COCCOLITHS IN SEDIMENTS OF THE EASTERN ARCTIC BASIN

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ABSTRACT. Surface sediment samples and five sediment cores recovered during the *Polarstern* ARK IV/3 cruise have been investigated in detail for species composition and nannofossil abundance using light and scanning electron microscopes. Coccoliths were observed in all surface sediments and cores north of the continental margin of the Barents Sea, indicating oxygen isotope stages 1 to at least 5. During the last interglacial, North Atlantic Current water and pack-ice distribution, comparable to ice conditions during stage 3 in the Fram Strait, enabled coccolithophorids to live up to at least 86°08'N. In the southern region of the Eastern Arctic Basin sedimentation rates are in the order of several centimeters per 1000 yr but decrease to a few millimeters per 1000 yr in sediments near the Nansen-Gakkel Ridge.

Introduction

The present northern extent of coccolithophorids in the Arctic Ocean as well as the extent of the ice-cover and the influence of Atlantic water during the last glacial and interglacial times are still unknown. Coccolithophorids are carried with the warm North Atlantic Current into the Norwegian Sea and the Arctic Ocean (Braarud *et al.*, 1958; Rey, 1981). The crop size and the number of species which make up the coccolithophorid floras are dependent on sea surface temperatures and diminish considerably at higher latitudes (McIntyre & Bé, 1967). In Arctic and polar regimes of the North Atlantic the occurrence of coccoliths in sediments reflects the influx of the North Atlantic Current water (Gard, 1988). In cold stages either this influx was smaller or the region was covered with ice-sheets thus prohibiting the northward transport and sedimentation of phytoplankton blooms.

The abundance variations, the presence or absence of marker species and characteristic abundance relationships between different species of coccoliths in combination with oxygen isotope records and magnetostratigraphy have been used by Gard (1988) to establish a biochronology in sub-Arctic to Arctic sediments. In cores of the *Ymer*-Expedition (Boström & Thiede, 1984) from the northern continental slope of Spitsbergen and the Barents Sea, coccoliths were exclusively observed in surface sediments (Gard, 1988).

During the *Polarstern* ARK IV/3 cruise (Thiede *et al.*, 1988), sediments were recovered up to 86°08'N. Coccoliths were not only observed in surface samples but also in deeper parts of most cores.

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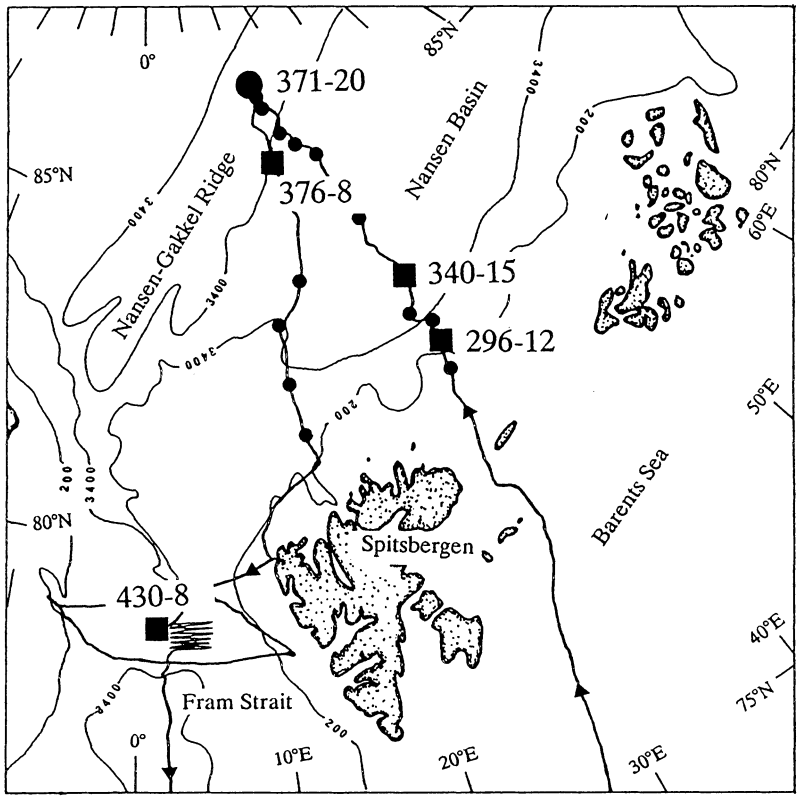

Figure 1 ARK IV/3 cruise track chart and locations of investigated surface samples (small dots), box cores (squares) and gravity core (large dot).

