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Pollen Analysis of the Quaternary Marine Deposits at Tornskov in South Jutland

by
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With 1 Plate

Dansk sammendrag:

Pollenanalyse af de kvartære marine lag
ved Tornskov i Sønderjylland

I kommission hos
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Contents

Abstract

At Tornskov 4 km north of Løgumkloster, south Jutland, a Quaternary marine deposit was found at 27–95 m below the surface. The marine deposit is covered by glacial deposits, which contain a dislocated fragment of the marine deposit. Tertiary deposits occur below 107 m. The deposits were investigated with pollen analysis. Re-deposited pollen is very frequent below 77 m. The layers at 27–77 m correspond to a major part of an interglacial succession beginning with *Betula-Pinus* dominance, and continuing with *Alnus-Pinus* dominance. *Picea, Quercus, Ulmus, Carpinus, Abies, Corylus, Taxus* and other trees and shrubs are represented with rather low frequencies. The interglacial marine deposit at Tornskov is contemporaneous with the interglacial marine deposit at Inder Bjergum near Ribe, and with deposits of the interglacial Holstein Sea in north Germany and the northern Netherlands, in which there is a similar vegetational development. Pollen diagrams typical of the Holsteinian Interglacial are also known from fresh-water deposits in north Germany, the Netherlands and Poland. The interglacial fresh-water deposits at Harreskov, Starup and Ølgod in western Jutland belong to another, presumably older interglacial stage.

Introduction

In 1958 the Geological Survey of Denmark carried out a boring at Tornskov 4 km north of Løgumkloster in south Jutland (DGU file nr. 159.243, altitude ab. 22 m, see the map fig. 1), in which a Quaternary marine deposit extending to a considerable depth was encountered. The boring was supervised by LEIF BANKE RASMUSSEN. The marine layers contain considerable quantities of foraminifera, which are being investigated in detail by ARNE BUCH (cf. BUCH 1963).

The description of the sediments given by BANKE RASMUSSEN is summarized briefly below. The information about the origin of the sediments is based on preliminary results of the examination of the foraminifera by BUCH.

Fig. 1. Section of the map sheet No. 4006 (1:20000) showing the location of the boring near Tornskov. Authorized by the Geodetic Institute of Denmark.
Udsnit af målebordsblad Nr. 4006 (1:20000) visende beliggenheden af boringen ved Tornskov.

A	0.0– 0.6 m	Agricultural soil.
B	0.6– 2.2 m	Fine sand and sandy clay.
C	2.2– 13.7 m	Sand and gravel.
D	13.7– 22.4 m	Fine-sandy clay (marine).
E	22.4– 24.7 m	Stony clay (boulder clay).
F	24.7– 27.4 m	Sand and gravel.
G 1	27.4– 30.7 m	Argillaceous fine sand (marine).
2	30.7– 72.5 m	Fine-sandy clay (marine).
3	72.5– 79.3 m	Clay (marine).
4	79.3– 90.8 m	Sand (marine).
5	90.8– 92.6 m	Clay (marine).
6	92.6– 93.1 m	Sand (marine).
7	93.1– 93.3 m	Clay (marine).
8	93.3– 93.5 m	Sand (marine).
9	93.5– 94.7 m	Clay (marine).
H	94.7–107.2 m	Sand, in the upper part two thin clay layers (presumably melt water deposit).
I	107.2–107.6 m	Clay (Tertiary).

The boring was carried out at the edge of a "hill island" consisting of glacial deposits of the Saalian Glacial (s.l., cf. the map in MILTHERS 1948). According to the description above, a marine environment is indicated in the sediments at 13.7–22.4 m (D) and at 27.4–94.7 m (G). The pollen analyses reported below show that the upper marine sediment is a fragment of the lower marine deposit, presumably dislocated by glacial activity. The lower marine deposit is likely to be undisturbed. The Quaternary marine sediments occupy a deep fiord-like depression of the Tertiary surface (BANKE RASMUSSEN, personal communication).

The Quaternary marine deposits at Tornskov are covered by glacial deposits, and hence must be older than the Eemian Interglacial. Marine interglacial deposits referred to the Penultimate Interglacial (Holsteinian Interglacial) occur in deep borings in the Ribe area and in the vicinity of Esbjerg further north (JESSEN 1922, NORDMANN 1928, BUCH 1955). All these deposits, including the one encountered at Tornskov, presumably belong to the interglacial Holstein Sea, which is known from occurrences in northwest Germany and the northern Netherlands (see especially GRAHLE 1936, BROUWER 1949).

According to preliminary results by BUCH (cf. BUCH 1963), the Quaternary foraminiferal succession represented at Tornskov is similar to the one encountered at Inder Bjergum near Ribe (BUCH 1955) and may be divided into a lower *Elphidium clavatum-Cassidulina crassa* zone (82–94 m), a middle *Elphidium clavatum-Elphidium (Nonion) orbicularis* zone (77–81 m), and an upper *Elphidium clavatum-Streblus Beccarii* zone (27–76 m). The zone with *Cassidulina crassa* indicates cold water conditions, while the zone with *Elphidium orbicularis* represents an interval of rising temperature, and the zone with *Streblus Beccarii* suggests conditions similar to the present North Sea (BUCH 1955).

The botanical investigation of the deposits constitutes the main subject of this article.

Vegetational History

Interglacial marine horizons constitute important guide horizons in Pleistocene stratigraphy. Pollen analysis of such deposits is of great interest because it provides a basis for a correlation between the marine and the continental sequences. Heck (1932), Vermeer-Louman (1934), Woldstedt (1949), Halicki (1951) and von der Brelie (1954) published pollen diagrams from deposits of the interglacial Eem Sea from northern Germany, the Netherlands and north Poland, which comprise fragments of the development known from pollen diagrams from fresh-water deposits of the same areas. Deposits belonging to the Holstein Sea were examined with pollen analysis by Brouwer (1949, northern Netherlands) and recently by Hallik (1960, Hummelsbüttel near Hamburg). The important pollen diagram published by Hallik (l.c.) shows a sequence, which corresponds to the vegetational development recognized in certain fresh-water deposits.

