Furthermore, revisions in ice-core timescales directly impact the radionuclide flux calculation. For the last glacial maximum (LGM) interval, the latest Greenland ice core timescale (Svensson et al., 2008) results in adjustments to the ^{10}Be-based VADM estimates of Muscheler et al. (2005).

Magnetic concentration parameters in sediments, such as susceptibility or anhysteretic remanent magnetization (ARM) intensity, are less affected by subtle drilling disturbance than natural remanent magnetization (NRM) intensities. Sedimentary NRM intensities depend on magnetic grain alignment, and are an essential entity in RPI proxies. Published RPI stacks (Fig. 1a) rely largely on cores collected from the *Marion Dufresne* (MD) using the Calypso corer, and cores collected using the Advanced Piston Corer (APC) of the Ocean Drilling Program and Integrated Ocean Drilling Program (ODP/IODP). The stretching (oversampling) of the upper part of sediment cores collected by the Calypso corer has been well documented (Skinner and McCave, 2003; Széréméta et al., 2004). Deformation of the upper part of APC cores is less well documented although familiar to shipboard scientists who regularly observe