DANMARKS GEOLOGISKE UNDERSØGELSE · SERIE B · NR. 10
MILJØMINISTERIET · Geological Survey of Denmark

Foraminifera and Ostracoda in Late Elsterian-Holsteinian deposits at Tornskov and adjacent areas in Jutland, Denmark

BY
KAREN LUISE KNUDSEN AND DAVID NORMAN PENNEY

I kommission hos C. A. Reitzels Forlag · København 1987

DGU DANMARKS GEOLOGISKE UNDERSØGELSE · SERIE B · NR. 10
MILJØMINISTERIET · Geological Survey of Denmark

Foraminifera and Ostracoda in Late Elsterian-Holsteinian deposits at Tornskov and adjacent areas in Jutland, Denmark

BY
KAREN LUISE KNUDSEN AND DAVID NORMAN PENNEY

I kommission hos C. A. Reitzels Forlag · København 1987

Key-words:
Biostratigraphy, Benthonic Foraminifera, Ostracoda, Quaternary, Holsteinian Interglacial, Palaeoecology, Shallow-marine environments, SW Denmark.

with 2 plates and 1 range chart

Vignette:
Cassidulina reniforme Nørvang
Carinocythereis whitei (Baird)

DGU · serie B · nr. 10
ISBN 87-421-0736-9
ISSN 0901-0289
Oplag: 1200
Tryk: Aio Tryk as, Odense
Tegning: Jette Gissel Nielsen
Foto: Svend Meldgaard Christiansen
Dato: 1987-06-01
Karen Luise Knudsen and David Norman Penney
Geological Institute, University of Aarhus, DK-8000 Århus C, Denmark.
Redaktion: Leif Banke Rasmussen

Preface

The following two papers examine the foraminiferal and ostracod palaeoecology and stratigraphy of Late Elsterian and Holsteinian deposits in Jutland, Denmark. Each site is discussed individually and the results are compared with the published Holsteinian pollen record at Tornskov, and with other Mid-Pleistocene records of Foraminifera and Ostracoda in Northwest Europe. Of particular interest is the occurrence of certain characteristic species-associations and individual taxa of both Foraminifera and Ostracoda, which when used carefully in combination with pollen and various dating techniques, may be of invaluable help in unravelling the Quaternary history of Northwest Europe. The study demonstrates the value of combining the results of several biological and dating tecniques on the same material, in order to obtain a more reliable chronology of the events within the Quaternary. It also highlights where further work is required in this field. It is our hope that the results presented here may prove helpful to Quaternary researchers in their quest to establish a reliable Quaternary chronology for Northwest Europe.

Contents

Foraminifera in Late Elsterian-Holsteinian deposits of the Tornskov area in South Jutland, Denmark

BY

KAREN LUISE KNUDSEN

Abstract

Foraminiferal faunas from marine Late Elsterian and Holsteinian deposits in the Tornskov borehole have been investigated. The faunal succession is correlated with the pollen zones of the same boring, and the assemblages are compared with Late Elsterian and Holsteinian faunas described from adjacent areas.

Arctic foraminiferal faunas at the base of the marine sequence at Tornskov indicate that a marine transgression occurred prior to the establishment of full interglacial conditions, i.e. in the Late Elsterian. Marine sedimentation continued during much of the Holsteinian Interglacial. The assemblages here indicate boreal, mainly sublittoral conditions and relatively open access to the North Sea. Evidence for withdrawal of the Holsteinian sea from the area is not recorded in the faunas at Tornskov, the uppermost part of the marine sequence having probably been removed by subsequent glacial erosion.

The general trend for corresponding deposits over the whole area of SW Denmark and N. Germany is that the regression took place before any indication of climatic deterioration is seen in either the fauna or the flora.

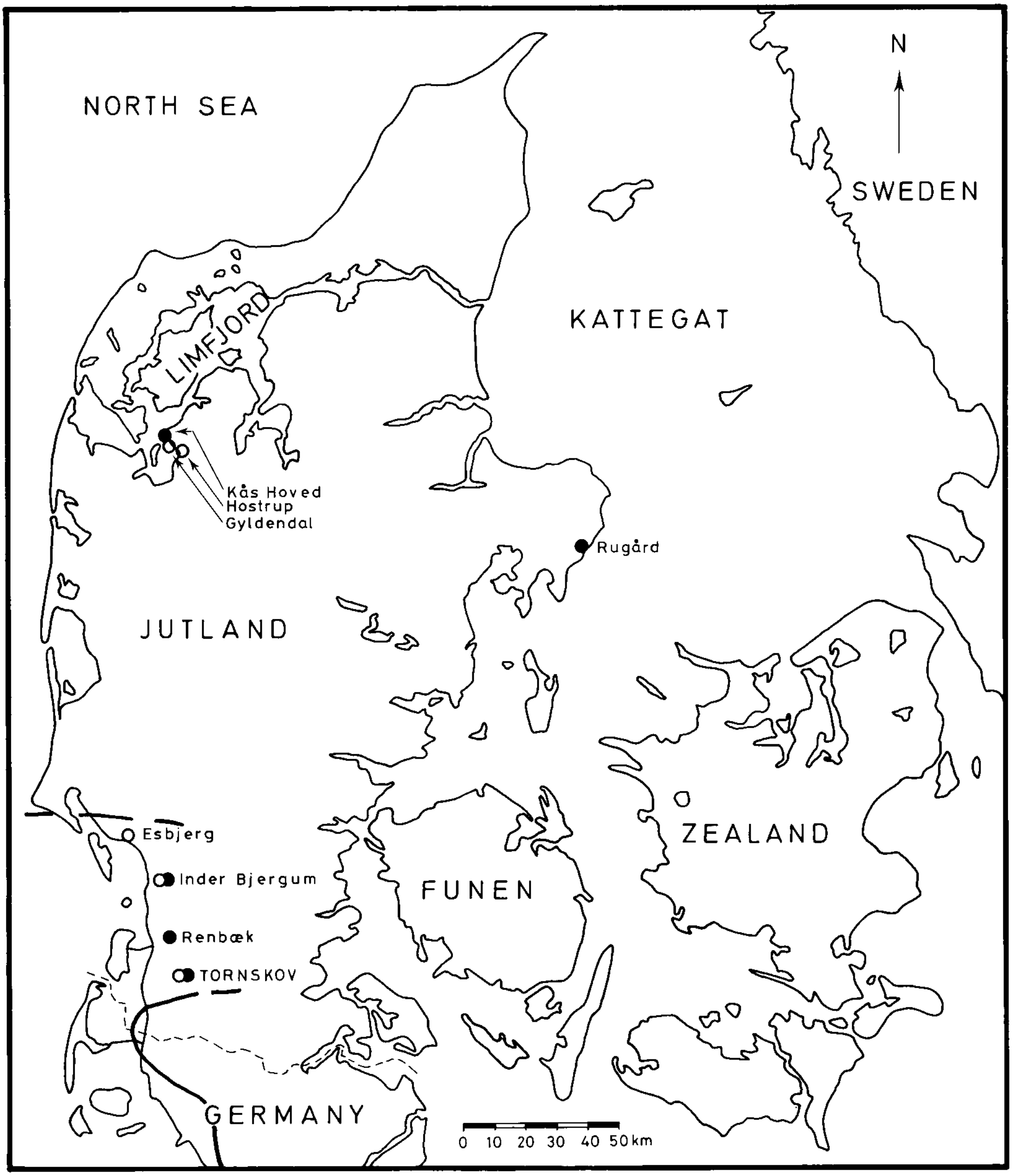


Fig. 1. Locality map. Open circles = marine Elsterian deposits; filled circles = marine Holsteinian deposits; solid line = Elsterian-Holsteinian coastline in SW Jutland.

Introduction

A 107.6 m deep borehole at Tornskov in S. Jutland (figs. 1 and 2) penetrated marine and non-marine Quaternary deposits, and reached down into the marine Miocene. The boring was undertaken in 1958 by the Geological Survey of Denmark (Geol. Surv. file no. 159.243). The site is 22 m above sea-level, and was located at the edge of a hill-island of Saalian age (Milthers 1948), in an area which was not covered by ice during the Weichselian.

