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Paleoecological significance of laminated diatomaceous oozes during the middle-to-late Pleistocene, North Atlantic Ocean (IODP Site U1304)

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ABSTRACT

We examined diatom assemblages in a series of remarkable laminated diatomaceous ooze (LDO) horizons in the marine sediments from Integrated Ocean Drilling Program (IODP) Site U1304 to reconstruct the middle-to-late Pleistocene paleoceanographic evolution of the northern North Atlantic Ocean. Four confirmed diatom biohorizons combined with calcareous nannofossil and paleomagnetic stratigraphies established the chronological framework for the material. The planktonic, araphid, needle-like species *Thalassiothrix longissima* was the greatest contributor to the LDO facies. From the results of a principal component analysis using the percent abundances of 65 significant (p=5%) diatom taxa, except for *Tx. longissima*, which was extremely dominant in almost all horizons observed, we identified two principal component (PC) axes. Taxa probably associated with the stratigraphic distribution of the major zonal marker *Neodenticula seminae* (ranging from 1.26 to 0.84 Ma in this ocean) loaded on PC1 with a high value. PC2 was related to the ocean surface temperature. The stratigraphic variability of the PC2 score indicated that switching between warm- and cold-water assemblages occurred concurrently with LDO deposition (or extreme *Tx. longissima* dominance) episodes in several horizons (particularly after 0.84 Ma), suggesting that the Subarctic Convergence (SAC) oceanic front passed over Site U1304 during Pleistocene glacial/interglacial cycles. Our floral evidence supports the model of nearly monospecific LDO formation caused by the enhanced physical accumulation of particular diatoms such as *Tx. longissima*. On the other hand, *Nd. seminae*, which probably contributes to spring phytoplankton blooms in the modern ocean, was present only between 1.26 and 0.84 Ma in this area. Thus, we infer that the main contributor of export flux in the regional annual primary production cycle would have shifted drastically from one of a spring phytoplankton bloom leader (*Nd. seminae*) to minor but mass dump assemblages (*Tx. longissima* etc.) in the mid-Pleistocene.

1. Introduction

Drilling at Integrated Ocean Drilling Program Site U1304 was conducted during Expedition 303 to obtain a several-million-year-long climatic record within the ice-rafted debris belt, at a water depth sufficient to monitor past North Atlantic Deep Water (NADW) properties. In the Site U1304, we encountered a remarkable and unusual sedimentary facies of thinly laminated diatomaceous ooze (LDO), consisting mostly of monospecific frustules, deposited episodically but spanning the whole recovered interval.

Previous studies have investigated such LDO occurrences from most of the world's (semi-) pelagic oceans (e.g., Peruvian upwelling region, Kemp, 1990; Patience et al., 1990; eastern subtropical Pacific, Kemp and Baldauf, 1993; Kemp et al., 1995; Pearce et al., 1995; subarctic North Pacific, Dickens and Barron, 1997; off California, Pike and Kemp, 1999; Southern Ocean, Grigorov et al., 2002). In the materials obtained during Expedition 303 in the northern North Atlantic, the LDO facies strikingly

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covers the full Pleistocene period, dating back to a time far older than the last interglacial period [marine isotopic stage (MIS) 5], the LDO age reported by Bodén and Backman (1996).

It has been suggested that such LDO formation was likely associated with the mechanical mass deposition of diatom frustules in convergent oceanic fronts (Kemp and Baldauf, 1993; Kemp et al., 1995). Thus, our LDO from the northern North Atlantic is expected to be a key sedimentary record of high (annual-scale) resolution climatic signals in the subarctic convergence (SAC) region. Variations in the northern North Atlantic surface hydrography have been implicated not only in the deep thermohaline dynamics regulating the global climate but also in the poleward transport and redistribution of heat and moisture in regional environments (e.g., Wright and Flower, 2002). From this point of view, it is important to decode temporal and spatial variations in the past SAC, which may be reflected in the LDO sequence.

In this paper, we present detailed micropaleontological evidence of the middle-to-late Pleistocene surface environmental variation using diatoms as hydrographic indicators and paying special attention to the paleoecological significance of the LDO deposition.