Interglacial marine deposits are thus inviting objects for pollen analysis. Marine deposits may in some cases be excellently suited for this technique, but in other cases difficulties may arise due to poor pollen preservation, irregularities of pollen deposition or the presence of rebedded material.

Methods.

The marine sediments from the Tornskov boring contained very few macroscopic plant remains; only a few wood fragments, highly modified by pressure, were found (at 28 m, wood of *Pinus*, and at 31 m, wood of *Pinus* and a twig of *Populus* or *Salix*). There were no diatoms in the untreated samples.

The samples for pollen analysis were extracted from the larger samples obtained during the boring. Only a small amount of material was used (1–2 ccm), and care was taken to extract these samples from the undisturbed parts of the larger samples. Satisfactory samples could not be obtained from the purely sandy parts of the section.

The samples consisted almost exclusively of mineral matter. They were treated chemically as follows,

(1) treatment with cold HCl,

(2) boiling with 10% KOH for 6 min. (in water bath), removal of sand by decanting,

(3) boiling with 40% HF for 10–15 min., heating with 10% HCl 2 or 3 times,

(4) boiling with 10 ml acetic anhydride + 1 ml conc. H_2SO_4 for 1 min. (in water bath),

(5) staining with fuchsin and mounting in silicone oil according to the procedure in Andersen (1960).

The organic content was very slight. The pollen was rather abundant, but much crumpled, and the analysis work accordingly rather elaborate. About 500 pollen grains were counted in most of the samples.

The pollen analyses are shown in two diagrams (fig. 2 and plate I), and in the tables 1 and 2. The diagram fig. 2 shows the frequencies for pre-Quaternary pollen and spore types, including all pollen and spore types belonging to plants extinct in northern Europe since the Tertiary (and the Early Pleistocene), as a percentage of the total pollen and spores. Table 1 shows the pollen and spore content of the samples between 77 and 107 m as a percentage of the total pollen and spores. These pollen spectra contain abundant pre-Quaternary material. The pollen diagram on plate I shows the curves for the most important pollen and spores between 13.7 and 77.0 m. In this diagram the pre-Quaternary pollen and spore types were omitted from the total pollen. A few "local" types also were excluded. Frequencies for *Pediastrum* also are shown in the pollen diagram. Pollen and spores not shown in this pollen diagram are indicated in table 2.

Sources of Error.

Fractionation of the pollen rain during transportation in the air may influence the pollen content of marine sediments formed at some distance from the coast. However, there is evidence that the heavy *Picea* pollen is dispersed just as effectively as *Pinus* at distances up to 100 km (HESSELMAN 1919, VON POST 1924, AARIO 1940). Mixing by air tubulence thus seems to influence the horizontal dispersal of pollen grains over such distances (see especially the discussion in FÆGRI and IVERSEN 1950).

The different floating capacities of pollen grains in water may also introduce a source of error in marine sediments. FÆGRI (1943) and FLORIN (1945, 1957) found *Pinus* pollen to be overrepresented in marine sediments from quiet bays, and FROMM (1938) found overrepresentation of *Pinus* pollen in distal delta deposits from northern Sweden. The *Pinus* pollen is also more frequent in the deep water sediments from Gullmarsfjord, western Sweden (FRIES 1951) than in the nearby lake deposits. MULLER (1959) found that fractionation took place during the transportation of pollen by sea currents, resulting in overrepresentation of pollen types with high floating capacity. As the sediment from the boring at Tornskov consists of water-transported material, the *Pinus* pollen may prove to be somewhat overrepresented compared with lake deposits.

Re-deposited Material.

Marine sediments consisting principally of derived mineral matter are likely to contain older pollen and spores eroded and deposited together with the mineral matter (IVERSEN 1936). The secondary fraction can in some cases be calculated and excluded, but even then the presence of secondary pollen is likely to make it impossible to distinguish the finer details of the pollen diagrams (cf. IVERSEN 1943).

The incidence of re-deposited pollen in the Quaternary series at Tornskov is illustrated by the frequencies of the pre-Quaternary pollen and spore types shown in fig. 2. These types dominate the pollen spectrum in the Tertiary clay I and the melt-

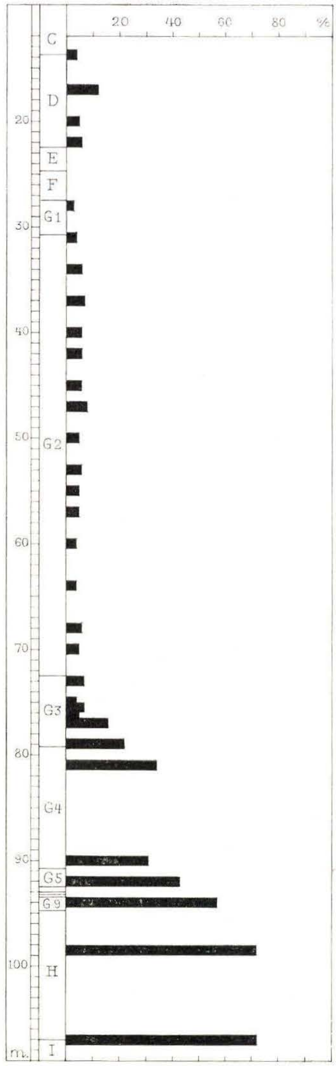

Fig. 2. Frequencies for pre-Quaternary pollen and spore types, as percentage of the total pollen and spores.
Hyppighed af prækvartære pollen- og spore-typer, i procent af alle pollen og sporer.

water deposit H (72%). They occur in the marine deposits G and D with varying frequencies. Between 81 and 94 m the frequency of the pre-Quaternary types is 31–57%. This shows that there is pollen of both Tertiary and Quaternary age. The high frequency of the Tertiary pollen indicates strong contamination with re-deposited material, and one may assume that also a good deal of the Quaternary pollen is secondary. This assumption is supported by the fact that pollen of several thermophilous plants occurs (see table 1) in spite of the cold conditions indicated by the foraminiferal community (cf. p. 6). However, some primary pollen disseminated from a contemporaneous vegetation may also occur (*Pinus*?, *Betula*, *Juniperus*, herbaceous plants, see table 1). The pre-Quaternary pollen types decrease from 34% at 81 m to 5% at 76 m. This change indicates decreased contamination with re-deposited pollen and increased frequency of primary pollen. It coincides with the temperature increase indicated by the foraminiferal succession, and presumably it was due to increased pollen dissemination from a denser vegetation cover. In fact, the pollen analyses at 77 and 76 m indicate an early-interglacial *Betula-Pinus* forest of a pioneer type with relics from forestless vegetation (zone H 1, see below).