A rough description of the sediments in the boring was given by Leif Banke Rasmussen (in Andersen 1963), and a preliminary investigation of their foraminiferal content was undertaken by Buch (1963 and in Andersen 1963). A detailed pollen stratigraphy of the marine Quaternary deposits was, however, established by Andersen (1963), who referred pollen zones H1-H5 to the Holsteinian Interglacial.

The purpose of this investigation has been, firstly, to establish a detailed foraminiferal zonation of the Tornskov boring, secondly, to correlate these with Andersen's pollen zones, and thirdly, to interpret the environmental conditions at the site on the basis of the Foraminifera. The availability of the same samples as were used in the pollen investigation enabled a comparison of the two methods, thus giving us an excellent opportunity to see how they could be coordinated. The knowledge obtained could, therefore, be used more productively in attempting a regional correlation, and in identifying the position of the Elsterian-Holsteinian boundary.

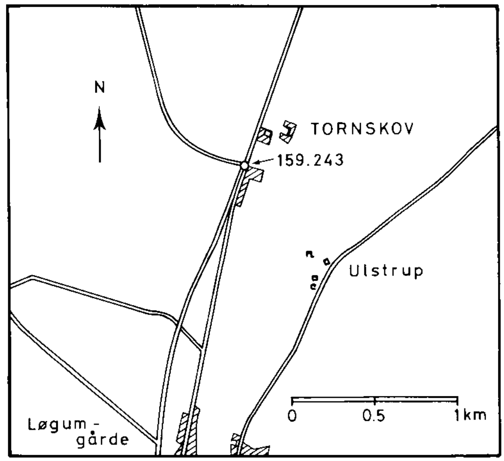


Fig. 2. The location of the Tornskov borehole. (From the Geodetic Institute map sheet 1112 II).

Methods

A total of 115 samples from the Tornskov borehole were treated for foraminiferal analysis according to the laboratory methods described by Feyling-Hanssen et al. (1971) and Meldgaard & Knudsen (1979). At least 300 specimens of Foraminifera were counted where possible. The frequency distribution of selected foraminiferal species is shown in the range chart (fig. 3, p. 31). In samples with few Foraminifera the whole assemblage was counted. The actual number of tests for each species in the analysed samples has been entered in the range chart where this did not total 100 specimens.

The faunal diversity index used in the diagram was defined by Walton (1964) as the number of ranked species which accounts for 95% of a fauna, and the faunal dominance is the percentage of the most frequent species in each fauna (Walton 1964). Another diversity index was introduced by Pielou in 1979. This pielou index (p'3) was defined as the ratio between the third ranked species and the total amount of the three most frequent species in a fauna. This index, thus, supplements Walton's diversity index. The relationship between the three most important species in a sample might, according to Pielou, be of value in palaeoenvironmental analysis.

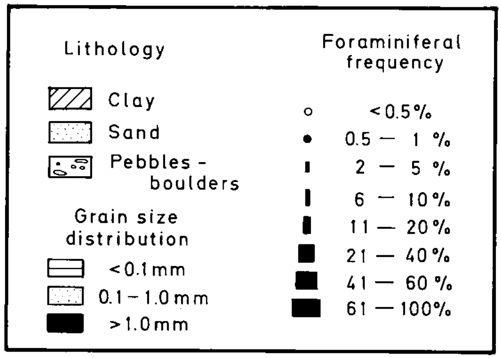


Fig. 4. Legend for fig. 3 (p. 31).

A simplified outline of the lithology and grain size distribution is given on the left side of the range chart. Correlation with pollen zones (Andersen 1963) and a stratigraphical interpretation are shown to the right.

The foraminiferal "zones" in the present work are assemblage zones according to the definition given by Hedberg (1976). The term "zone" is used for the purpose of brevity only.

Fig. 3. Range chart for the Tornskov borehole (p. 31). The percentage distributions of the most common foraminiferal species are shown. Legend fig. 4. The bore site is 22 m above sea-level.

Foraminiferal zonation and palaeoecology

The interval between 107 and 95 m in the Tornskov borehole is a massive sand, with laminae of sandy clay in the lower and upper part of the unit. This unit contains many Pre-Quaternary Foraminifera, mostly of Miocene origin, but with a few specimens from the Cretaceous. A few Quaternary Foraminifera occur in nearly all of the 15 analysed samples, and the unit is probably glacifluvial in origin, as Andersen concluded (1963) on the basis of the lithology and high frequency of Pre-Quaternary pollen.

This unit is overlain by a 56 m thick marine sequence, which can be subdivided into 5 foraminiferal assemblage zones (zone A to zone E, fig. 3). The upper 28 m of the borehole contain two non-marine units separated by about 8 m of marine sediments (fig. 3), which are presumably not in situ. Each of the marine zones and non-marine units is described in details below.

Zone A. The Cassidulina reniforme – Elphidium excavatum zone

The sediments between 95 and 92 m are composed of alternating layers of sand, silty clay, and clay. Foraminiferal faunas of samples 98–93 (fig. 3) are characteristically dominated by the the arctic forma *clavata* (see Feyling-Hanssen 1972) of *Elphidium excavatum* (66–82%), and *Cassidulina reniforme* is also common (9–24% of the total fauna.). The most important accessory species are *Nonion orbiculare* and *Elphidium hallandense,* but specimens of *Elphidium albiumbilicatum* and *E. asklundi* also occur. Both the faunal diversity (3–4) and the p'3 indices (0.04–0.07) are low compared to the succeeding zone.

The ecological parameters indicate extreme marine environmental conditions, and the faunal composition shows that an arctic environment prevailed during deposition (Nagy 1965, Elverhøi et al. 1980).

Zone B. The Nonion orbiculare – Elphidium hallandense zone

Zone B occurs between 91 and 80 m (fig. 3). The sediment is silty sand throughout. *Elphidium excavatum,* forma *clavata* and *Nonion orbiculare* are dominant, accounting for 41–50% and 14–37% of the faunas, respectively. Other important species are *Elphidium hallandense* (8–20%) and *E. asklundi* (2–4%). Only in the uppermost sample are the latter two species less frequent.

The zone B faunas are mainly arctic in character, but the presence of *Elphidium albiumbilicatum* throughout indicates an amelioration in marine climatic conditions when compared with the zone A faunas. The slowly increasing frequencies of boreal species such as *Ammonia batavus, Elphidium magellanicum,* and *Nonion germanicum* herald a gradual rise in temperature. The high content of *N. orbiculare* and *E. hallandense,* together with the presence of *E. asklundi* and *E. albiumbilicatum,* are indicators of shallower conditions than during the deposition of zone A. Decreasing precentages of *Cassidulina reniforme* could also indicate this, but discharge of meltwater into the area could also have had a detrimental effect on that species (Buzas 1965, Knudsen 1982).

Both faunal diversity (5–7) and the p'3 index (0.09–0.23) are higher than in zone A, and the faunal dominance is lower (41–50) (fig. 3). All these parameters point to less severe conditions here than during the depostition of zone A.

Zone C. The Elphidium excavatum – Nonion orbiculare zone.

There is a marked change both in sediment type and in faunal composition at the zone B/C boundary. The silty sand of zone B is overlain by a silty clay in the lowermost part of zone C, and clay in the upper part. A characteristic element of the faunas in zone C (79–75 m) is the high content of *Ammonia batavus,* especially in the lower samples (11–25%). *Nonion orbiculare* continues up into the zone, but with lower frequencies (5–12%) than in zone B. The boreal forma *selseyensis* (Feyling-Hanssen 1972) of *E. excavatum* (59–86%) dominates the assemblages.

The Foraminifera of zone C indicate the establishment of full interglacial (boreal) conditions, as most of the arctic species have completely disappeared. A relatively low faunal diversity and p'3 index, together with high faunal dominance, suggests the presence of extreme environmental conditions. The very high numbers of specimens in sample 80 at the bottom of the zone (23,000 per 100 g sediment) may indicate that there was an initial period of slow accumulation.

The water depth is difficult to estimate because of the unusual composition of the faunas. Assemblages with *Nonion orbiculare* as an important element of otherwise boreal faunas have not ben recorded from any Recent faunas in NW Europe, but this distinct species-association is quite often encountered in Eemian and Holsteinian deposits in Denmark and N. Germany.

