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Changes in sedimentation patterns of the Nordic seas region across the mid-Pleistocene

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Abstract

Sediment core data from a site in the central Nordic seas suggest that during the mid-Pleistocene revolution (MPR) this region has experienced a systematic change in its overall oceanographic and climatic conditions. First distinct changes occur around 1 Ma and reveal the beginning of a shift in climate periodicity from stronger 41-ka cycles towards a dominant 100-ka cyclicity. Most pronounced are the changes at the study region between about 700 and 420 ka, when parallel to the evolution of large 100-ka cycles a distinct decrease in the input of magnetic particles is observed. Also, for this interval an intensification of glacial conditions is indicated by a marked increase in the accumulation rates of ice-rafted debris (IRD) during marine isotope stages 16 and 12.

The observed mid-Pleistocene changes were likely due to a gradual shift from a more zonal behavior of the coupled ocean–atmosphere system at high northern latitudes prior to the MPR to more meridionality thereafter, a shift that affected both the patterns of ocean circulation and ice drift in the Nordic seas region. Accordingly, the subsequent MPR-related changes of these two climate parameters should be responsible for the decrease in the concentration of magnetic particles at the study site after 700 ka. With the mid-Pleistocene strengthening of the Nordic heat pump the mode of deep-water production and the flow of bottom currents changed at high northern latitudes, which led to an increased export of magnetic particles from basaltic source regions around Greenland and Iceland into the subpolar North Atlantic. Consequently, less magnetic material was deposited in the Nordic seas than before the MPR when water mass exchange between the Nordic seas and the North Atlantic was more restricted. In addition, the large Late-Pleistocene expansions of glacial ice caps on the eastern margin of the Nordic seas led to a major change in the composition of IRD material in the study area, with more material originating from the Scandinavian and Barents Sea shelf regions, which ultimately caused a dilution of the magnetic signal.

Keywords: mid-Pleistocene revolution; Nordic seas; sedimentation patterns

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1. Introduction

It is well known that the strong glacial–interglacial climate cyclicity of the Northern Hemisphere as it is recognized for the past about 500 kyr is not representative for the behavior of the entire Pleistocene climate system (Shackleton et al., 1988; Berger and Jansen, 1994; Baumann and Huber, 1999). During Early to early Middle Pleistocene times, the climatic conditions in the northern North Atlantic (Nordic seas) showed long periods of moderate glacial conditions and only episodic interglacial intervals, i.e., northward-directed intrusions of temperate water masses into the Nordic seas (e.g., Henrich, 1989; Fronval and Jansen, 1996). It was only after the so-called mid-Pleistocene revolution (MPR) that the characteristics of glacial and interglacial climates intensified, leading to the more pronounced contrasts of the high northern climate system so typical for the Late Pleistocene (Jansen et al., 1989; Henrich and Baumann, 1994; Baumann et al., 1996).

Along with the mid-Pleistocene climate intensification goes the mid-Pleistocene shift from a dominant climate periodicity around 41 ka (Earth's orbital obliquity) to a dominant periodicity around 100 ka (Earth's orbital eccentricity) (e.g., Ruddiman et al., 1989; Berger et al., 1994; Bolton et al., 1995). It is still under debate why we observe this pronounced increase in glacial–interglacial climate contrasts and the systematic shift into the late-Pleistocene 100 ka world (Boyle, 1988; Maasch and Saltzman, 1990; Clark and Pollard, 1998; Berger et al., 1999), as the orbital forcing parameters did not change across the mid-Pleistocene (Saltzman and Verbitsky, 1994; Raymo et al., 1997).

To improve our current knowledge as well as our concepts about forcing factors and environmental consequences of the mid-Pleistocene climate shift, we need further high quality proxy records. However, the current proxy information about character and timing of the mid-Pleistocene paleoceanographic and paleoclimatic changes are rather limited, especially from the region where the climatic consequences of the MPR are expected to be rather pronounced, i.e., the Nordic seas. Here, most of the evidence about Early and Middle Pleistocene conditions comes from some sediment records obtained by the Ocean Drilling Program (e.g., (Henrich, 1989; Jansen et al., 1989; Fronval and Jansen, 1996), which are, in general, characterized by relatively low sample resolution. To gain more detailed insights into the specific climatic response of the high northern latitudes, we present a number of high-resolution sediment records from an IMAGES core site in the deep Norwegian Sea (eastern Nordic seas), which cover the past about 1.6 Ma.

2. Core material, methods and chronology

The about 34-m-long piston core MD992277 (Fig. 1) was recovered from the eastern slope of the Iceland Plateau in the western Norwegian Sea during the IMAGES V campaign in 1999. Magnetic remanence and low field bulk susceptibility (volume) were measured at the Laboratoire des Sciences du Climat et de ĺEnvironnement, Gif-sur-Yvette, France (Fig. 2; for details see Helmke et al., 2003a). Magnetic susceptibility (MS) of the core was recorded onboard at 2 cm steps (Fig. 3). Planktic $\delta^{18}O$ (given as per mil deviations relative to the Pee Dee Belemnite (PDB) carbonate standard) was sampled at a resolution of 2.5 cm across the studied mid-Pleistocene interval (resolution for Early Pleistocene sections is 5 cm) and measured at the Leibniz Laboratory (University of Kiel) with the automated Kiel Carbonate Preparation Device and a Finnigan MAT 251 mass spectrometer system. On average, 20 specimens of the polar planktic foraminifer *Neogloboquadrina pachyderma* (sinistral) from the size fraction 125–250 μm were taken for each analysis. From 10 m core depth down, IRD was counted in the mesh size >250 μm with an average sample interval of 2.5 cm. The results are expressed as lithic grains per gram (Fig. 2). The bulk carbonate content (% weight) was measured every 5 cm in the same core sections as IRD (Fig. 2). Calcium (Ca), iron (Fe) and titanium (Ti) concentrations in the sediment were measured in 2 cm steps using the X-ray fluorescence (XRF) corescanner (Röhl and Abrams, 2000; Haug et al., 2001) at the University of Bremen, Germany (Figs. 2 and 3).

A number of parameters were used to obtain an age model for the study site. Core PS1243 is located in