Above 77 m the frequency of the pre-Quaternary pollen types is less than 10%, and so the contamination with re-deposited pollen is low. However, as the subjacent layers may contain primary pollen, their pollen content is unsuitable for a calculation and subtraction of the secondary fraction, but the influence of re-deposited Quaternary pollen on the pollen diagram can only be rather insignificant.

Pollen Zones.

The pollen diagram from the levels 28–77 m (plate I) reflects a vegetational development which is clearly interglacial, but of a type not yet described from interglacial sections in Denmark. The following preliminary zones can be distinguished.

Zone H 1 (?–76 m). The zone is characterized by the dominance of *Betula* pollen. *Pinus* pollen is fairly frequent. Pollen of *Populus*, *Salix*, *Juniperus* and herbaceous plants is rather common.

Zone H 2 (75.7 m). A maximum for *Pinus* pollen characterizes the zone. The *Betula* pollen frequency decreases, that of *Alnus* increases, and there is a small maximum of *Fraxinus* pollen (6%). The values for *Populus* and *Juniperus* decrease.

Zone H 3 (75–53 m). *Pinus* and *Alnus* pollen is dominant in this zone, the *Pinus* pollen occurring with a frequency of 30–40% and the *Alnus* pollen with a frequency of about 20%. The *Betula* pollen frequency decreases to about 10%. Pollen of *Picea*, *Quercus* and *Corylus* occurs with frequencies of 5–10%, that of *Carpinus* with 0.5–1%.

Zone H 4 (50–40 m). The zone is similar to the previous one, but the *Carpinus* frequency increases somewhat (up to nearly 6%). *Abies* pollen appears with a frequency less than 1%.

Zone H 5 (37–28 m). The frequency for the *Abies* pollen increases to about 5%, and the frequency for the *Carpinus* pollen decreases slightly. The *Pinus* pollen frequency increases somewhat.

The record is truncated above 28 m by the gravelly layer F and the boulder clay E. The argillaceous sand at 13–22.4 m, according to the pollen analyses, is a fragment of the interglacial marine sediment derived from layers corresponding to zone H 3. Presumably it was dislocated by glacial activity.

Ecological Interpretation.

There is no clear evidence of arctic or subarctic vegetation at the base of the pollen diagram, presumably because the pollen production was too low compared with the sedimentation of secondary pollen. In zone H 1, the frequent occurrence of *Betula, Populus, Salix, Juniperus, Gramineae* and *Cyperaceae* suggests that the forest of that time was of pioneer type with relics from an open-country vegetation like those known from other interglacials and the early Post-glacial.

In zone H 2 *Pinus* apparently increased at the expense of *Betula*, and the decrease of light-demanding plants presumably was due to this increased density of the forest.

The ensuing part of the pollen diagram, which comprises the pollen zones H 3–H 5, is rather monotonous. Although the record is truncated upwards, and there are no traces of a climatic deterioration, this development clearly covers a considerable part of an interglacial succession. Characteristic features are the increases in *Carpinus* and *Abies* pollen, delimiting in turn zones H 4 and H 5. The general dominance of *Pinus* pollen contrasts with the rareness of the other forest components except for *Alnus*. *Picea, Quercus, Ulmus, Tilia, Corylus, Taxus* and later *Carpinus* and *Abies* were present, and we might expect that these trees and shrubs established themselves at the expense of the more light-demanding forest elements. As mentioned on p. 8, the *Pinus* pollen is probably somewhat overrepresented, but the frequencies for *Quercus, Ulmus, Carpinus* and *Corylus* still seem remarkably low. This may mean that the soils were infertile, but the problem can hardly be solved with the present material. *Alnus* reaches notable frequencies (20–30%). The pollen of this genus could not be identified at the species level. It conceivably represents *Alnus glutinosa*, which might have formed extensive carr forest on low-lying ground.

Except for the earliest phases, the climate undoubtedly was temperate, and, due to the rather frequent occurrence of *Taxus, Ilex* and *Myrica*, of moist-oceanic type.

Acidophilous plants such as *Calluna, Myrica, Pteridium* and *Sphagnum* were apparently quite important, presumably indicating that acid soils with heathy and boggy vegetation began to develop rather early. *Salix, Juniperus* and *Frangula* were also fairly abundant.

The pollen of Chenopodiaceae and *Plantago maritima* recorded rather frequently from zone H 1 and upwards indicates the presence of salt marshes. The *Pediastrum* colonies present throughout the diagram may have been derived from older deposits, or the colonies may have been transported by water currents from the river mouths.

In summary, the characteristic features of the pollen diagram from the marine interglacial deposit at Tornskov are,

(1) early phases with high frequencies of *Betula* and *Pinus* pollen,
(2) high values for *Alnus* in the rest of the diagram,
(3) rather low values for *Picea, Quercus, Ulmus, Fraxinus, Tilia, Corylus* and *Taxus* throughout,
(4) a phase, in which *Carpinus* pollen reaches 6%,
(5) a phase, in which *Abies* pollen reaches 5%.

Comparison with other Interglacial Deposits

(for localities, see the map fig. 3)

Inder Bjergum.

It was mentioned on p. 6 that Quaternary marine deposits similar to those encountered at Tornskov occur in westernmost Jutland northwards to the vicinity of Esbjerg. The disturbed clays exposed near Esbjerg have not yielded pollen analyses with primary pollen, presumably because they were deposited at a time, when the sedimentation of primary pollen still was very low. Samples from the boring Inder Bjergum 2 near Ribe, carried out by the Geological Survey of Denmark in 1932 (cp. Buch 1955), did contain pollen, but the samples are too widely spaced for a detailed pollen diagram. Pollen analyses of the available samples are shown in table 3.