Ammonia batavus occurs mainly as the large lobulate form, often with an umbilical plug, both in zone C and in the succeeding zones D and E. This form is typical for Recent North Sea faunas, and its occurrence here, thus, suggests rather open conditions, with direct access to the North Sea during deposition of the whole marine interglacial sequence.

The ostracod faunas in zone C suggest similar, but at the same time slightly cooler conditions than exist in the North Sea at present (Penney present volume).

Zone D. The Elphidium excavatum – Elphidium magellanicum zone.

Silty clays were found between 74 and 43 m. The assemblages here are dominated by *Elphidium excavatum,* forma *selseyensis* (usually 40–75%) and *E. magellanicum* (usually 10–30%). The sudden appearance and importance of the latter species is one of the characteristic features of the zone, although *Ammonia batavus* is also quite well represented (mostly 5–15%) throughout the zone. Especially typical for all the faunas is, however, the presence of many accessory species such as *Elphidium albiumbilicatum, E. williamsoni, E. gerthi, E. margaritaceum, Nonion germanicum, N. depressulum, N. orbiculare, Cibicides lobatulus,* and *Quinqueloculina stalkeri.*

This faunal composition suggests the existance of a stable, fully marine, sublittoral environment (Culver & Banner 1978). Generally the faunal diversity and p'3 indices are higher and the dominance lower than in zone C. The greater number of specimens in the lower part of zone D might be an indication of a period with a slow accumulation rate.

The Ostracoda also support this interpretation, as they suggest marine-climatic conditions compatible with those present in the North Sea today (Penney this volume).

Zone E. The Elphidium excavatum – Ammonia batavus zone.

The sediments of zone E (42–29 m depth) are silty clays grading upwards into a silty fine sand at the top. A short period with a more extreme marine environment would appear to have occurred at the beginning of this zone. Both faunal diversity and the p'3 index decrease, and are particularly low in samples 39 and 40. There may have been a temporary change in the coastline during this period, which may have taken the form of the construction of some kind of a barrier preventing open access to the sea. In this lower part of zone E *Ammonia batavus* is a frequent species (18–26%), together with the dominant *Elphidium excavatum,* forma *selseyensis* (60–76%), and most of the accessory species disappear. These reappear upwards through the zone as more open conditions, similar to those present in zone D, return to the area. The decrease in specimen numbers in this upper sandier part presumably indicates a higher accumulation rate here, but may also have been influenced by differential post-depositional compaction of the sediments.

A characteristic feature of zone E is higher frequencies of *Buccella frigida* (mostly 1–9%, maximum 19%) than in zone D, where it never exceeds 1% of the total fauna. In the upper part of zone E, species such as *Elphidium albiumbilicatum, E. williamsoni,* and *E. margaritaceum* are slightly commoner than in any of the zone D faunas, but the actual palaeoenvironment cannot have been much different in the two zones.

The top of the marine sequence, thus, contains relatively open and deep water faunas indicating sublittoral environments. No shallower water zone is found here. If there was one, it must have been eroded away later, probably during the following glaciation (see below).

Ostracod assemblages at the base of zone E are indicative of a shallow sublittoral environment with normal marine salinity (Penney this volume), and they contain an indication of slightly warmer conditions than in the other foraminiferal zones of the borehole. The corresponding foraminiferal faunas do not, however, show any indication of a warming trend.

The dislocated units

The upper 28 m of the Tornskov borehole comprises three different lithological units, viz. two non-marine deposits separated by a unit of marine sediments.

Between 28 and 22.4 m depth the sediment is coarse sand and gravels at the base and sandy clay with stones (till) in the upper part. Seven samples from this unit have been analysed. One is unfossiliferous, and the other six contain a few Quaternary specimens. These were presumably redeposited from the underlying zones, as the species are the same. A few of the samples have quite a high Pre-Quaternary foraminiferal content, mainly of Miocene origin, but species from the Cretaceous also occur.

The sediment between 22 and 13.7 m depth is silty clay. The ten analysed samples (nos. 22–13) from this stratum contain rich foraminiferal assemblages. The composition of the faunas is very close to those found in the lower middle part of zone D (between samples no. 67 and no. 58), even though they are not exactly the same. Specimen numbers are, for instance, generally larger in samples 22–13 than in this part of zone D.

The uppermost 12 m of the borehole consists of alternating layers of sand, sand with pebbles, and stones, and in the upper part of sandy clay and fine sand. All twelve samples analysed here are unfossiliferous.

Correlation and age

This section compares the foraminiferal zonation at Tornskov with the pollen stratigraphy established by Andersen (1963) from the same borehole. The Foraminifera are also compared with data from Inder Bjergum and Esbjerg, and from several localities in N. Germany and Jutland. The stratigraphic position of these deposits is discussed.

The Tornskov zones, Foraminifera and pollen

Andersen (1963, 1965) recorded a vegetational succession at Tornskov that is both clearly interglacial in character and similar to the Holsteinian succession recorded in marine and non-marine deposits in the Netherlands, Germany, and Poland (i.a. Hallik 1960, Brouwer 1949). The interpretation that the Tornskov sequence is Holsteinian in age has been supported by more recent pollen investigations in NW Europe (i.a. Menke 1968, Müller 1974; see also Menke & Behre 1973). Amino acid measurements correspondingly point to a Late Elsterian-Holsteinian age for Tornskov (Knudsen & Sejrup in prep.).

In his preliminary study of the foraminiferal content in the Tornskov borehole, Buch (1963 and in Andersen 1963) divided the marine sequence into three foraminiferal zones. He identified a lower arctic unit (called the *Elphidium clavatum-Cassidulina crassa* zone, 94–82 m depth), an intermediate unit representing an interval of rising temperature (called the *Elphidium clavatum-Elphidium (Nonion) orbicularis* zone, 81–77 m), and an upper zone with faunas reflecting conditions similar to those in the present North Sea (called the *Elphidium clavatum-Streblus beccarii* zone, 76–27 m). A similar zonation has been found in the present study, but some of the zones have been further subdivided (figs. 3 and 5).

The zone A and B assemblages in Tornskov indicate a gradual transition from a high arctic marine environment to a milder climate with shallower waters in zone B. These two units are here referred to the Late Elsterian. The non-marine sandy deposit below zone A may be a glacigenic formation from the Elsterian, but it could also be from an even older period. The boundary between the Elsterian and the Holsteinian occurs where foraminiferal faunas show a marked change to warmer conditions at 79.5 m depth.

According to Andersen (1963), there is a high frequency of re-deposited Pre-Quaternary pollen in the lower part of the marine sequence, but from 94 m these are mixed with pollen of Quaternary age, which also partly may be secondary. Primary pollen from the contemporaneous vegetation may, however, also occur here (*Pinus?, Betula, Juniperus,* and herbaceous plants). Above 76 m depth, the number of contaminants decreases, while primary pollen increases in importance. At 77 and 76 m the pollen spectra indicate an early interglacial *Pinus-Betula* forest of a pioneer type, with relicts from forestless vegetation (zone H1, Andersen 1963). Pollen zone H1, together with zone H2, where the amount of *Pinus* pollen increases, consequently correspond to the lowermost of the Holsteinian foraminiferal zones, zone C.

Foraminiferal zones D and E correspond to pollen zones H3 to H5. These three pollen zones were subdivided later by Andersen (1964, 1965) into five zones, zone 3 to zone 7 (zone H3 (1963) was subdivided into zones 3, 4 and 5 (1964)). A typical Holsteinian pollen succession is seen in these zones. Zone H3 (1963) is rich in *Pinus* and *Alnus*. There is an increase in *Carpinus* to about 6% in zone H4, and *Abies* appears. In zone H5 the *Abies* content reaches a maximum of 5%.

There is no indication of a subsequent climatic deterioration in the upper part of the boring. This is the case for both the pollen and the Foraminifera. The vegetational succession, however, shows that a considerable part of the interglacial succession is represented in the marine sequence (Andersen 1963).

