15. CALCAREOUS NANNOFOSSILS

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INTRODUCTION

Coccoliths, the 2–20 microns large calcareous plates covering the cells of marine coccolithophorid algae, are common constituents of open ocean sediments. The coccolithophorids are living in the euphotic zone of the oceans and are not thriving in brakish or fresh water environments.

Fossil coccoliths provide an important tool for biostratigraphical and palaeoecological work. Within the Quaternary period, five calcareous nannofossil zones are recognized (Gartner 1977), but none of these define the Pleistocene/Holocene boundary. In palaeooceanographic work coccoliths have provided useful information on the deglaciation history of the North Atlantic (McIntyre 1967), and at present the postglacial history of the Skagerrak is being investigated by multidisciplinary studies including coccoliths of corematerial from that area (Thiede *et al.*, in prep.).

Coccoliths generally leave a minor imprint in near-shore sediments compared to open ocean deposits due to dilution by clastic material. The sediments deposited during the Pleistocene-Holocene period along the Swedish West Coast represent such a depositional environment with a pronounced influence of terrestrial material. This material includes rock fragments and a number of microfossil groups reworked from sediments of various ages. As a result, Quaternary coccoliths have a very sparce occurrence in the cores studied and the coccolith assemblages are dominated by reworked species. In the present paper the occurrence of Quaternary and reworked coccoliths in the south-western Swedish cores is outlined and the palaeoecological significance of their distribution discussed.

MATERIAL AND METHODS

The occurrence of calcareous nannofossils has been investigated in samples from three cores, the Brastad core (37 samples), the Moltemyr core (46