According to Buch (l.c.), the Quaternary marine series at Inder Bjergum extends from 12 m to 70 m below the surface. The foraminifera become frequent above 64 m, and warm conditions prevailed from 43.2 m upwards (*Elphidium clavatum-Streblus Beccarii* zone, cf. p. 6). Tertiary pollen is abundant up to 45 m, so these samples must be strongly contaminated with re-deposited material. *Betula* and herb pollen occurs here with notable frequencies. *Pinus* pollen is abundant throughout the series with values increasing from 29 to 62%. There is less re-deposited material above 45 m. Here *Alnus*, *Picea* and *Quercus* occur with notable frequencies, accompanied by *Ulmus*, *Fraxinus*, *Tilia*, *Carpinus*, *Corylus* and *Taxus* pollen in smaller quantities, whilst *Abies* is represented regularly from 28 m. These pollen analyses are therefore similar to the diagram from Tornskov, and so confirm the belief that the interglacial marine deposits in the two areas belong to the same marine horizon.

Chenopodiaceae pollen is constantly present in low frequencies thus indicating deep water deposition rather than salt marsh conditions (cf. Buch l.c., p. 637). In salt marsh deposits the Chenopodiaceae frequency is much higher (see Averdieck 1958).

Interglacial Fresh-Water Deposits at Harreskov, Starup and Ølgod.

Interglacial fresh-water deposits, which pre-date the Eemian Interglacial, are known at Starup and at Harreskov in western Jutland (A. Jessen 1922, Jessen and Milthers 1928), and at Ølgod in the same area (Andersen, in print). A. Jessen (l.c.) assumed that the deposit at Starup belongs to the same interglacial stage as the marine deposits from the vicinity of Esbjerg, and Jessen and Milthers (l.c.) also accepted

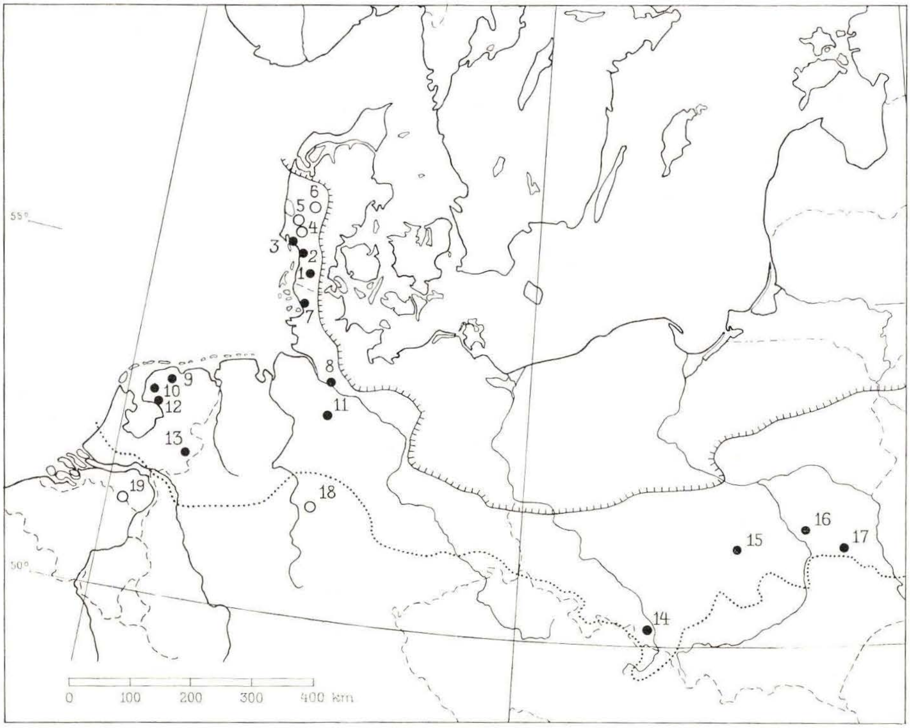

Fig. 3. Interglacial sites mentioned in the text. ● Holsteinian Interglacial deposit. ○ deposit of another age. · · · · · · limit of the Saale glaciation. |||||| limit of the Weichsel glaciation.

Lokaliteter med interglaciale lag omtalt i teksten. ● aflejring fra Holstein Interglacialtiden. ○ aflejring af anden alder. · · · · · · grænse for Saale-nedisningen. |||||| grænse for Weichsel nedisningen.

1. Tornskov	8. Hummelsbüttel	14. Gościecin
2. Inder Bjergum	9. Bergumerheide	15. Olszewice
3. Esbjerg	10. Sneek	16. Wylezin
4. Starup	11. Wiechel	17. Syrniki
5. Ølgod	12. Bantega	18. Bilshausen
6. Harreskov	13. Neede	19. Westerhoven
7. Bredstedt		

this point of view. JESSEN's correlation is open to doubt, and the deposits are not dated with certainty. The deposit at Harreskov is covered by boulder clay (JESSEN and MILTHERS l.c.), but no moraine cover exists above the interglacial layers at Starup and at Ølgod. The covering layers apparently were affected by periglacial erosion during the Weichselian Glacial, and it is not possible to decide whether the deposits were transgressed by one or several glaciations.

Pollen diagrams from the deposits at Harreskov and Starup were published by JESSEN and MILTHERS (l.c.), and the vegetational successions of these interglacials are being re-studied by the present author.

According to JESSEN and MILTHERS (l. c.) the development at Harreskov covers a complete interglacial. Its most significant features are (1) an early *Ulmus* maximum (38 %), (2) up to 26 % of *Quercus*, (3) *Picea* present throughout, (4) rather low *Corylus*, and (5) absence of *Carpinus* and *Abies*. The deposit at Starup only comprises the early vegetational stages of the interglacial. These are identical with the ones known from Harreskov. The vegetational succession represented in the fresh-water deposit at Ølgod is very similar to the one known from Harreskov. In addition to the stages recognized at Harreskov by JESSEN and MILTHERS (l. c.), the succession at Ølgod contains an early maximum of *Taxus*. This *Taxus* maximum has also been recognized in new pollen analyses from Harreskov.