As mentioned above, no marine regression is seen in the foraminiferal faunas in the upper part of the marine sequence. Glaciers from the following glaciation, the Saalian, may have eroded the top of the marine sediments away. There is no indication of glacial disturbance in terms of repetition of sequences within the marine deposits between 95 and 29 m depth. That the layers may be slightly tilted, for instance in the upper part, cannot, however, be refuted.

Shallower water facies preserved at the top of the Holsteinian sequence in N. Germany all contain true interglacial faunas (Knudsen in prep.). The regression in the southern North Sea area would, thus, appear to have taken place prior to any climatic cooling.

The marine sequence between 22 and 13.7 m depth in the Tornskov borehole is probably a glacially dislocated block originating from a Holsteinian zone D deposit nearby. Andersen (1963) reached a similar conclusion on the basis of the pollen (see also fig. 3). As the Weichselian ice did not cover the present area, this dislocation must have taken place during the Saalian glaciation. The non-marine units below and above the marine block are, thus, probably glacigenic deposits (glacifluvials and tills) from the Saalian (see also Andersen 1963).

Correlation with Inder Bjergum

Marine Quaternary deposits similar to those at Tornskov were described by Buch (1955) from the Inder Bjergum No. 2 borehole south of Esbjerg (fig. 1) (Geol. Surv. file no. 140.82.b). Material left over from this investigation has been processed and reanalysed, and a foraminiferal zonation has been established on the basis of this material, in combination with the results already published by Buch.

Despite evidence for the occurrence of different environmental conditions during certain periods of deposition at Tornskov and at Inder Bjergum, it has been possible to make a correlation between the zones in the two areas (fig. 5). This foraminiferal correlation is also supported by pollen investigations on the same samples at Inder Bjergum (Andersen 1963).

Zone A in Tornskov, the *Cassidulina reniform – Elphidium excavatum* zone, also occurs at Inder Bjergum (zone A_1). The faunal composition is similar at the onset of the marine transgression at both sites.

An assemblage corresponding to that found in zone B, the *Nonion orbiculare – Elphidium hallandense* zone, is only recorded from a single sample at Inder Bjergum, sample 21 from the interval between 62.5 and 57.5 m depth (Buch 1955, p. 635). Percentage distributions of the most common species are shown in fig. 6. Sample 21 (AB) contains relatively large numbers of *Nonion orbiculare, Elphidium hallandense,* and *E. asklundi,* but the dominant species are *E. excavatum* and *Cassidulina reniforme*. Sample 21 (KLK), from the same interval, contains 10% *Quinqueloculina stalkeri,* while the frequencies of *C. reniforme, E. asklundi,* and *N. orbiculare* have decreased markedly, and *E. hallandense* is totally absent. This faunal composition is similar to those found in two samples from the overlying interval (between 54.5 and 48.5 m), where *Q. stalkeri* is a characteristic element of the faunas (20 (KLK) and 20 (AB), fig. 6), *C. reniforme* has disappeared,

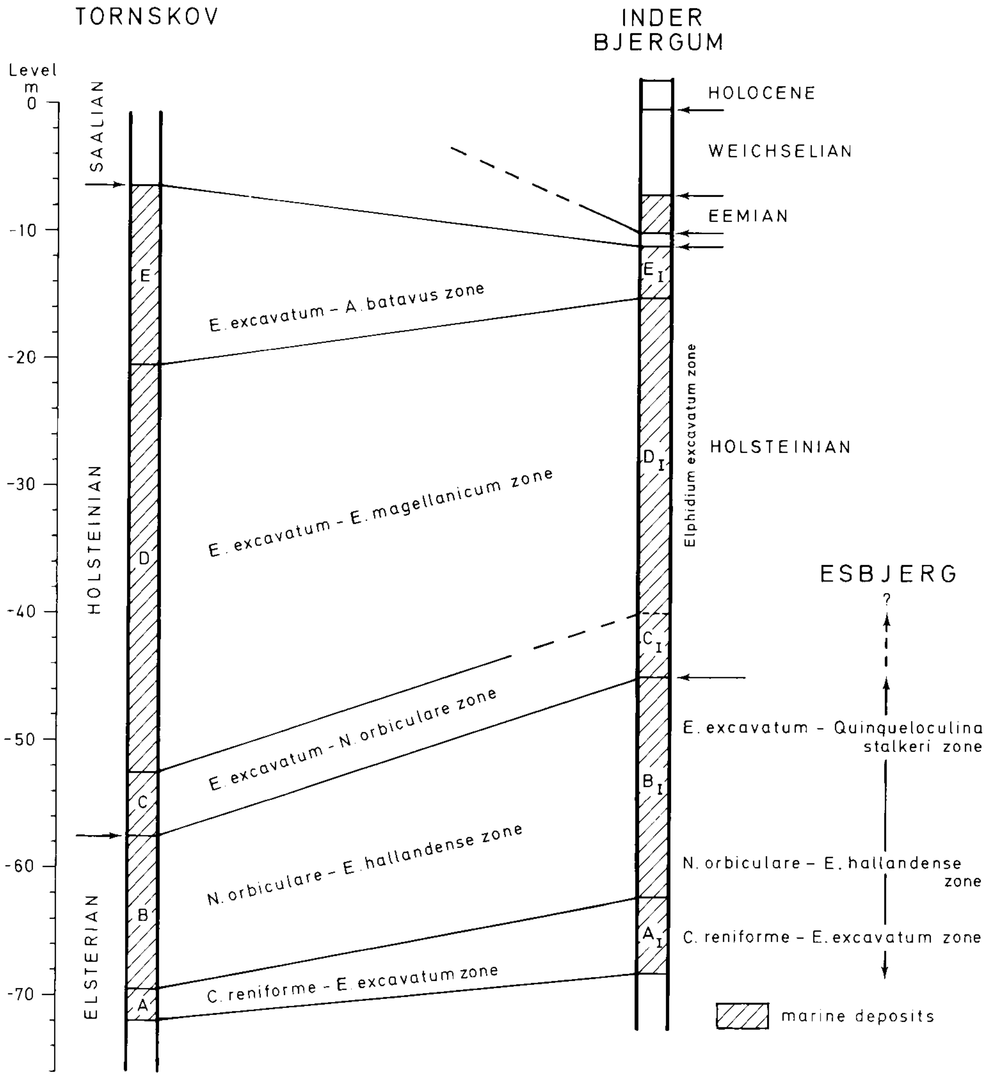


Fig. 5. Correlation of the foraminiferal zones in Tornskov and Inder Bjergum. Faunal types registered in samples from the clay pit of Esbjerg are shown to the right. The marine sediments at Esbjerg are, however, dislocated and found today at a much higher level, i.e. at about present-day sea-level.

and the dominance of *E. excavatum* is high (see also Buch 1955).

The above faunas show that different facies seem to be present within zone B_I at Inder Bjergum. The species composition reflects an arctic environment, in the upper part maybe from deeper water than in the corresponding zone B at Tornskov. A decrease in the content of *C. reniforme* is, however, seen in the upper part of both zones.

The boundary between the Elsterian and the Holsteinian is placed at about 45 m below sea-level at Inder Bjergum. In the zone C_I faunas above this boundary there is a marked change to boreal faunas. *Elphidium excavatum* is dominant, and the boreal species *Ammonia batavus* is always present.

This boundary is, however, difficult to place accurately using Ostracoda (Penney this volume).

Zone C at Tornskov, with its characteristic content of *Nonion orbiculare,* can be compared with zone C_I at Inder Bjergum. This correlation is also supported by pollen investigations. (Andersen 1963). Redeposited Tertiary pollen is abundant up to 45 m depth at Inder Bjergum. *Betula, Pinus,* and herbs also occur here in notable amounts. Above 45 m there is less redeposited material, and *Alnus, Picea,* and *Quercus* occur, together with other deciduous taxa. The change in pollen found in zone C_I at Inder Bjergum correspond to similar changes in zone H1 and zone H2 within foraminiferal zone C at Tornskov.

The foraminiferal correlation higher up in the sequences is also supported by the pollen content. *Abies* pollen is, for instances, characteristic above 28 m depth in Inder Bjergum, which is within foraminiferal zone D_I. This is also the case in zone H4, which is in the upper middle part of foraminiferal zone D at Tornskov.

