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Paleomagnetism of Quaternary sediments from Lomonosov Ridge and Yermak Plateau: implications for age models in the Arctic Ocean

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ABSTRACT

Inclination patterns of natural remanent magnetization (NRM) in Quaternary sediment cores from the Arctic Ocean have been widely used for stratigraphic correlation and the construction of age models, however, shallow and negative NRM inclinations in sediments deposited during the Brunhes Chron in the Arctic Ocean appear to have a partly diagenetic origin. Rock magnetic and mineralogical studies demonstrate the presence of titanomagnetite and titanomaghemite. Thermal demagnetization of the NRM indicates that shallow and negative inclination components are largely “unblocked” below ~300 °C, consistent with a titanomaghemite remanence carrier. Following earlier studies on the Mendeleev–Alpha Ridge, shallow and negative NRM inclination intervals in cores from the Lomonosov Ridge and Yermak Plateau are attributed to partial self-reversed chemical remanent magnetization (CRM) carried by titanomaghemite formed during seafloor oxidation of host (detrital) titanomagnetite grains. Distortion of paleomagnetic records due to seafloor maghemitization appears to be especially important in the perennially ice covered western (Mendeleev–Alpha Ridge) and central Arctic Ocean (Lomonosov Ridge) and, to a lesser extent, near the ice edge (Yermak Plateau). On the Yermak Plateau, magnetic grain size parameters mimic the global benthic oxygen isotope record back to at least marine isotope stage 6, implying that magnetic grain size is sensitive to glacial–interglacial changes in bottom-current velocity and/or detrital provenance.

1. Introduction

Sediment cores from the Arctic Ocean commonly record intervals of shallow to negative magnetic inclination, typically tens of centimeters thick. These negative and intervening positive inclination intervals were initially interpreted as polarity chronozones implying very low (fractions of mm to few mm per kyr) deposition rates throughout the central Arctic Ocean (e.g., Steuerwald et al., 1968; Clark, 1970; Hunkins et al., 1971; Herman, 1974; Witte and Kent, 1988). When alternative age models emerged, it became clear that sedimentation rates were probably an order of magnitude higher (Løvlie et al., 1986; Darby et al., 1997; Jakobsson et al., 2000, 2001, 2003; Backman et al., 2004; Spielhagen et al., 2004; Kaufman et al., 2008; Polyak et al., 2009). Accordingly, the negative inclination intervals were attributed to geomagnetic excursions within the Brunhes Chron (e.g., Løvlie et al., 1986; Jakobsson et al., 2000; Spielhagen et al., 2004; O’Regan et al., 2008).

A number of geomagnetic excursions within the last few million years have been reported worldwide from deep-sea or lake sediment cores, lavas, and loess. At least seven magnetic excursions are reasonably well documented in the Brunhes Chron (Champion et al., 1988; Langereis et al., 1997; Worm, 1997; Lund et al., 2001, 2006; Laj and Channell, 2007). The higher fidelity magnetic excursion records with high quality age constraints generally yield excursion durations of <5 kyr (see Laj and Channell, 2007). For instance, the duration of the Laschamp excursion, the best known excursion in the Brunhes Chron, was estimated to be ~1.5 kyr by Laj et al. (2000) using a chronology based on correlation of a marine $\delta^{18}O$ record to the GISP2 (Greenland) ice core. A few-kyr duration for excursions is consistent with the model of Gubbins (1999) who proposed that “during excursions the field may reverse in the liquid outer core, which has timescales of 500 years or less, but not in the solid inner core, where the field must change by diffusion with a timescale of 3 kyr”. In the unlikely case that the outer core reversed field survives for >3 kyr, diffusion into the inner core gives rise to the long-lived polarity chron or subchron. Due to the brief duration of geomagnetic excursions (nominally <3 kyr), and smoothing effects of the sediment magnetization lock-in process,

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sediments would need to maintain deposition rates of at least 5–10 cm/kyr to record geomagnetic excursions (e.g., Roberts and Winklhofer, 2004).

Sediments deposited in the Brunhes Chron from the Arctic Ocean and the Norwegian–Greenland Sea have appeared to be anomalously efficient in recording geomagnetic excursions for sediments with mean deposition rates of a few cm/kyr. Nowaczyk et al. (2001) recognized six excursions in three cores from the Makarov Basin in the central Arctic Ocean, close to the Lomonosov Ridge (Cores PS 2178 and PS 2180; Fig. 1). For IODP (Integrated Ocean Drilling Program) Arctic Coring Expedition (ACEX) cores from the Lomonosov Ridge (Fig. 1), O'Regan et al. (2008) placed the Brunhes/Matuyama boundary at 10.82 m revised composite depth (rmcd) in accord with ^{10}Be stratigraphy and orbital tuning of bulk density and ARM/IRM data (ratio of anhysteretic remanent magnetization to isothermal remanent magnetization), implying a mean sedimentation rate of ~1.4 cm/kyr during the Brunhes Chron. Three apparent excursions in the upper 4.65 rmcd were associated with the Mono Lake/Laschamp excursion, the Norwegian–Greenland Sea excursion, and the Biwa II excursion, and eleven additional excursions were observed within the 4.65–10.82 rmcd interval (O'Regan et al., 2008). Near Yermak Plateau (Fig. 1), 3–4 intervals of negative inclination were observed in Cores PS 1533 and PS 2212 (Nowaczyk et al., 1994), and in Core PS 2138 (Nowaczyk and Knies, 2000), with age control provided by ^{14}C, δ^{18}O, ^{10}Be and ^{230}Th stratigraphies, and nannofossil biostratigraphy. The marine isotope stage (MIS) 5/6 boundary in these cores was often placed at a depth of ~4–5 m (Nowaczyk et al., 1994; Nowaczyk and Knies, 2000), indicating mean sedimentation rates of ~3 to 5 cm/kyr for the last ~130 kyr. Cores PS 1707, 1878, 1882, and 1892 from the Greenland Basin, north of Jan Mayen Island (Fig. 1), yielded negative remanence inclinations associated with the Mono Lake excursion, the Laschamp excursion, and the Biwa I excursion (Nowaczyk and Antonow, 1997), with mean sedimentation rates of ~2 to 4.5 cm/kyr estimated from planktic δ^{18}O-derived ages.