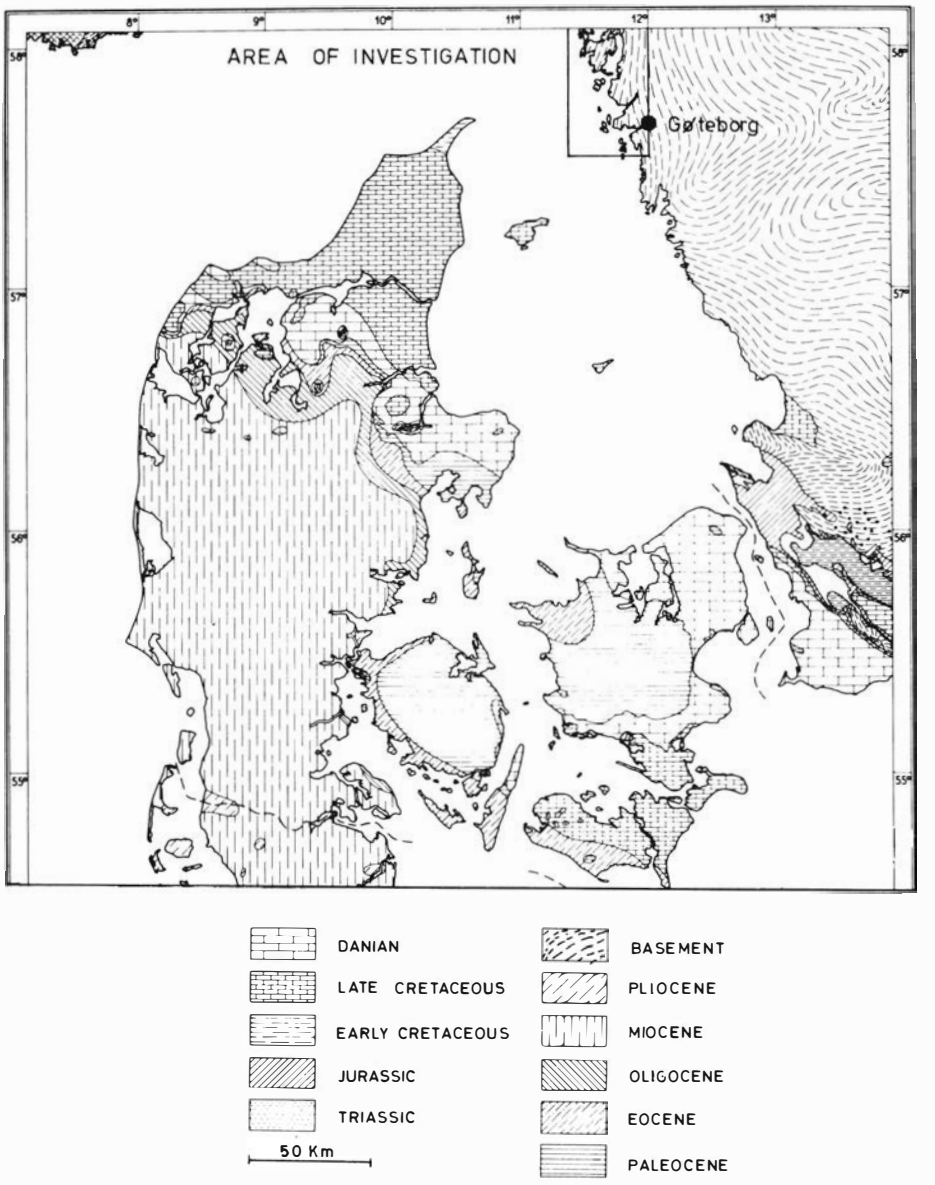


Fig. 15:1. Subsurface map of Denmark and Southern Sweden (after T. Sorgenfrei). Reworked material of Late Cretaceous and Early Tertiary ages occurs frequently in the cores selected for the study of the Pleistocene/Holocene boundary north of Gothenburg. In this area, only Quaternary sediments are overlying the basement. Accordingly the reworked material represents long distance transport by currents and/or ice.

samples) and the Solberga core (66 samples) in south-western Sweden (see Chapter 4).

A smearslide was prepared from each sample by smearing a small piece of the sample and a drop of distilled water on a glass-slide with a flat toothpick. The coarse fraction (larger than about 20 microns) was kept on one side of the slide, while the finer particles containing the calcareous nannofossils (approximately 2 to 15 microns) were allowed to flow over the middle part of the slide. The dried slide was covered with artificial canadabalsam and a cover-glass and left to cook on a hot-plate for about half a minute to harden the canadabalsam. The slides were studied by K. Perch-Nielsen with a Zeiss microscope fitted with 12.5x oculars and a 100x pol-objective, and parallel and crossed nicols were used for species determination.

RESULTS

Calcareous nannofossils are usually rare or absent in the three cores selected for the study of the Pleistocene/Holocene boundary. The coccoliths constitute less than 1% of the fine fraction of the sediments, and the coccolith assemblages are dominated by reworked species. These reworked forms are especially representing Early Tertiary and Late Cretaceous (Maastrichtian and Campanien) assemblages. The Quaternary contribution to the coccolith assemblages is less than 10% and it is characterized by a few species, *Emiliania huxleyi, Coccolithus pelagicus* and *Coccolithus leptoporus,* all of which are fairly solution resistant (Berger 1973).

In the Brastad and Solberga cores, Quaternary as well as reworked forms are present. In the Moltemyr core no Quaternary coccoliths were noted and only reworked species of Late Cretaceous, Danian and Eocene ages were observed.

Outcrops with sediments of Late Cretaceous and Tertiary ages are not present on land near by the Gothenburg area and possible sub-sea outcrops are almost uninvestigated. Coccoliths of ages comparable to the reworked forms are, however, described from Maastrichtian and Danian onshore localities in Denmark (Perch-Nielsen 1968, 1969, 1979) and Sweden (Forcheimer 1972, Åberg 1966) and from Danish Eocene-Oligocene localities (Perch-Nielsen 1971, Mikkelsen 1975, Thiede *et al.* 1980). These localities are located several hundred kilometers from the studied core localities (Fig. 15:1) and thus point to long distance transport of the reworked material, if we assume the reworked coccoliths to originate from there.