Zone D faunas, with *Elphidium magellanicum* as one of the dominant species, do not occur in Inder Bjergum. The corresponding sequence is totally dominated by *E. excavatum* and only a few accessory species occur. *Ammonia batavus* is, however, constantly present. Miliolids (*Quiqueloculina stalkeri, Q. seminulum,* and *Miliolinella subrotunda*) and some specimens of *Bulimina marginata* are present in the lowermost part of zone D_I in Inder Bjergum. This indicates that salinity was probably higher at Inder Bjergum than at Tornskov during this period of deposition.

Zone E in the Tornskov boring is correlated with zone E_I at Inder Bjergum (fig. 5) because of a similar increase in *Ammonia batavus* and the appearance of *Buccella frigida* here. In fact only the lower part of zone E contains faunas which are comparable with the assemblages found in zone E_I. A gradual increase in the frequency of the brackish, shallow water species *Elphidium albiumbilicatum,* together with the common occurrence of *A. batavus,* might be an indication of the beginning of a regression in the Inder Bjergum area. The top of the marine sequence may, however, also have been eroded away during the succeeding glaciation.

In a borehole at Renbæk, between Tornskov and Inder Bjergum (fig. 1), a similar Holsteinian foraminiferal succession is found between 13 and 33 m below present day sea-level (samples kindly placed at my disposal by Rud Friborg, Sønderjyllands Amtskommune, Tønder). *Buccella frigida* is also characteristic of the uppermost part of the marine sequence here (above −23 m). Marine Late Elsterian deposits do not, however, occur in this borehole. The marine Holsteinian rests directly upon a non-marine glacigenic deposit.

The foraminiferal faunas in the uppermost marine zone of the Inder Bjergum boring (−7.2 to −10.2 m, fig. 5) reflect marine environmental conditions which were warmer than those of the North Sea area today (see also Buch 1955). Lusitanean species, such as *Elphidium translucens* and *E. lidoense,* are characteristic faunal elements. These faunas correspond to those described from Eemian deposits in the Danish and N. German areas (Lafrenz 1963, Konradi 1976, Knudsen 1985), and the sequence is, therefore, considered to be Eemian in age.

It must be mentioned here that the Inder Bjergum area is exceptional, because it is hitherto the only place in the whole Danish and N. German region where marine Eemian deposits have been described overlying the marine Holsteinian (Buch 1955, Mertz 1977). At Inder Bjergum these two marine interglacial units are only separated by relatively thin layers of non-marine deposits. In the Inder Bjergum 2 borehole, described here (fig. 5), this non-marine unit comprises only 1 m of silty clay, which may be a freshwater deposit. The marine Eemian deposits are separated from the Holsteinian by 0.3 to 3.2 m of glacifluvial sands and gravels in two adjacent boreholes (Buch

1955). According to Mertz (1977) a Saalian till is present between the two interglacials in an area to the NE of Inder Bjergum.

Correlation with Esbjerg

The assemblages present in zone B at Tornskov and in zone B_I at Inder Bjergum (20 and 21, fig. 6) resemble those found in a clay pit in Esbjerg (fig. 1), the so-called "Esbjerg Yoldia Clay" (Jessen 1922, Hansen 1965). Assemblages from three different levels in this deposit are also shown in fig. 6. The level of the samples is not known, so they have been termed the lower, middle, and upper sample respectively.

The faunal succession in the three samples from Esbjerg corresponds closely to that described above from zone B_I, and, in addition, the lower sample from Esbjerg has a similar species composition as the bottom sample of zone B from Tornskov. Here *Nonion orbiculare, Elphidium hallandense,* and *E. asklundi* are important species, and the low percentage of *Buccella frigida* is also typical. A large number of *Quinqueloculina stalkeri* is typical for the upper Esbjerg sample, as it is at the top of zone B_I in the Inder Bjergum boring. A suggested correlation of the sequences is given in fig. 5.

Two additional samples (E1 and E2, fig. 6, collected by Peter Willumsen) from the clay pit at Esbjerg may correspond to the upper part of the Esbjerg and Inder Bjergum sequences described above. The content of *Cassidulina reniforme* is extremely low, as is *Ammonia batavus,* but *Q. stalkeri* is lacking in both assemblages.

According to Buch (1955, p. 633) a zone A-type fauna has also been found in nine samples from the clay pit at Esbjerg (coll. Th. Sorgenfrei 1948). These results have been entered on the correlation chart (fig. 5).

The marine deposit at Esbjerg is generally assumed to be Late Elsterian-Holsteinian in age (Madsen 1895, Jessen 1922, Buch 1955, Feyling-Hanssen & Knudsen 1979). The above faunal comparisons seem to support correlation with the Late Elsterian. Foraminiferal evidence for true interglacial conditions at Esbjerg has also recently been found (material kindly placed at my disposal by Mikael Jørgensen, Rambøll & Hannemann A/S). The marine sediments are glacially disturbed at Esbjerg, and today they occur at about present-day sea-level. At Tornskov and Inder Bjergum, however, the Late Elsterian deposits are assumed to be undisturbed, and the sequences are found at much deeper levels (fig. 5).

Recent amino acid measurements made

SAMPLES \ SPECIES			CASSIDULINA RENIFORME	ELPHIDIUM ASKLUNDI	ELPHIDIUM HALLANDENSE	NONION ORBICULARE	BUCCELLA FRIGIDA	ELPHIDIUM EXCAVATUM	QUINQUELOCULINA STALKERI	AMMONIA BATAVUS	OTHER SPECIES	NUMBER OF SPECIMENS PER 100g SEDIMENT
INDER BJERGUM		20 (AB)		1	+	5		81	5	2	6	3,000
		20 (KLK)						76	7	3	14	330
		21 (KLK)	3	1		2	+	79	10	1	4	3,000
		21 (AB)	16	7	7	15		51		+	4	14,000
ESBJERG	Upper	(ALA)	3		+		1	80	9		7	2,600
		(KLK)	4		+	+		82	10		3	3,200
	Middle	(ALA)	3	+	1	2	+	89	+		4	?
	Lower	(ALA)	11	2	11	16	4	50			6	2,500
		(KLK)	14	1	5	16	4	50			10	710
		E2 (ALA)		1	2	3	1	85		4	4	990
		E1 (ALA)	1	+	3	5	+	83		2	5	720

Fig. 6. Percentage distribution of the most common foraminiferal species in samples from zone B_I of the Inder Bjergum borehole and from the clay pit at Esbjerg. Values less than 0.5% are marked with a cross. (AB)-Analyses from Buch (1955; Q. stalkeri *was here referred to* Sigmoilina distorta *Phleger & Parker 1951). (ALA)-Analyses placed at my disposal by Anne-Lise Lykke-Andersen. (KLK)-Additional analyses made by the author.*

by Miller & Mangerud (1986) suggest that the marine deposit at Esbjerg may be even older than the Elsterian. It is, therefore, clear that much more detailed biostratigraphical studies, combined with absolute dating, need to be carried out in the Esbjerg area to try to solve these stratigraphical problems.

Late Elsterian – Holsteinian faunas in adjacent areas

The foraminiferal faunas present in the Holsteinian deposits of the Tornskov borehole can be compared with those described from East Germany (Wiegank 1972) and N. Germany (Woszidlo 1962, Knudsen 1976 and 1980), but generally the species numbers are greater in the Tornskov faunas than in the corresponding deposits in Germany. This suggests a more open access from Tornskov to the North Sea.

The occurrence of the characteristic lobulate North Sea form of *Ammonia batavus* throughout the Holsteinian sequence at Tornskov also supports this interpretation. In most of the marine sequences known from N. Germany at least certain intervals are dominated by the brackish form of the same species (called *A. batavus,* var. *a* by Woszidlo 1962 and Knudsen 1980). The lobulate form dominates all the Holsteinian assemblages only in the westernmost part of the Hamburg area and in borings at Cuxhaven (Knudsen in prep.).