Table 1 Locations and water depths of investigated cores.

Station No.	Core No.	Latitude N	Longitude E	Water Depth (m)
296	1519-12	81°47.4'	31°30.1'	2998
340	1521-15	82°56.5'	32°05.2'	3752
371	1527-20	86°08.5'	22°03,3'	3780
376	1529-8	85°23.1'	21°44.1'	2917
430	1535-8	78°44.8'	01°52.8'	2557

MATERIALS AND METHODS

Of the ARK IV/3 cruise materials, surface sediment samples, four long box cores, and one gravity core (Fig. 1, Table 1) have been investigated in detail for species composition and nannofossil abundance using light and scanning electron microscopes. All cores were sampled at 5 cm intervals, except for Core 1519-12 which was sampled only at 10 cm intervals because of its high sedimentation rates. Smearslides were analyzed, following a method described by Backman & Shackleton (1983), with a light microscope at a magnification of x1600. For 50 fields of view the number of the specimen of the following taxonomic groups were recorded: *Calcidiscus leptoporus* (Murray & Blackman) Loeblich & Tappan, *Coccolithus pelagicus* (Wallich) Schiller, *Helicosphaera carteri* (Wallich) Kamptner, and placoliths smaller than 5 μm, mainly consisting of *Emiliania huxleyi* (Lohmann) Hay & Mohler, and *Gephyrocapsa* species (*G. margereli* Bréhéret, *G. muellerae* Bréhéret, *G. aperta* Kamptner). *Syracosphaera spp.* reworked Tertiary and Cretaceous species were also observed. Abundances are expressed as the number of specimen per mm^2 of the smearslide. Sediment samples containing extremely low numbers of coccoliths may not always show the complete range and exact number of species actually present in the sediment. It should be stressed however, that the pattern of frequencies in combination with species composition of only three taxonomic groups of the whole sedimentary record is important for nannofossil stratigraphy at high latitudes.

In this paper abundances and species composition of coccoliths in four long box cores, Cores 1519-12, 350-15, 1529-8 from the Nansen Basin, and a gravity core, Core 1527-20 from the Nansen-Gakkel Ridge, are compared with those of a well dated box core, Core 1535-8 from the Fram Strait (Fig. 2a). The oxygen isotope stratigraphy of planktic foraminifers was provided by Köhler & Spielhagen (this volume). High resolution magnetostratigraphy using Earth's magnetic field excursions within the Brunhes Chron and magnetic susceptibility records were provided by N. R. Nowaczyk, Bremen. Because of the generally low frequencies of planktic foraminifers in the sedimentary records, an oxygen isotope stratigraphy on planktic foraminifers was not possible in other cores of ARK IV/3. Due to changing sedimentation rates and lithologies, magnetostratigraphy and magnetic susceptibility logs are difficult to interpret and to correlate in some intervals of the cores.

Stratigraphy of ARK IV/3 Cores

Surface sediments have been investigated at all stations of the ARK IV/3 cruise (Fig. 1). On the Barents Sea shelf and continental slope (Stations 269 to 287) only scarce numbers of coccoliths were detected in surface sediment samples. Further north, all sediment samples showed relatively high numbers of coccoliths dominated by *C. pelagicus* and *E. huxleyi*. Surface water samples and water samples taken underneath the ice during the ARK IV/3 cruise contained coccolithophorids (Honjo, pers. comm.). This shows that coccolithophorids penetrate into the Arctic regime although there is a permanent pack-ice coverage.

All sediment cores are dominated by three taxonomic groups: *C. pelagicus, E. huxleyi* and *Gephyrocapsa* species. They are all subpolar to polar species (Honjo & Okada, 1974). *C. pelagicus* occurs irregularly since the Tertiary. In Holocene times it is very abundant at

high latitudes. *Gephyrocapsa* evolved in the late Tertiary. In the Atlantic, *G. muellerae* evolved from *G. magereli* at around 200 ka. It is an eurythermal species, preferring cold waters. In oxygen isotope stage 5 it is very abundant (Samtleben, 1980). *E. huxleyi* first appeared at 278 ka (Thierstein *et al.*, 1977).