These pollen diagrams are so similar that the deposits must be contemporaneous. They differ significantly from the marine deposits of the Holsteinian Interglacial in South Jutland, and so it is doubtful if they belong to that interglacial.

Interglacial Holstein Sea Deposits in Northern Germany and the Netherlands.

Pollen diagrams related to the interglacial Holstein Sea deposits are known from Germany and the Netherlands. At Bredstedt, just south of the Danish border, HECK (1947) found brackish water sediments from the Holstein Sea overlain by fresh-water gyttja. The pollen diagrams from the fresh-water deposits comprise the younger part of an interglacial succession.

Pinus and *Betula* pollen dominates, and *Alnus* and *Picea* are represented with values decreasing from about 20 % to about 5 %. *Quercus, Tilia, Corylus, Carpinus* and *Abies* are represented at the bottom with low values. This diagram forms a natural upward continuation of the pollen diagram from Tornskov.

The most important pollen diagram from interglacial Holstein Sea deposits is that from Hummelsbüttel near Hamburg recently published by HALLIK (1960). The diagram covers nearly 1 m of fresh-water clay-gyttja and about 2 m of marine fine-sand, overlying the fresh-water deposit. It is nearly identical with the diagram from Tornskov and has the following phases,

(1) *Betula* and *Pinus* dominant, *Picea* and *Alnus* very rare, *Hippophaë* and herb pollen frequent at the bottom,
(2) *Alnus* dominant, *Pinus* and *Betula* decreasing, *Picea* rather frequent (10–20 %), *Quercus, Ulmus, Tilia* and *Corylus* frequencies between 1 and 5 %.
(3) *Carpinus* appears with frequencies of up to 4 %, *Abies* increases to 10–20 % somewhat later.

This series, situated above the present sea-level, records a transgression of the Holstein Sea, which is also shown in the pollen diagram by the appearance of Chenopodiaceae pollen – and by an increase in the *Pinus* frequencies (from 20 to about 50%).

BROUWER (1949) found interglacial Holstein Sea deposits in two borings in the northern part of the Netherlands, at Bergumerheide at 46–62 m below sea level, and at Sneek at 31–42 m below sea level. The pollen diagrams lack detail and seem influenced by various sources of error. *Pinus* and *Alnus* pollen dominates, *Picea* pollen is rather frequent, "*Quercetum mixtum*" and *Corylus* obtain only low frequencies, and *Abies* and *Carpinus* are represented. The marine deposits are covered by "Keileem", a boulder clay belonging to the Drenthe-Amersfoort substage (GIJZEL, OVERWEEL en VEENSTRA 1960).

Interglacial Fresh-Water Deposits in Northern Germany, the Netherlands and Poland.

HALLIK (1960) published an important pollen diagram from a diatomaceous earth deposit at Wiechel in the Lüneburger Heide. It comprises a major part of an interglacial vegetational succession. HALLIK (l.c.) distinguished the following phases,

(1) *Pinus-Betula* phase, *Salix, Alnus* and *Picea* rare (with a *Pinus* maximum at the top, resembling zone H 2 at Tornskov),
(2) *Pinus-Alnus* phase, *Quercus, Ulmus, Tilia, Corylus, Picea* rare,
(3) *Carpinus-Abies* phase (*Pinus* and *Alnus* dominant).

The pollen diagrams from Tornskov and Hummelsbüttel resemble the pollen diagram from the diatomaceous earth at Wiechel, and although the *Pinus* values are somewhat higher in the marine deposits, they must belong to the same interglacial stage. Some sites in Northern Germany with less complete pollen diagrams probably belong to the same interglacial (Krefeld, Ohe, Ummendorf, Klieken, Berlin, see SELLE 1960, HALLIK l.c.). As mentioned by HALLIK (l.c.), the pollen diagram from Bantega in the Netherlands (BROUWER 1949) resembles the diagrams from Wiechel and Hummelsbüttel, and the pollen diagram from Neede (VAN DER VLERK and FLORSCHÜTZ 1953) shows a fragment of a similar development. *Abies* is represented at some of these sites with frequencies of up to 45%. Most of the deposits mentioned are either covered with till, or have been disturbed by ice-push. Their pollen diagrams differ essentially from those of the Eemian Interglacial, and are placed in the Holsteinian Interglacial by the German and Dutch authors just mentioned.

A great number of pollen diagrams are known from fresh-water deposits of the Masovien I Interglacial in Poland. These deposits were transgressed by the Middle Polish (Saale) glaciation. As mentioned by HALLIK (l.c.), the diagrams closely resemble those of the Holsteinian Interglacial of northern Germany and the Netherlands. Pollen of *Quercus, Ulmus, Tilia* and *Corylus* is rare, *Carpinus* and *Abies* pollen increases to 20–50% in the upper part, and *Alnus* and *Pinus* pollen is common[1]).

Discussion.

Interglacial fresh-water and marine deposits with pollen diagrams similar to that from Tornskov thus occur in northern Germany, the Netherlands and Poland. Their pollen diagrams represent the typical vegetational succession of the Holsteinian Interglacial (cp. HALLIK 1960).

As mentioned on p. 14, the pollen diagrams from the limnic deposits at Harreskov, Starup and Ølgod in western Jutland differ so essentially from those of the marine

[1]) BRELIE, KILPPER und TEICHMÜLLER (1959) found macrofossils and pollen of *Pterocarya* cf. *fraxinifolia* Spach. in a peat deposit at Frimmersdorf near Köln which they referred to the Holsteinian Interglacial. *Pterocarya* pollen also was recorded from Masovien I Interglacial sites in Poland (ŚRODOŃ 1957, SOBOLEWSKA 1956 b, STACHURSKA 1957), in the *Carpinus-Abies* zone, where it is undoubtedly primary. Pollen of *Pterocarya* type was also recorded at Tornskov, at the following levels, 28 m: 0.2 %, 42 m: 0.2 %, 45 m: 0.2 %, 53 m: 0.2 %, 55 m: 0.2 %, 57 m: 0.2 %, 79 m: 0.3 %, 81 m: 1.2 %, 90 m: 0.5 %, 92 m: 0.2 %, 94 m: 0.7 %, 98.5 m: 2.0 %, 107 m: 0.7 %. Thus it is most frequent below the 80 m level where there are many pre-Quaternary pollen and spore types, and so it is most likely to be secondary at this site.