The lusitanian species *Aubignyna perlucida,* which is common in many of the Holsteinian faunas in the N. German region (Knudsen 1980), seems to decrease in importance northwards towards Denmark. *A. perlucida* occurs in most of the Holsteinian faunas at Tornskov and Inder Bjergum, but it usually does not exceed 1% of the total assemblages. The reason for this might be that *A. perlucida* is a typical shallow water species (Rosset-Moulinier 1972), and that conditions here were too deep. In shallow and brackish water Holsteinian sediments further north in Denmark, however, *A. perlucida* also occurs only sporadically (Kronborg & Knudsen 1985).

In an interglacial marine sequence of presumed Holsteinian age at Kirmington, E. England (kindly placed at my disposal by D. Gregory, British Geological Survey, Keyworth) the total faunas consisted of *A. perlucida,* and it is a common species also in the Holsteinian Nar Valley assemblages (kindly placed at my disposal by A. Lord, University College, London) from eastern England.

The restriction in distribution of the lusitanian faunal element to the southern and western parts of the North Sea region may mirror the geographical extent of lusitanian water masses in the area during the Holsteinian. It is not possible, however, on the basis of the present results, to tell whether these warmer water masses reached the North Sea through the English Channel or by currents north of Great Britain.

As is the case at Tornskov, a marine transgression also occurred in N. Germany in the Late Elsterian, but the deposits are dislocated at most of the sites, and an exact definition of the Elsterian-Holsteinian boundary is, therefore, not possible (Woszidlo 1962, Knudsen 1976 and 1980). This boundary has, nonetheless, recently been found in marine sediments in a deep boring at Eggstedt in Schleswig-Holstein, where it is believed to be undisturbed. The foraminiferal faunal succession here is closely comparable with the Tornskov assemblages (Knudsen in prep.). Zone A faunas are not recorded at Eggstedt, but the transition from a shallow boreal-arctic zone B-type fauna to boreal faunas close to the zone C assemblages is also found here. Moreover, the vegetational succession above the Elsterian-Holsteinian boundary at Eggstedt (B. Menke, pers. comm.) is also similar to that described from Tornskov.

Certain marine deposits in N. Denmark may also belong to the Elsterian and Holsteinian. These are, however, difficult to interpret, because practically all known findings here are glacially disturbed (Knudsen 1987).

Presumed Late Elsterian marine deposits have been recorded from several exposures and borings in the western Limfjord area (fig. 1), i.a. at Hostrup (Knudsen 1977) and at Gyldendal (Jensen & Knudsen 1984). The faunal composition in these deposits are similar to the Elsterian Tornskov assemblages. A particular small and lobulate form of *Cassidulina reniforme* is also a characteristic element in the assemblages of both areas (see also Knudsen 1977).

Holsteinian Interglacial faunas have been described from Kås Hoved in the Limfjord (Jensen & Knudsen 1984) and from Rugård in E. Jutland (Kronborg & Knudsen 1985), and several other probable Elsterian and Holsteinian sites in the same areas are being worked on (Knudsen 1987).

As an aid in tying the chronology down more precisely, absolute dates are currently being made at many sites, i.e. amino acid measurements and thermoluminiscence datings. Preliminary results from Kås Hoved seem to support a Holsteinian age (Miller & Mangerud 1986), while values from Gyldendal suggest an older age than the Elsterian (Knudsen & Sejrup in prep.). TL-measurements from Rugård support the interpretation of a Holsteinian age (Kronborg pers. comm.).

Foraminiferal list

The species mentioned in the text are arranged alphabetically in the following list. More than 50 other species were found in low numbers in the samples, but these have been excluded from the discussion, as they are not significant for the interpretation.

Ammonia batavus (Hofker 1951)
Aubignyna perlucida (Heron-Allen & Earland 1913)
Buccella frigida (Cushman 1922)
Buccella frigida (Cushman), var. *calida* (Cushman & Cole 1930)
Bulimina marginata d'Orbigny 1826
Cassidulina reniforme Nørvang 1945
Cibicides lobatulus (Walker & Jacob 1798)
Elphidium albiumbilicatum (Weiss 1954)
Elphidium asklundi Brotzen 1943
Elphidium excavatum (Terquem), forma *clavata* Cushman 1930
Elphidium excavatum (Terquem), forma *selseyensis* (Heron-Allen & Earland 1911)
Elphidium gerthi van Voorthuysen 1957
Elphidium hallandense Brotzen 1943
Elphidium lidoense Cushman 1936
Elphidium magellanicum Heron-Allen & Earland 1932
Elphidium margaritaceum Cushman 1930
Elphidium translucens Natland 1938
Elphidium voorthuyseni Haake 1962
Elphidium williamsoni Haynes 1973
Fissurina Reuss 1850
Miliolinella subrotunda (Montagu 1803)
Nonion depressulum (Walker & Jacob 1798)
Nonion germanicum (Ehrenberg 1940)
Nonion orbiculare (Brady 1881)
Quinqueloculina stalkeri Loeblich & Tappan 1953

Summary

The Tornskov borehole is situated at the edge of a Saalian hill-island in S. Jutland (fig. 1).

Foraminiferal faunas have been described from a continuous marine sequence reaching down into the Late Elsterian and comprising a major part of the Holsteinian Interglacial. The marine sequence, which rests upon a non-marine glacigenic deposit, is subdivided into five foraminiferal zones, zone A to zone E (fig. 3).

The lowermost zones, *zone A* and *zone B,* from 95 to 80 m depth in the borehole, contain arctic Foraminifera at the bottom, but there is a gradual increase in the content of boreal species in zone B. These assemblages indicate that marine conditions first reached this area in Late Elsterian times.

Full interglacial conditions are established at the base of *zone C.* Only *Nonion orbiculare* remains as an important element of the faunas in this zone (79–75 m), together with the otherwise boreal species. The environment must have been similar to that in the North Sea today in *zone D* and *zone E* (74–29 m). The special lobulate form of *Ammonia batavus* and the large numbers of accessory species indicate quite open conditions with direct access to the North Sea during deposition of all the Holsteinian zones.

The faunal composition of zone D and the top of zone E reflects rather stable environmental conditions as found in sublittoral areas, while the faunas of zone C and the lower part of zone E show that a more extreme environment prevailed during these periods of deposition.

Because the present foraminiferal investigation is made on the same sample material as used by Andersen (1963) for his pollen zonation, it has been possible to make a direct comparison of the results of both methods within the Holsteinian part of the sequence.

Zone H1 (fig. 3) contains pollen indicative of open-country vegetation and pioneer-type forest, while the zone H2 pollen reflects a closed canopy forest with increased amounts of *Pinus* at the expense of *Betula* (Andersen 1963). Andersen's results fit very well with my interpretation of a Late Elsterian-Holsteinian boundary between 80 and 79 m depth (at 57.5 m below present day sea-level, fig. 5).

Pollen zones H3 to H5, which equate with foraminiferal zones D and E, clearly extend over a considerable part of the interglacial, and no indication of a climatic deterioration is seen in either flora or fauna in the upper part of the marine sequence.

The uppermost 28 m of the Tornskov borehole contains glacially disturbed layers comprising a lower unit of glacifluvials and tills from the Saalian, a block of marine Holsteinian deposits originating from a zone D-type sediment, and another glacigenic deposit of Saalian age at the top (fig. 3).

The foraminiferal zones at Tornskov are correlated with the faunal succession at Inder Bjergum and Esbjerg (fig. 5). Both the pollen and Foraminifera at Inder Bjergum indicate that the Elsterian-Holsteinian boundary occurs at about 45 m below sea-level. A similar succession is seen at Eggsted in N. Germany.

Scattered occurrences of both marine Elsterian and marine Holsteinian sediments are found at many localities in N. Germany and Denmark, but very often these are gla-

cially dislocated, and the Elsterian-Holsteinian boundary is frequently lacking.

The Late Elsterian-Holsteinian coastline appears to have had deep and often wide embayments both in N. Germany and Denmark. The marine Tornskov and Inder Bjergum sequences are representative for the deposits in such embayments in SW Jutland. There is a remarkable coincidence between the areal extent of the marine Elsterian and Holsteinian occurrences here and the Pre-Quaternary surface of the same area (see also Rasmussen 1966, p. 121). The transgression may, therefore, have been at least partially controlled by these structures.