C. leptoporus regulary occurs as from Tertiary and it is the only warm water species observed in interglacial sediments of the Fram Strait and Nansen Basin, but not found in Nansen-Gakkel Ridge sediments.

The biostratigraphic results of the short box cores have been used to mark the 1/2 oxygen isotope boundary when the tops of long box cores have not been sampled. Holocene age (less than 10 ka) is indicated by a considerable increase in the abundance of *C. pelagicus* (Gard, 1988). The top centimetres of all the cores are dominated by an increase in the abundance of *C. pelagicus* and *E. huxleyi*, thus indicating the last warming event. Further downcore the sediment is either barren of coccoliths or only small amounts of coccoliths, dominated by *E. huxleyi*, are present. In Norwegian Sea and Arctic sediments the *Emiliania huxleyi* Acme Zone starts at the boundary of oxygen isotope stages 5/4 (71 ka), (Gard, 1988). In the Nansen Basin (Cores 1519, 1521) the coccolith abundance is relatively low compared to Fram Strait sediments (Core 1535). Stage 4 and stage 2 seem to be barren of coccoliths. Therefore, the dominance of *Emiliania huxleyi* probably marks stage 3 only (59 to 24 ka). Still further downcore high abundances of small placoliths dominated by *Gephyrocapsa* species, mainly *G. muellerae*, were observed, indicating oxygen isotope stage 5 (Gard, 1988). Small, very distinct layers with higher numbers of coccoliths, dominated by *Gephyrocapsa* species, separate barren intervals further downcore. *E. huxleyi*, which evolved towards the end of oxygen isotope stage 8 (Thierstein *et al.*, 1977), was observed in all peaks throughout the cores investigated. Thus, within the coccolith bearing intervals of the cores, the age of the sediments must be less than 278 ka.

In comparison with Fram Strait (Core 1535) the thickness of intervals of coccolith abundance in Nansen Basin sediments (Cores 1519, 1521) is reduced whereas intervals barren of coccoliths are extended. The numbers of coccoliths are one order of magnitude lower in the Eastern Arctic Basin cores (Figs. 2a, b, c).

A high resolution magnetostratigraphy using excursions in the Brunhes Chron and magnetic susceptibility logs of the cores generally show a consistent correlation to the nannofossil abundance pattern (Nowaczyk & Baumann, in prep.).

Fram Strait. At Station 430, investigation of a short box core shows a sharp increase in abundance of *Coccolithus pelagicus* between 5 cm and 10 cm, indicating Holocene age. In the lower parts of Core 1535-8 taken at this station, high numbers of coccoliths correlate with low $\delta^{18}O$ values. In particular, high numbers of *Gephyrocapsa* af. *muellerae* in 210 cm to 240 cm and in 295 cm and 320 cm depth correlate with low $\delta^{18}O$ values in the same two depth intervals, thus indicating oxygen isotope stages 5a and 5e. Correlation of the nannofossil and the oxygen isotope stratigraphy in the upper parts of the core is less clear (see Fig. 2a). Köhler & Spielhagen (this volume) identify oxygen isotope stage boundaries 4/3, 3/2, 2/1 at 200 cm, 88 cm and 30 cm core depth, respectively. In the nannofossil record two barren intervals are observed between 185 and 175 cm and between 35 and 10 cm depth. This possibly indicates an extension of stage 4 up to 175 cm depth. The sharp rise in abundance of *C. pelagicus* in the upper 10 centimeters of the short box core at this station marks the stage 2/1 boundary. In the oxygen isotope record no values are available between 6 and 29 cm. Therefore, the stage 2/1 boundary placed at 30 cm by Köhler &