2. Oceanographic setting

The study area is located within a semi-enclosed basin near the southern limit of the Gardar Drift, just to the north of the Charlie Gibbs Fracture Zone (Expedition 303 Scientists, 2006). The SAC is a distinct oceanic front between (1) the warm saline North Atlantic Current and the Irminger Current, and (2) the cold and less saline East Greenland Current and the waters flowing out from the Labrador Sea. The northernmost position of the SAC is still uncertain because of the complicated meanderlike pattern of the SAC (Ruddiman and Glover, 1975). The westward-flowing West Greenland Current and the southward-flowing current originating in the surface water of Baffin Bay converge to become the Labrador Current, which flows counterclockwise, forming the subarctic gyre on the northern side of the SAC (Fig. 1).

3. Materials and methods

3.1. Lithofacies

The materials from Site U1304 (53°03.40′N, 33°31.78′W; water depth, 3024 m) were recovered by the R/V *JOIDES Resolution* with the Advanced Piston Corer, October 2004 (Fig. 1). The spliced core length of the four drilled (A–D) holes was 263.8 m composite depth (mcd). A 13-cm-thick brownish oxidized facies found at the core top in Hole B (=the sediment/water interface) suggests full coverage of the uppermost sediments. The dominant lithofacies was an alternation of biogenic constituents: calcareous nannofossil ooze and the LDO, both in highly variable grayish colors. In general, LDO occurred (1) between the core bottom and 200 mcd and in the (2) 165–140 mcd, (3) 120–85 mcd, and (4) 65–45 mcd horizons (Fig. 2).

Burrows were often observed except in the LDO horizons. In total, the entire interval (recognized as Unit I) was exclusively of biogenic origin and difficult to subdivide. Boundaries between LDO and other lithofacies were very sharp, in contrast to those between other lithofacies, which were generally gradational. Although a tiny slump structure was observed within U1304B-19H-3, 107–138 cm, foreign components such as dropstones were very rare throughout the whole interval, suggesting that the whole of Unit I can be considered in situ pelagic sediments (Fig. 2; Expedition 303 Scientists, 2006).

3.2. Diatom species analysis

Dried and weighed materials from each selected horizon were processed with HCl and H_2O_2 to remove calcareous and organic materials, respectively. The suspensions produced were

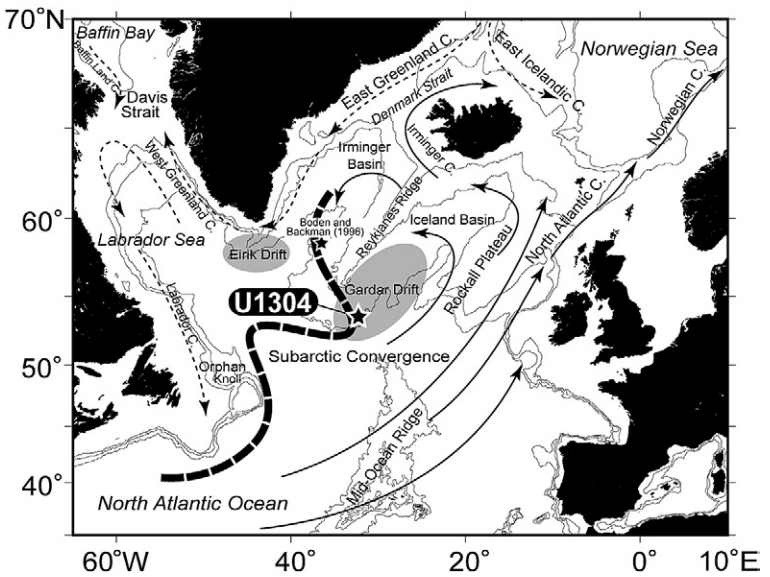

Fig. 1. Index map of IODP Site U1304 and the surface current system. Locality of core EW3903-17 studied by Bodén and Backman (1996) is also indicated. Illustrated mostly after Ruddiman and Glover (1975).