BRASTAD CORE

In the core from Brastad, coccoliths were found in varying, low quantities – very rare to rare – in the samples from 240 cm downwards (Fig. 15:2). The assemblages are dominated by reworked Maastrichtian and Eocene coccoliths. Together with the occasional autochtonous *Emiliania huxleyi, Gephyrocapsa* sp. and *Coccolithus pelagicus,* coccoliths always constitute far less than 1% of the sediment.

The reworked Cretaceous forms include usually *Watznaueria barnesae, Micula decussata, Prediscosphaera cretacea, Arkhangelskiella cymbiformis,* and occasionally *Nephrolithus frequens,* a marker for the Late Maastrichtian, and *Reinhardtites anthophorus, R. levis* and *Eiffellithus eximius,* markers for the Late Campanian and Early Maastrichtian, when occurring together with *A. cymbiformis.* The reworked Tertiary forms include mainly Prinsiaceae of different sizes and *Ericsonia ovalis* with an occasional *Reticulofenestra umbilica, Zygrhablithus bijugatus, Discoaster binodosus, Chiasmolithus solitus, Transversopontis* sp., and *Ericsonia formosa.* None of these forms allow a precise age assignment, but an Eocene and/or Early Oligocene age is likely.

The coccolith assemblages and their abundance (Fig. 15:2) provide no conclusive evidence for the palaeoenvironment during the Pleistocene/Holocene transition. The data, however, support the signals provided by the foraminifers (Chapter 14), the ostracods (Chapter 13), and the sedimentology (Chapter 6). The lowermost 5 meters of the Brastad core thus have a low content of coccoliths compared to the overlying section from approximately 10 to 6 m below surface. According to the ostracods this lower part of the core represents a shallow-water environment which upwards grades into open-sea conditions. This situation is reflected in the abundance of coccoliths, where the masking of the coccoliths by input of clastic material is reduced from the lower to the middle part of the core.

At a depth of approximately 2.4 m the sedimentological studies indicate a sedimentation brake (Chapter 6), and the Holocene interval is apparently missing in the core.

MOLTEMYR CORE

Coccoliths have a scattered and rare occurrence throughout the Moltemyr core (Fig. 15:2), and they are absent in the upper part of the core down to 270 cm. Below this level, very rare and moderately well to poorly preserved, reworked Late Cretaceous and/or Eocene coccoliths occur in samples 280, 320, 350, 410, 420, and 460 cm, while the samples inbetween (a sample for