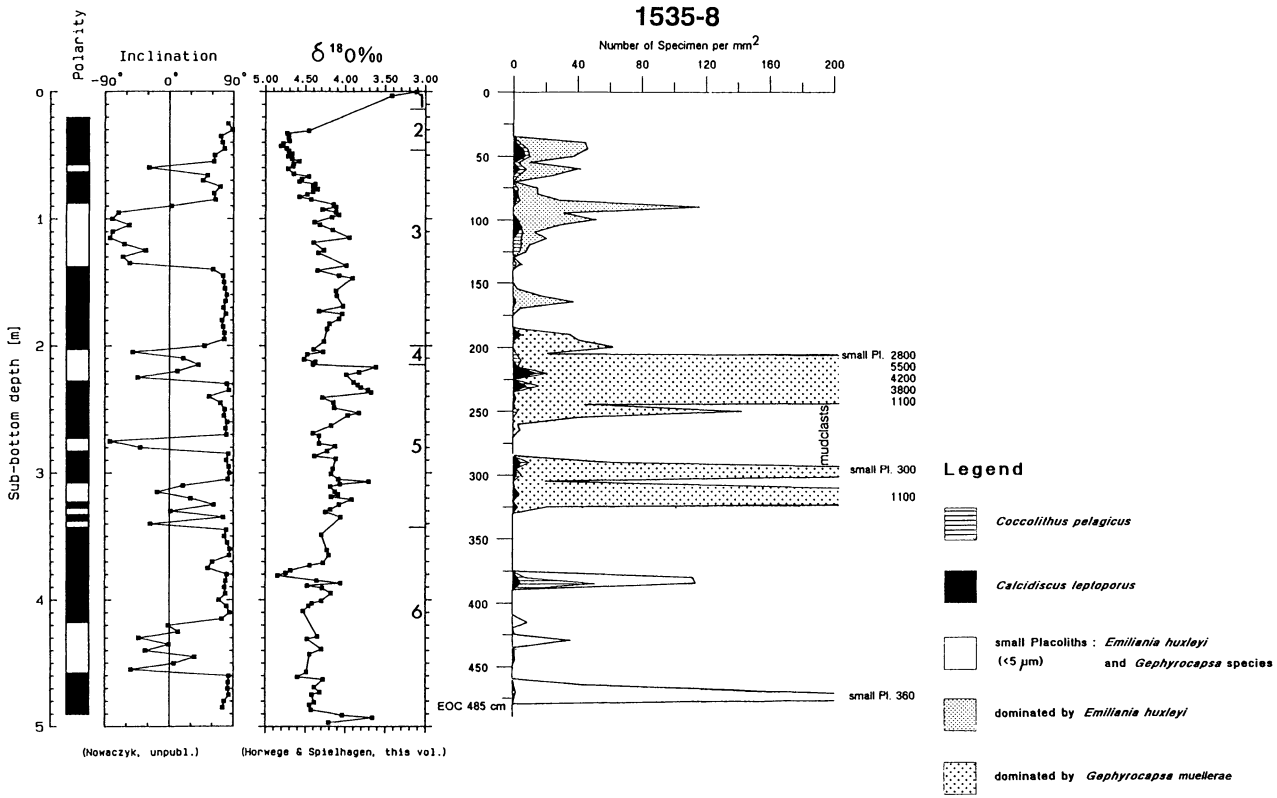

Figure 2a Nannofossil abundances, oxygen isotope record (Köhler & Spielhagen, this volume), and magnetostratigraphy (Nowaczyk & Baumann, in prep.) in Core 1535-8 from the Fram Strait. The abundances of coccoliths are plotted non-cumulatively. Dotted intervals indicate the range of oxygen isotope stage 5, dominated by *Gephyrocapsa muellerae*, shaded intervals the range of oxygen isotope stage 3, dominated by *Emiliania huxleyi*.

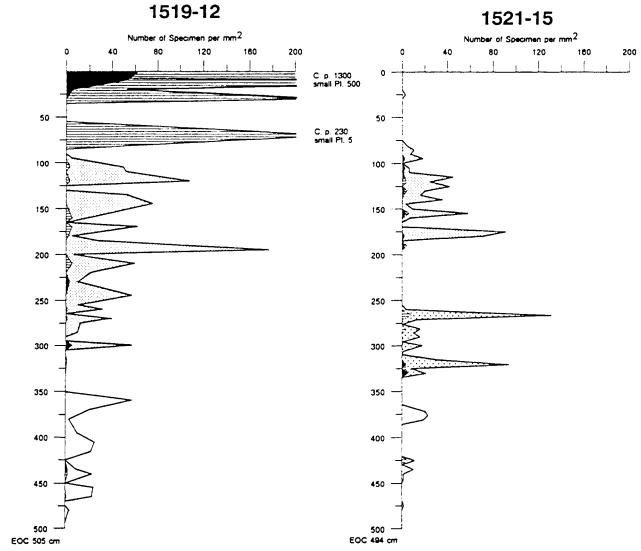

Figure 2b Nannofossil abundances in Core 1519-12 from near the foot of the continental slope north of Svalbard and of Core 1521-15 from the southern Nansen Basin. See Figure 2a for further explanations.