Acknowledgements

I am grateful to the Geological Survey of Denmark for placing material from the Tornskov and Inder Bjergum boreholes at my disposal. My sincere thanks to Anne-Lise Lykke-Andersen for permission to include her foraminiferal analyses from Esbjerg and for valuable discussions about the stratigraphy and to Dr. David N. Penney, Århus, for critically reading the manuscript and for improving the English text. I would also like to thank Svend Meldgaard, who processed the samples, Jette Gissel Nielsen for making the drawings and Lissi Ø. Mogensen for arranging the manuscript.

Dansk Sammendrag

Foraminiferer i en sen Elster-Holstein lagserie ved Tornskov i Syd-Jylland, Danmark.

Tornskov boringen (fig. 1) er udført ved foden af glacialt højland fra Saale Istiden (kote +22 m).

Der er undersøgt foraminifer-faunaer fra en kontinuerlig marin lagserie, som omfatter aflejringer fra sen Elster og en større del af Holstein Interglacial tid. Denne marine lagserie, som overlejrer en ikke-marin glacial enhed, er inddelt i fem foraminifer-zoner, zone A til zone E (fig. 3).

I den nedre del af den marine serie (95–80 m dybde) viser foraminifererne en udvikling fra højarktiske forhold i *zone A* til gradvist mildere, men stadig hovedsagelig arktiske marin-klimatiske betingelser i *zone B*. Disse faunaer viser, at den marine transgression i dette område er startet allerede i sen Elster.

Ved overgangen til *zone C* er der en markant ændring af faunaen, idet boreale arter nu bliver dominerende. Samtidig fortsætter arten *Nonion orbiculare* dog som et vigtigt element af faunaen gennem hele zone C (79–75 m). I *zonerne D og E* (74–29 m) svarer fauna-sammensætningen stort set til recente Nordsøfaunaer. Et indhold af relativt mange arter i de fleste prøver, samt den specielle lobulate form af *Ammonia batavus* viser, at der har været ret åbne forhold ud mod Nordsøen under aflejringen af hele det marine Holstein.

Zone D og den øvre del af zone E afspejler sublittorale forhold, mens der i zone C og den nedre del af zone E synes at have været mere ekstreme økologiske forhold.

Da foraminifer-undersøgelsen er lavet på det samme prøvemateriale, som Andersen anvendte til en pollen-stratigrafisk zonation af Holstein i 1963, har det her været muligt at foretage en meget nøjagtig sammenligning af resultaterne fra disse to forskellige stratigrafiske metoder.

Pollen-zonerne H1 og H2 repræsenterer birke-fyrreskov af pioner-type (Andersen 1963), som typisk udgør de første stadier af en interglacial skovudvikling. Dette passer godt med den faunistiske tolkning, som placerer grænsen mellem sen Elster og Holstein ved 79,5 m dybde (kote −57,5 m) (fig. 3 og 5). Pollen-zonerne H1 og H2 falder begge inden for foraminifer-zone C.

Vegetationsudviklingen gennem pollen-zonerne H3-H5 viser, at en stor del af interglacialtiden er repræsenteret i den marine lagserie. Disse tre pollen-zoner svarer til foraminifer-zonerne D og E. Hverken i flora eller i fauna er der tegn på forværring af klimaet igen i den øvre del af lagserien. Dette er generelt for hele det nordtyske og det danske område, hvor regressionen af Holsteinhavet er foregået, mens der endnu herskede interglaciale forhold her.

De øverste 28 m i Tornskov boringen tolkes som glacialt forstyrrede lag. De omfatter en nedre ikke-marin enhed af glaciale sedimenter, en flage af det marine Holstein (fra zone D), og en øvre glacial lagserie uden fossiler. Disse øvre enheder må være afsat under Saale glaciationen, idet Tornskov ligger udenfor Weichsel-isens maximale udbredelsesområde.

Foraminifer-zonerne i Tornskov er korreleret med en tilsvarende marin lagserie ved Inder Bjergum (Buch 1955), hvor grænsen mellem Elster og Holstein kan placeres ved kote ca. −45 m. Også her kan denne grænsedragning støttes af vegetationsudviklingen i området. Foraminifer-faunaer i prøver fra

Esbjerg Teglværk tyder på, at de marine aflejringer her kan korreleres med zonerne A og B i Tornskov (fig. 5). Disse må således også formodes at være af sen Elster alder.

Mange steder i Nord-Tyskland og i Danmark findes spredte forekomster af marine aflejringer fra Holstein. Meget ofte er disse glacialt forstyrrede, og normalt er grænsen mellem Elster og Holstein ikke repræsenteret. I en boring ved Eggstedt i Nord-Tyskland forekommer dog uforstyrret en marin lagserie med en flora- og fauna-udvikling, der svarer nøje til den, som her er beskrevet fra Tornskov.

Kystlinien har under Elster-Holstein transgressionen været præget af dybe og ofte også brede fjorde, som har skåret sig ind i landet både i Nord-Tyskland og i Danmark. De marine lagserier ved Tornskov og Inder Bjergum repræsenterer aflejringer fra sådanne fjordsystemer. Udbredelsen af de marine Elster-Holstein aflejringer i SV Jylland svarer nøje til områder med en dybtliggende prækvartær overflade (se også Rasmussen 1966, p. 121), og transgression har sandsynligvis delvist været bestemt af disse strukturer.

References

Andersen, S. T., 1963: Pollen Analysis of the Quaternary Marine Deposits at Tornskov in South Jutland. Danm. geol. Unders. IV Række 4 (8). 23 pp.

Andersen, S. T., 1964: Interglacial vegetational successions in the light of environmental changes. Report VI. International Congress on Quaternary, Warsaw 1961, 359–368.

Andersen, S. T., 1965: Interglacialer og interstadialer i Danmarks kvartær. Medd. dansk geol. Foren. 15 (4), 486–504.

Brouwer, A., 1949: Pollenanalytisch en geologisch onderzoek van het Onder- en Midden-pleistocaen van Noord-Nederland. Leidse Geol. Med. 14B, 259–346.

Buch, A., 1955: De marine interglaciale lag ved Inder Bjergum. Foraminiferfauna og stratigrafi. Medd. dansk geol. Foren. 12 (6), 593–652.

Buch, A., 1963: Marine kvartæraflejringers foraminiferfauna i Danmark. Medd. dansk geol. Foren. 15, 240.

Buzas, M. A., 1965: Foraminifera from Late Pleistocene Clay near Waterville, Maine. Smithsonian Misc. Coll. 145 (8). 30 pp.

Culver, S. J. & Banner, F. T., 1978: Foraminiferal assemblages as Flandrian palaeoenvironmental indicators. Palaeogeogr., Palaeoclimatol., Palaeoecol. 24, 53–72.

Elverhøi, A., Liestøl, O. & Nagy, J., 1980: Glacial erosion, sedimentation and microfauna in the inner part of Kongsfjorden, Spitsbergen. Norsk Polarinst. Skr. 172, 33–60.

Feyling-Hanssen, R. W., 1972: The foraminifer *Elphidium excavatum* (Terquem) and its variant forms. Micropaleontology 18 (3), 337–354.

Feyling-Hanssen, R. W., Jørgensen, J. A., Knudsen, K. L. & Lykke-Andersen, A.-L., 1971: Late Quaternary Foraminifera from Vendsyssel, Denmark and Sandnes, Norway. Bull. geol. Soc. Denmark 21 (2–3), 67–317.

Feyling-Hanssen, R. W. & Knudsen, K. L., 1979: Foraminiferer og deres betydning i skandinavisk kvartær geologi. Dansk Natur – Dansk Skole, Årsskrift 1979, 3–45.

Hallik, R., 1960: Die Vegetationsentwicklung der Holstein-Warmzeit in Nordwestdeutschland und die Alterstellung der Kiselgurlager der südlichen Lüneburger Heide. Z. deutsch. geol. Ges. 112, 326–333.

Hansen, S., 1965: The Quaternary of Denmark. 90 pp. In: Rankama, K. (editor): The Geologic Systems. The Quaternary 1. Interscience publishers, New York.