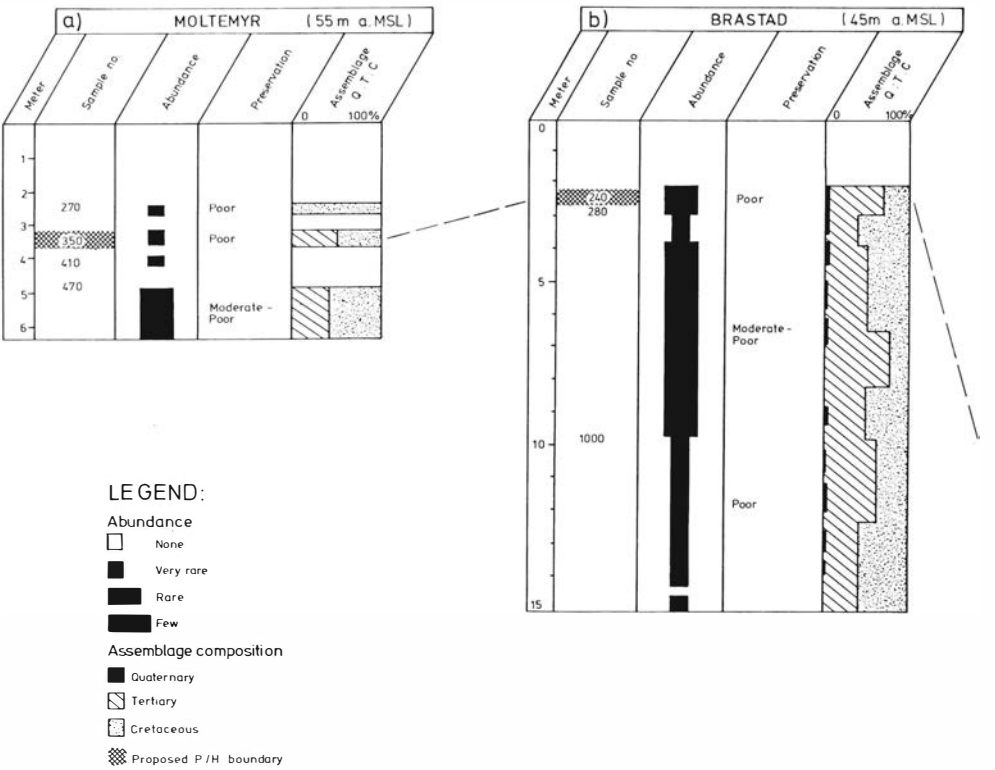
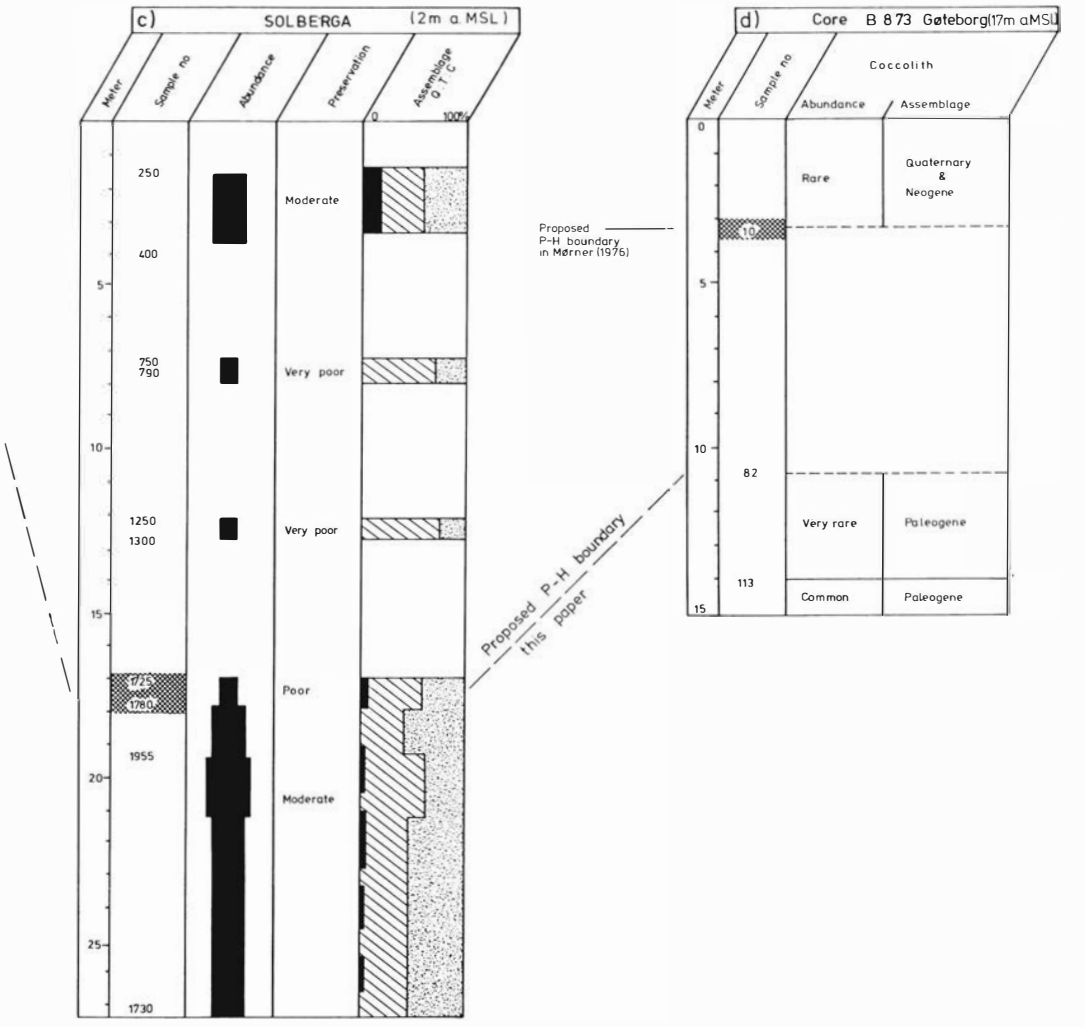