deposits in southwest Jutland, that it is doubtful if they belong to the same interglacial. A survey of the maximum percentages of various important genera in the most representative pollen diagrams mentioned above is shown below. The quality of these pollen analyses varies somewhat. The pollen diagrams from the Netherlands do not show percentages for the "*Quercetum mixtum*" components, and *Taxus* pollen is only recorded in a few of the diagrams. However, it is clear that *Quercus* and *Ulmus* obtain much higher percentages at Harreskov and at Ølgod than at the other sites, and the *Taxus*-frequencies recorded at Tornskov and at Gościecin are much lower than the figure recorded at Ølgod. Hence, although more detailed pollen diagrams are desirable, the discrepancy noticed between the pollen diagrams from Harreskov-Ølgod and the one from Tornskov obviously extends to the other Holsteinian Interglacial diagrams from Northern Europe.

Maximum percentage	Harreskov JESSEN and MILTHERS 1928	Ølgod	Tornskov[2])	Hummelsbüttel[2]) HALLIK 1960	Wiechel HALLIK 1960	Bantega BROUWER 1949	Gościecin ŚRODOŃ 1957	Olszwice SOBOLEWSKA 1956a	Wylezin DYAKOWSKA 1956	Syrniki SOBOLEWSKA 1956a
Quercus	26	39	10	7	9	·	9	7	4	13
Ulmus	38	35	2	2	4	·	4	2	2	6
"*Q. M.*"	48	58	15	7	10	15	13	9	8	13
Carpinus	·	0.2	7	4	15	3	16	26	22	25
Abies	·	0.1	6	16	4	6	19	33	42	23
Picea	28	10	9	21	13	25	26	12	29	34
Corylus[1])	49	20	9	15	28	6	12	14	8	24
Taxus[1])	[3])	102	8	[3])	[3])	[3])	12	[3])	[3])	[3])

[1]) Considered outside the pollen totals. [2]) Marine deposits. [3]) Not counted.

The age of the Harreskov-Starup-Ølgod deposits remains uncertain. Somewhat similar pollen diagrams are known from the interglacial deposits at Bilshausen, Unter Eichsfeld, in Germany (LÜTTIG and REIN 1954), and at Westerhoven in the Netherlands (ZAGWIJN and ZONNEVELD 1956). They have been referred to the "Cromerian Interglacial" in the general chronology of northern Europe. However, as these diagrams are rather incomplete, this problem has yet to be solved.

Table 1. Tornskov. Pollen analyses at the levels 77–107.3 m.
Pollenanalyser fra niveauerne 77–107.3 m.

Stratum Depth, m	I 107.3	H 98.5	G 9 94	G 5 92	G 4 90	G 4 81	G 3 79	G 3 77
Carpinus	·	0.5	0.3	0.2	0.2	1	0.3	·
Quercus	·	1	0.3	0.2	0.6	1	2	2
Ulmus	0.3	0.5	·	0.8	0.9	0.4	·	0.8
Tilia	0.7	·	0.3	·	0.1	·	0.3	0.1
Fraxinus	·	·	·	0.2	0.1	·	2	1
Alnus	1	3	4	9	10	8	6	5
Corylus	1	·	0.3	1	1	0.8	1	1
Ilex	1	·	0.3	0.2	0.4	0.4	1	0.2
Picea	4	5	4	3	4	2	1	1
Pinus (*silvestris* type)	13	5	15	20	19	26	22	23
Betula	2	4	3	7	7	13	23	29
Populus	·	·	·	·	·	·	·	0.3
Juniperus	1	0.5	·	0.8	0.4	0.4	1	2
Salix	·	·	·	0.4	·	·	0.6	1
Frangula	·	·	·	·	0.6	·	·	0.1
Myrica	0.3	·	0.7	0.4	0.2	·	·	·
Calluna	·	0.5	0.7	0.2	2	0.4	0.6	0.2
Other *Ericales*	1	1	1	2	2	1	0.6	1
Herbaceous plants, total	0.3	2	2	4	4	3	9	11
Gramineae	0.3	0.5	2	2	2	2	5	5
Cyperaceae	·	0.5	·	2	1	·	4	3
Artemisia	·	·	·	·	0.5	0.4	0.6	0.2
Caryophyllaceae	·	0.5	·	·	·	·	·	·
Chenopodiaceae	·	·	·	·	0.2	·	·	·
Humulus	·	·	·	·	·	·	·	0.2
Liguliflorae	·	·	·	·	0.1	·	·	·
Lycopodium	·	1	·	·	·	·	·	·
Pteridium	·	·	·	·	0.3	·	·	·
Rumex acet. type	·	·	·	·	·	·	·	0.3
Thalictrum	·	·	·	·	·	0.4	·	·
Tubuliflorae	·	·	·	·	·	·	·	0.2
Osmunda	·	·	·	·	0.4	0.4	·	0.2
Typha-Sparganium	·	·	·	·	·	·	0.3	0.1
Thelypteris type	2	1	2	1	4	2	3	2.4
Sphagnum	0.7	3	6	9	11	4	4	4
Pre-Quaternary pollen and spore types	72	72	57	43	31	34	22	16
Total	*300*	*205*	*296*	*507*	*775*	*248*	*312*	*963*
Pediastrum	·	0.5	2	3	3	7	3	4

Table 2. Tornskov. Pollen and spores not shown in the pollen diagram (Plate I).
Pollen og sporer ikke vist på pollendiagrammet (Plate I).