Cores from the Arctic Ocean and the Norwegian–Greenland Sea generally yield larger duration estimates for supposed geomagnetic

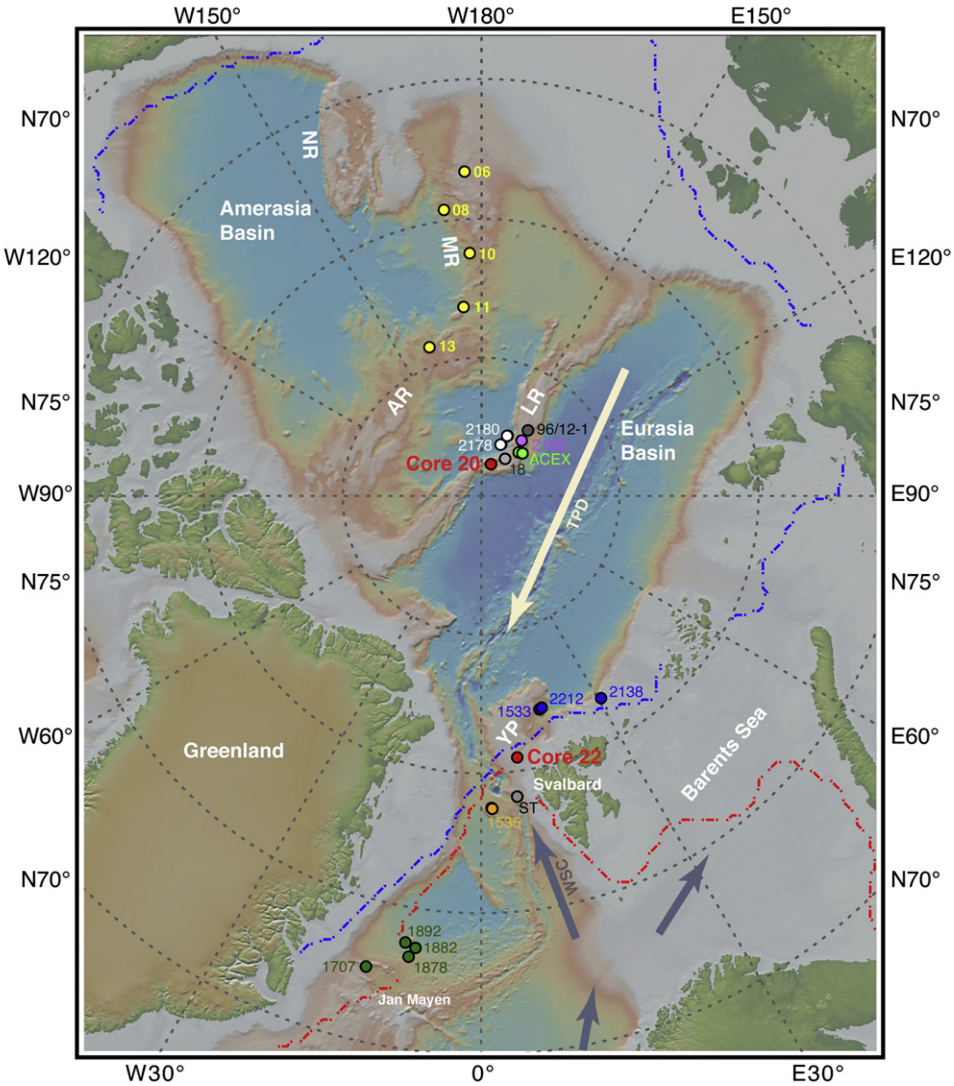

Fig. 1. Location of Cores 20 and 22 (red solid circles) retrieved by the HOTRAX'05 expedition, in comparison with location of previously studied cores. Base map data are from international bathymetric chart of Arctic Ocean (IBCAO, Jakobsson et al., 2008). Map is processed using the GeoMapApp© software. Labeled features are: Lomonosov Ridge (LR), Mendeleev Ridge (MR), Alpha Ridge (AR), Northwind Ridge (NR), Yermak Plateau (YP), Transpolar Drift (TPD, yellow arrow), and North Atlantic water inflows (gray arrows) including the West Spitsbergen Current (WSC). Blue and red dash dot lines are extent of sea ice of March and September medians for 1979–2000 (data from National Snow and Ice Data Center), respectively. References for previously studied cores listed on the map are as following. 06: Channell and Xuan, 2009; 08, 10, 11, and 13: Xuan and Channell, 2010; 18: Sellén et al., 2010; 2178 and 2180: Nowaczyk et al., 2001; 96/12-1: Jakobsson et al., 2000, 2001, 2003; 2185: Spielhagen et al., 2004; ACEX: Backman et al., 2008; O'Regan et al., 2008; 1533 and 2212: Nowaczyk et al., 1994; 2138: Nowaczyk and Knies, 2000; Nowaczyk et al., 2003; 1535: Nowaczyk et al., 2003; 1707, 1878, 1882, and 1892: Nowaczyk and Antonow, 1997; ST: sediment traps location of Hebbeln (2000). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)