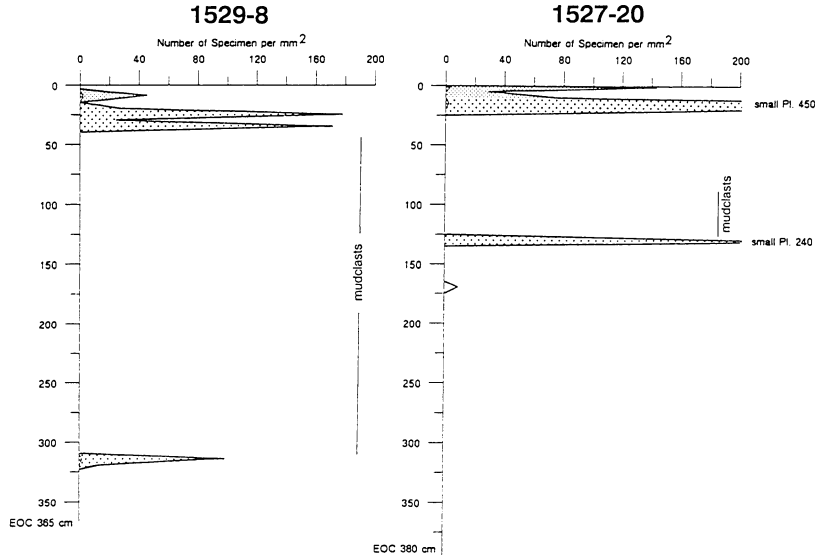

Figure 2c Nannofossil abundances in Core 1529-8 from the northern Nansen Basin and Core 1527-20 from the Nansen-Gakkel Ridge. See Figure 2a for further explanations.

Spielhagen (this volume) should be raised to approximately 10 cm. Based on the last occurrence of coccoliths, the onset of stage 2 could be located at about 35 cm depth in this core.

The occurrence of coal fragments between 340 and 440 cm depth may correlate to a coal bearing layer in Core 23235 (78°52'N, 01°20'E) which was dated to occur in oxygen isotope stage 6 (Eisenhauer *et al.*, this volume). The abundance pattern of coccoliths in Core 23235 (Gard, 1988) is very similar to the one observed here.

Nansen Basin. The short box core at Station 296 revealed an increase in the abundance of *C. pelagicus* between 22 cm and 9 cm, indicating Holocene age. In the long box core (Core 1519-12) *E. huxleyi* is found to dominate almost all horizons containing nannofossils between 80 and 305 cm, representing oxygen isotope stage 3. The interval between 310 and 350 cm is almost barren of coccoliths. Small numbers of nannofossils, dominated by *Gephyrocapsa* species below 400 cm core depth, most likely indicate the uppermost part of the previous warm stage 5.

In the short box core at Station 340 a sharp increase in the number of *C. pelagicus* was observed between 3 and 5 cm, indicating the last warming event. The long box core (Core 1521-15) shows abundance peaks of coccoliths, dominated by *Emiliania huxleyi* between 100 to 200 cm, followed by a barren interval and again high numbers of small placoliths, dominated by *G. muellerae*, representing oxygen isotope stages 3, 4 and 5, respectively.