Fig. 15:2. Distribution of nannofossils in the Moltemyr core (a) the Brastad core (b), the Solberga core (c) and the Botanical Garden core B873 (d). A tentative correlation is made between the proposed Pleistocene/Holocene boundaries in the cores.

every 10 cm was studied) are barren of coccoliths. While coccoliths are still very rare in sample 460 cm, they are rare in the following three samples and coccoliths are very rare to rare in the remainder of the core, down to 650 cm. Throughout the core, only reworked coccoliths were found. Among the Late Cretaceous assemblage, the same forms were observed as in the Brastad core, including the markers for the Late Maastrichtian *(Nephrolithus frequens)* and the Maastrichtian/Campanian interval *(Reinhardtites anthophorus)*. Danian forms include *Chiasmolithus danicus, Cyclagelosphaera reinhardtii, Markalius inversus, Placozygus sigmoides,* and *Biscutum* sp. The probably Eocene forms include mainly *Ericsonia ovalis* and small Prinsiaceae, but also *Neococcolithes dubius, Cyclicargolithus floridanus, Reticulofenestra umbilica, Transversopontis* sp., *Chiasmolithus expansus, Ericsonia formosa* and, in sample 560 cm, a specimen of *Isthmolithus recurvus,* a form which is limited to the Eocene/Oligocene boundary interval in high latitudes.



Reworked coccoliths were deposited and preserved at the Moltemyr locality during most of the presumed Late Quaternary interval, but with a more consistant occurrence in the lower than in the upper part of the core. The apparent lack of Quaternary species in samples containing reworked coccoliths indicates that their absence is not a result of dissolution.

The occurrence of coccoliths in the Moltemyr core parallels other micropalaeontological observations. According to both ostracods and foraminifers (Chapters 13 and 14) the lower part of the core is deposited in an open marine environment which shows a shallowing upwards. This

shallowing influences on the coccolith abundance by diluting the coccolith assemblages with clastic material. The diatom assemblages as well as the ostracods show the influence of freshwater from a core depth of approximately 3.5 m upwards. According to the diatoms (Chapter 16) the Moltemyr area was isolated from the sea at a time corresponding to deposition of the sediments at a core depth of approximately 3 meters. This isolation may account for the lack of Quaternary coccoliths in this part of the core.

SOLBERGA CORE

The Solberga core represents the most complete section of coccolith-events recorded in the cores studied (Fig. 15:2). Reworked and Quaternary coccoliths are consistently present and moderately well preserved in two parts of the Solberga core – between 250 and 400 cm and between 1 800 cm and the bottom of the core at 2 730 cm. The assemblage of reworked coccoliths furnishes the same forms as in the Brastad core, but includes also the Danian forms *Cruciplacolithus tenuis, Chiasmolithus danicus* and *Neochiastozygus* sp. as well as the Eocene form *Neococcolithes dubius* besides the more common Campanian/Maastrichtian and other Eocene coccoliths. The probably Quaternary assemblage includes *Emiliania huxleyi, Gephyrocapsa* sp., *Coccolithus pelagicus* and some well preserved *Braarudosphaera bigelowii.*