Depth m.	Zone	*Acer*	*Buxus*	*Ericales (-Calluna)*	*Hippophäe*	*Hedera*	*Larix*	*Vitis*	*Artemisia*	*Caryophyllaceae*	*Galium* type	*Humulus*	*Liguliflorae*	*Lycopodium annotinum*	*Lycopodium selago*	*Ophioglossum*	*Polygonum persicaria* type	*Polypodium*	*Rumex acet.* type	*Thalictrum*	*Tubuliflorae*	*Umbelliferae*	*Urtica*	*Menyanthes*	*Osmunda*	*Potamogeton*	*Typa-Sparganium*	*Thelypteris* type
13.7		·	·	0.5	·	·	·	·	0.2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	0.2	0.2	·	0.9
17.0	H3	·	·	2.3	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	0.2	·	·	0.2	·	·	4.1
20.0		·	·	2.0	·	·	·	·	·	·	·	·	·	0.2	·	·	·	·	·	·	·	·	·	·	·	·	·	4.3
22.0		·	·	1.7	·	·	·	·	·	·	·	·	·	·	·	·	·	0.2	·	·	0.2	·	·	0.2	0.6	·	·	3.0
28.0		·	·	2.4	·	·	·	0.2	0.4	·	·	·	·	·	·	·	·	·	·	·	0.2	·	·	·	·	·	·	4.3
31.0	H5	·	+	1.1	·	·	·	0.2	·	·	·	·	·	0.2	·	·	+	0.2	·	·	·	·	·	·	·	·	0.4	3.2
34.0		·	0.2	1.3	·	·	0.2	·	·	·	·	·	·	0.2	·	·	·	·	·	·	·	·	·	·	·	·	·	2.4
37.0		·	·	1.2	·	·	·	·	0.5	·	0.2	·	·	·	0.2	·	·	·	·	·	·	·	·	·	·	·	·	2.8
40.0		·	0.2	2.3	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	0.2	·	0.3	1.6
42.0		·	·	2.2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	0.5	·	·	1.7
45.0	H4	·	·	0.7	·	·	·	·	0.2	·	·	·	·	0.3	·	·	·	·	·	·	·	·	·	·	·	·	·	1.9
47.0		·	0.4	1.7	·	·	·	·	0.2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	0.2	·	0.4	1.3
50.0		·	·	0.4	·	·	·	·	0.2	0.2	·	·	·	·	·	·	·	0.2	·	0.2	·	·	0.2	·	0.4	·	·	1.3
53.0		·	·	2.0	·	·	·	·	·	·	·	·	·	·	·	·	0.2	·	·	·	·	·	·	·	0.4	·	0.2	1.1
55.0		·	·	0.6	·	·	·	·	·	·	·	·	·	·	·	·	·	0.2	0.2	·	·	·	·	·	·	·	·	1.6
57.0		·	0.2	0.9	·	0.2	0.2	·	·	0.2	·	·	·	·	·	·	·	·	·	0.2	·	·	·	·	·	·	·	1.0
60.0		·	·	0.9	·	·	·	·	0.2	·	·	·	·	·	·	·	·	·	0.6	0.2	·	·	·	·	0.2	·	0.2	2.5
64.0	H3	·	·	·	·	·	·	·	·	0.2	·	·	·	·	·	·	·	·	0.2	·	·	·	·	·	0.2	·	·	1.4
68.0		0.4	·	0.2	·	·	·	·	0.4	·	·	·	·	·	·	·	0.2	·	·	·	0.2	·	·	·	0.2	·	0.2	1.6
70.0		·	·	0.6	·	·	·	·	·	·	·	·	0.4	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2.5
73.0		·	·	0.7	·	·	·	·	·	·	0.2	·	·	·	·	·	·	·	·	·	·	·	·	·	0.2	·	·	2.2
75.0		·	·	0.3	·	·	·	·	·	·	·	·	·	·	·	·	·	·	0.2	·	·	·	·	·	·	·	0.2	1.3
75.7	H2	·	·	0.4	0.2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	0.3	·	·	2.2
76.0	H1	·	·	0.9	0.2	·	·	·	·	·	·	·	·	0.2	·	0.2	·	·	·	·	0.2	·	·	·	·	0.2	0.2	3.3
77.0		·	·	1.5	·	·	·	·	0.3	·	·	0.3	·	·	·	·	·	·	0.4	·	0.3	·	·	·	0.2	·	0.2	3.1

Table 3. Inder Bjergum. Pollen analyses.

Depth, m	57.5 –62.5	48.5 –54.5	45.0	41.25	37.0	28.0	21.0	14.5	12–13
Pinus	**29**	**33**	**45**	**51**	**42**	**47**	**50**	**62**	**50**
Betula	**22**	**33**	**25**	12	9	5	6	3	7
Alnus	16	13	6	**21**	**16**	**14**	**13**	**10**	**19**
Picea	6	2	2	**4**	**2**	**5**	**6**	**7**	**7**
Quercus	4	3	1	**3**	**6**	**9**	**3**	**3**	2
Ulmus	2	1	1	0.5	1	0.4	1	0.4	1
Fraxinus	·	·	·	1	2	2	1	0.4	0.6
Tilia	1	·	·	·	0.4	0.4	·	·	0.6
Carpinus	1	·	1	·	**1**	**0.4**	**0.5**	**0.8**	**0.6**
Abies	2	·	·	0.5	·	**0.8**	**2**	**3**	**1**
Salix	·	1	2	0.5	0.8	·	·	·	0.6
Juniperus	**3**	1	·	·	·	0.4	0.5	0.4	·
Corylus	·	1	·	**3**	**5**	**1**	**2**	0.4	·
Taxus	·	·	·	**1**	**6**	**5**	**2**	**4**	0.6
Buxus	·	·	·	·	·	·	·	0.4	·
Ilex	·	0.5	0.5	0.5	0.4	·	·	·	·
Frangula	·	·	0.5	0.5	0.4	0.4	·	·	·
Myrica	·	·	·	·	0.4	·	·	0.4	·
Calluna	3	·	·	0.5	2	2	0.5	·	0.6
Other *Ericales*	5	1	2	1	·	1	2	0.8	2
Total of herbaceous plants	**14**	**7**	**15**	1	5	5	12	4	6
Gramineae	6	3	6	0.5	2	2	2	2	2
Cyperaceae	1	4	6	1	2	·	4	0.8	1
Pteridium	·	·	1	·	**1**	**3**	**5**	·	0.6
Chenopodiaceae	·	0.5	0.5	·	0.4	0.4	0.5	0.8	·
Plantago maritima	·	·	0.5	·	·	·	·	0.4	0.6
Artemisia	·	0.5	0.5	·	·	·	·	·	·
Liguliflorae	·	·	·	·	·	·	·	·	1
Lycopodium selago	·	·	0.5	·	·	·	·	·	·
Polypodium	·	·	·	·	·	·	·	·	1
Total	*125*	*219*	*198*	*211*	*266*	*255*	*199*	*252*	*165*
Osmunda	·	0.5	·	0.5	·	0.8	·	·	·
Thelypteris type	5	3	2	2	2	2	1	3	4
Sphagnum	21	9	10	4	5	2	3	4	0.6
Pediastrum	14	5	10	5	1	0.8	3	1	2
Pre-Quaternary pollen and spore types[1]	**36**	**30**	**24**	10	4	9	12	10	19