In the short box core at Station 376 only the top 2 centimeters contain high numbers of *C. pelagicus*, indicating Holocene age. In the long box core (Core 1529-8), the coccolith flora of the top 20 cm is dominated by *E. huxleyi*, indicating oxygen isotope stage 3. At 25 to 35 cm core depth the flora is dominated by *G. muellerae*. Another small peak, showing the same species composition, is found at 314 cm depth. Between these peaks, from 35 to 314 cm depth, the sediment mainly consists of consolidated mudclasts within a soft muddy matrix. Mudclasts have also been found in the core materials of other nearby stations and on the Nansen-Gakkel Ridge (Thiede *et al.*, 1988). Except for some traces, the sediment matrix is barren of coccoliths. As a possible explanation, the mudballs mark a strong melting event or a mass movement of sediment at the sea floor in this region which occurred during oxygen isotope stage 5.

Nansen-Gakkel Ridge. The uppermost centimeters of sediment have not been recovered in the gravity core (Core 1527-20) at Station 371. The top 10 cm of the core are dominated by *E. huxleyi*, indicating isotope stage 3. From 15 to 20 cm depth *Gephyrocapsa* species prevail. Between 25 and 125 cm the sediment is barren of coccoliths. Another peak of coccoliths, dominated by *Gephyrocapsa* species, is observed at 130 cm. As a mudclast layer (80 to 123 cm) again separates the two nannofossil peaks dominated by *Gephyrocapsa* species, and because of the presence of *E. huxleyi*, they should both represent oxygen isotope stage 5.

Sedimentation Rates

The average sedimentation rate in Core 1535-8 from the Fram Strait amounts to about 2 to 3 cm/10^3 yr. During glacials, sedimentation rates were less than 2 cm/10^3 yr whereas in interglacials sedimentation rates increased to about 3 to 4 cm/10^3 yr.

Core 1519-12, recovered near the foot of the continental slope north of Svalbard, shows

an average high sedimentation rate of 4 to 5 cm/10^3 yr that may be explained by influx of allochtonous material from the Barents Sea Shelf. Core 1521-15 from the southern part of the Nansen Basin has an overall sedimentation rate of 2 to 3 cm/10^3 yr.

In contrast, Core 1529-8 at the foot of the Nansen-Gakkel Ridge shows low sedimentation rates in the uppermost 40 cm. For oxygen isotope stages 2 to 5 the rate is about 0.2 cm/10^3 yr, stage 1 may have slightly higher rates of 0.6 cm/10^3 yr. Assuming that in Core 1527-20 from the Nansen-Gakkel Ridge the upper 20 cm were not recovered, sedimentation rates from oxygen isotope stage 3 to 5 are about 0.5 cm/10^3 yr.

Sedimentation rates of several centimeters per 1000 yr calculated for the Cores 1535-8, 1519-12 and 1521-15 correlate well with findings in cores located north of Spitsbergen and on the northeast Greenland Shelf (Markussen *et al.*, 1985; Gard, 1989). Investigations of cores from northerly positions in the western Arctic Basin yield sedimentation rates in the order of some millimeters per 1000 yr in the upper Pleistocene (Worsley & Herman, 1980), results which compare very well with those found here in Cores 1527-20 and 1529-8 from the Nansen-Gakkel Ridge area.

Conclusions

Coccoliths were observed in all sediment cores taken during the ARK IV/3 cruise in the Nansen Basin and adjacent areas up to 86°08'N.

The sediments in the Nansen Basin and on the Nansen-Gakkel Ridge contain coccoliths of Holocene to Eemian age, substage 5e. Therefore, the North Atlantic Drift must have reached far north into the Eastern Arctic Basin during at least some periods of the late Quaternary interglacials.

In Core 1535-8 from the Fram Strait coccoliths are observed almost throughout the entire sediment column studied. Northward, they are more and more restricted to warm periods. Into the Arctic Ocean, the thickness of the intervals representing interglacials and the frequency of coccoliths in the sediments gradually decrease, ever increasing sections of the sediment column are found barren of coccoliths. This pattern of coccolith abundance in the Eastern Arctic Basin shows that also in the past the influence of North Atlantic Current water diminished and the Arctic ice-cover was more stable and complete towards the North.

In Nansen Basin sediments the frequencies of coccoliths during oxygen isotope stage 5 are comparable to those during oxygen isotope stage 3 in Fram Strait sediments indicating that the ice conditions during the last interglacial in the Nansen Basin may have been similar to the ice conditions in the Fram Strait during oxygen isotope stage 3. This would imply that there was only a relatively loose pack-ice coverage in the Eastern Arctic Basin during the last interglacial.

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