The configuration of coccolith abundance and species composition in the lowermost 10 meters of the Solberga core are comparable to the distribution pattern of coccoliths covered by the entire Brastad core. In the Solberga core this lower section is followed by an almost barren interval between 17 and 4 meters below the top of the core. Poorly preserved coccolith assemblages may occur sporadically in this interval where they are characterized by the total absence of Quaternary species. The coccoliths reappear at a depth interval between 3.6 and 2.5 m below the top of the core. These assemblages still furnish a lot of reworked coccoliths but also provide some Quaternary forms.

The configuration of coccoliths in the Solberga core again mirrors the foraminifer and ostracod distribution (Chapters 13 and 14). The mentioned fossil groups indicate normal marine conditions during deposition of the lower part of the Solberga core. At the depth interval between approximately 17 and 4.5 m foraminifers and ostracods point to extreme conditions which may represent a period of high sedimentation rates which diluted the coccoliths. Above this interval Quaternary coccoliths reappear in detectable abundances parallel with a normalized sedimentation rate.

THE BOTANICAL GARDEN B873-CORE

Backman (in Mörner 1976) described the occurrence of coccoliths in the Botanical Garden core, B873, selected for a study of a possible stratotype for the Pleistocene/Holocene boundary. The information given by Backman is summarized in Figure 15:2. Reworked Paleogene coccoliths are stated to be common in the lower part of this core. The coccolith abundance diminishes upwards into a barren zone. In the uppermost 2 meters of the core both Quaternary and reworked coccoliths reappear in a considerable quantity according to the published information. This distribution pattern conforms with the preceding three cores. However, there is a striking discrepancy relative to the almost identical micropalaeontological events recorded in the four cores between the proposed location of the Pleistocene/ Holocene boundary in the Botanical Garden core and the three cores mentioned. In the Botanical Garden core the boundary seems to have been placed at an interval corresponding to a period considerably younger than the Pleistocene/Holocene transition as suggested here.

SUMMARY AND CONCLUSION

The four cores discussed above all penetrate Upper Quaternary sediments which furnish Quaternary and older, reworked coccoliths. According to their coccolith content the cores share some common features which facilitate a correlation of the penetrated sections. The abundance of coccoliths shows a consistant occurrence below the Pleistocene/Holocene boundary. Just above this boundary coccoliths become very rare or entirely absent but they reappear in the uppermost part of the section.

The coccolith assemblages by themselves provide only minor information on the changing conditions in the area during the Late Quaternary. The Quaternary assemblages are thus highly diluted by clastic material including a high percentage of reworked coccoliths transported to the area from distant land- or submarine outcorps. However, the abundance and sequences of appearance and disappearance of Quaternary coccoliths in the cores tied to the distribution of the reworked coccoliths provide some information on the changing depositional environment. The lower part of the Quaternary sequence with a fairly high abundance of coccoliths including Quaternary forms may correspond to the period of existence of the Baltic Ice Lake, when open marine conditions prevailed in the area. During the regression period following the Pleistocene/Holocene transition, the marine conditions deteriorated and the Quaternary coccoliths disappeared. Reworked coccoliths were, however, still deposited occasionally

due to current and ice transport. The almost coccolith barren sediments were presumably deposited at the time of the pronounced meltwater discharge. This resulted in a very rapid sedimentation of the clastic material which totally masked the coccolith occurrences. On a global scale this and similar drainages could be reflected in the "meltwater spike" observed in the open ocean sediments (Berger *et al.* 1977). During the Postglacial Transgression normal marine conditions were reestablished and the production of Quaternary coccoliths could once again leave an imprint in the upper part of the Quaternary sequences of south-western Sweden.

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