[1]) Per cent of all pollen and spores.

Dansk sammendrag

Pollenanalyse af de kvartære marine lag ved Tornskov i Sønderjylland

I 1958 udførte DGU en boring i Tornskov ved Løgumkloster (fig. 1), hvorved kvartære marine lag af betydelig tykkelse blev påtruffet. Profilbeskrivelsen, der støtter sig på iagttagelser af LEIF BANKE RASMUSSEN og ARNE BUCH, kan opsummeres således:

A–C	0.0– 13.7 m	Sand- og gruslag.
D	13.7– 22.4 m	Marint finsandet ler.
E	22.4– 24.7 m	Moræneler.
F	24.7– 27.4 m	Sand- og gruslag.
G	27.4– 94.7 m	Marine ler- og sandlag.
H	94.7–107.2 m	Smeltevandssand.
I	107.2–107.6 m	Tertiært ler.

Boringen er udført i kanten af en bakkeø. Den øvre marine horisont (D) er ifølge pollenanalyserne et brudstykke af den nedre marine horisont, og udgør åbenbart en flage disloceret ved isvirksomhed. Den nedre marine horisont (G) er sandsynligvis uforstyrret og indtager en dyb sænkning i den tertiære overflade. Den er sandsynligvis samtidig med de marine lag ved Ribe og Esbjerg, der henregnes til Næstsidste Interglacialtid (Holstein Interglacialtid). Ifølge BUCHS undersøgelser indeholder den marine serie en foraminifersukcession, som ligner den han har undersøgt ved Inder Bjergum (BUCH 1955, 1963).

Resultaterne af pollenanalyserne er vist i fig. 2 og plate I, samt i tabel 1 og 2. Omlejret pollen forekommer hyppigt i de nederste kvartære lag (80–94 m), som er afsat i et koldt tidsrum med ringe plantedække. Ved 77–80 m aftager hyppigheden af omlejret pollen, hvilket sandsynligvis skyldes, at pollen fra den samtidige vegetation gør sig stærkere gældende. Pollendiagrammet på plate I omfatter kun lagene 13.7–77.0 m, hvor forureningen med omlejret pollen er af ret ringe betydning. Det repræsenterer en betydelig del af en interglacialudvikling, som ikke tidligere er kendt fra Danmark. Pollenzonerne H 1–5 er beskrevet kort på s. 10. De første pollenzoner (H 1 og H 2) repræsenterer birke-fyrreskov af pionertype, som typisk udgør de første stadier af en interglacial skovudvikling. De efterfølges af 3 pollenzoner (H 3–H 5), som præges af fremherskende *Alnus*- og *Pinus*pollen, mens andre træer og buske som *Betula*, *Picea*, *Quercus*, *Ulmus*, *Corylus*, *Taxus* o. a. kun opnår ret lave værdier. I pollenzone H 4 findes et lille maksimum af *Carpinus*pollen og i zone H 5 et tilsvarende af *Abies*pollen. Serien afbrydes af en diskordans ved 24.7 m. Den øvre marine horisont (D) tilhører pollenzone H 3.

Nogle pollenanalyser fra boringen ved Inder Bjergum (BUCH 1955) er anført (se tabel 3). I 12–45 m dybde afspejles i grove træk en udvikling svarende til den, der er konstateret ved Tornskov.

Pollendiagrammet fra Tornskov sammenlignes med pollendiagrammer fra Harreskov og Starup henført til Næstsidste Interglacialtid af JESSEN og MILTHERS (1928) samt den nye lokalitet ved Ølgod. Vegetationsudviklingen fra disse tre ferskvandsforekomster stemmer udmærket overens. Den adskiller sig tydeligt fra Eem Interglacialtiden, men ogsaa fra udviklingen kendt fra Tornskov.

Pollendiagrammet fra Tornskov stemmer udmærket med pollendiagrammer fra Holsteinhavets aflejringer ved Hamborg (HALLIK 1960) og i Holland, samt med pollendiagrammer fra samtidige ferskvandsaflejringer i Nordtyskland, Holland og Polen. Denne Vegetationsudvikling er typisk for Holstein Interglacialtiden (Næstsidste Interglacialtid), som ligger mellem Elster og Saale Glacialtiderne. Ferskvandsaflejringerne fra Harreskov, Starup og Ølgod må sandsynligvis henføres til en endnu ældre interglacialtid.

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Denne bog er sat med Monotype Fridericus Antiqua og trykt i 1500 eksemplarer på Andelsbogtrykkeriet i Odense. Papir: Kunsttryk, 125 g, fra De forenede Papirfabrikker.

Plate I.
Pollen diagram. Tornskov.

A. Total diagram. B. Curves for pollen and spores included in the pollen total. Black silhouettes indicate percentages, white silhouettes percentages exaggerated by 10 ×. C. Curves for microfossils not included in the pollen total.

A. Totaldiagram. B. Kurver for pollen og sporer indregnet i pollensummen. Sorte silhouetter viser procenter, hvide silhouetter procenter overdrevet 10 ×. C. Kurver for mikrofossiler ikke indregnet i pollensummen.

- gravel – grus
- sand
- clay – ler
- boulder clay – moræneler

TORNSKOV