Hedberg, H. D. (ed.), 1976: International stratigraphic guide. A guide to stratigraphic classification, terminology and procedure. Wiley & Sons, New York. 200 pp.

Jensen, J. B. & Knudsen, K. L. 1984: Kvartærstratigrafiske undersøgelser ved Gyldendal og Kås Hoved i det vestlige Limfjordsområde. Dansk geol. Foren., Årsskrift for 1983, 35–54.

Jessen, A., 1922: Beskrivelse til det geologiske Kortblad Varde. Danm. geol. Unders. I Række 14. 105 pp.

Knudsen, K. L., 1976: Die Holstein-Interglaziale Foraminiferen-Fauna von Wacken (West-Holstein) und Hamburg-Hummelsbüttel. Eiszeitalter u. Gegenwart 27, 206–207.

Knudsen, K. L. 1977: Foraminiferal faunas of the Quaternary Hostrup Clay from Northern Jutland, Denmark. Boreas 6, 229–245.

Knudsen, K. L., 1980: Foraminiferal faunas in marine Holsteinian Interglacial deposits of Hamburg-Hummelsbüttel. Mitt. Geol.-Paläont. Inst. Univ. Hamburg 49, 193–214.

Knudsen, K. L., 1982: Foraminifers, 148–177. In: Olausson, E. (ed.): The Pleistocene/Holocene boundary in south-western Sweden. Sveriges geol. Unders. Ser C 794.

Knudsen, K. L., 1985: Foraminiferal faunas in Eemian deposits of the Oldenbüttel area near the Kiel Canal, Germany. Geol. Jb. A86, 27–47.

Knudsen, K. L., 1987: Elsterian-Holsteinian foraminiferal stratigraphy in the North Jutland and Kattegat areas, Denmark. Boreas. (In press).

Konradi, P. B., 1976: Foraminifera in Eemian deposits at Stensigmose, southern Jutland. Danm. geol. Unders. II Række 105. 57 pp.

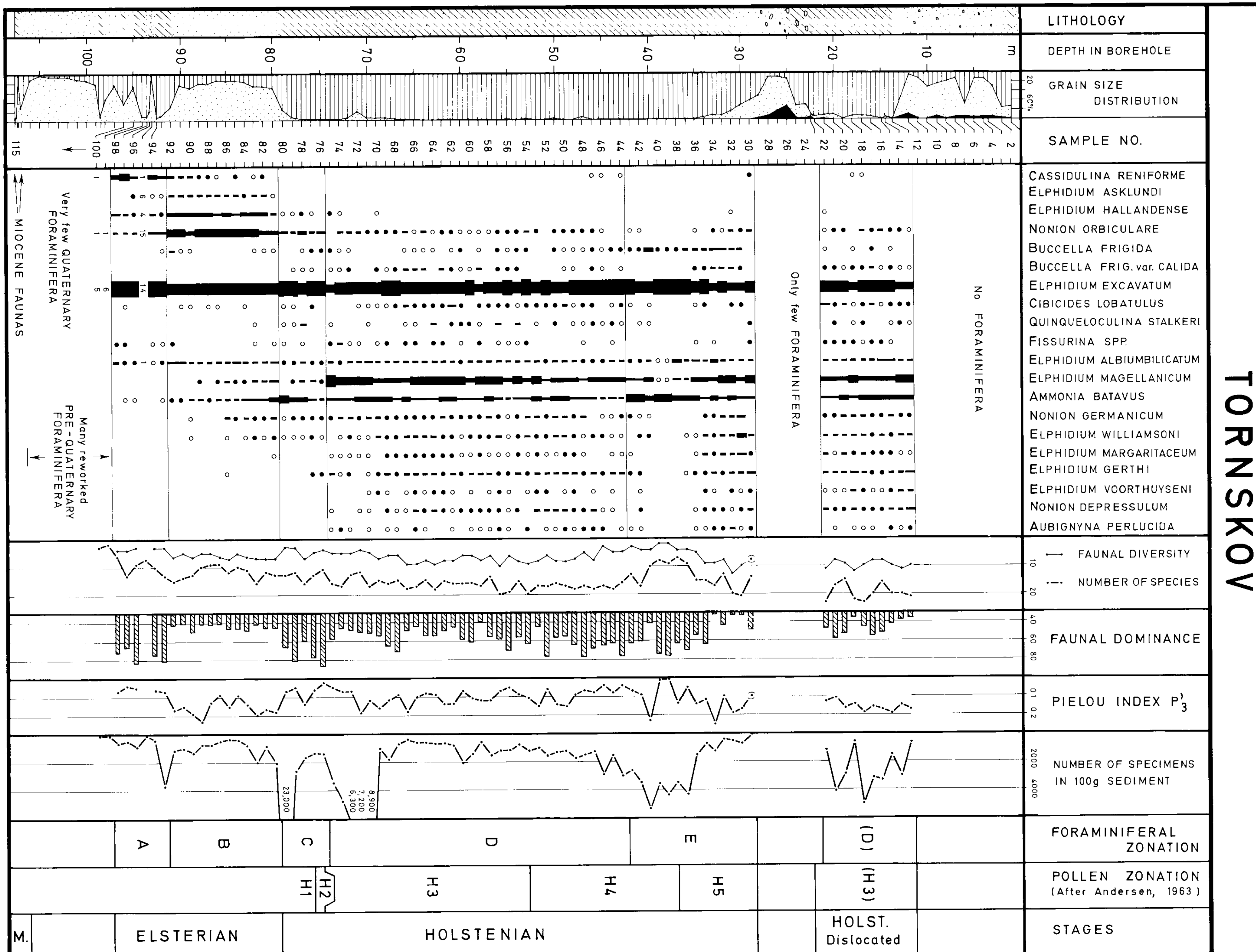
Kronborg, C. & Knudsen, K. L., 1985: Om Kvartæret ved Rugård: en foreløbig undersøgelse. Dansk geol. Foren., Årsskrift for 1984, 37–48.

Lafrenz, H. R., 1963: Foraminiferen aus dem marinen Riss-Würm-Interglazial (Eem) in Schleswig-Holstein. Meyniana 13, 10–46.

Madsen, V., 1895: Istidens Foraminiferer i Danmark og Holsten og deres Betydning for Studiet af Istidens Aflejringer. Medd. dansk geol. Foren. 2. 229 pp.

Meldgaard, S. & Knudsen, K. L., 1979: Metoder til indsamling og oparbejdning af prøver til foraminiferanalyser. Dansk Natur-Dansk Skole, Årsskrift 1979, 48–57.
Menke, B., 1968: Beiträge zur Biostratigraphie des Mittelpleistozäns in Norddeutschland. Meyniana 18, 35–42.
Menke, B. & Behre, K. E., 1973: State of Research on the Quaternary of the Federal Republic of Germany. 2. History of Vegetation and Biostratigraphy. Eiszeitalter u. Gegenwart 23/24, 251–267.
Mertz, E. L., 1977: Ribe og omegns jordbundsforhold. En ingeniør-geologisk beskrivelse. Danm. geol. Unders. Rapport 11. 52 pp.
Miller, G. H. & Mangerud, J., 1986: Aminostratigraphy of European Marine Interglacial deposits. Quaternary Science Reviews 4 (4) (for 1985), 215–278.
Milthers, V., 1948: Det danske Istidslandskabs Terrænformer og deres Opstaaen. Danm. geol. Unders. III Række 28. 233 pp.
Müller, H., 1974: Pollenanalytische Untersuchungen und Jahresschichtenzählungen an der Holstein-zeitlichen Kiselgur von Münster-Breloh. Geol. Jb. A21, 107–140.
Nagy, J., 1965: Foraminifera in some bottom samples from shallow waters in Vestspitsbergen. Norsk Polarinst., Årbok 1963, 109–125.
Pielou, E. C., 1979: A quick method of determining the diversity of foraminiferal assemblages. J. Paleont. 53 (5), 1237–1242.
Rasmussen, L. B., 1966: Molluscan Faunas and Biostratigraphy of the Marine Younger Miocene Formations in Denmark. Part I: Geology and Biostratigraphy. Danm. geol. Unders. II Række 88. 358 pp.
Rosset-Moulinier, M., 1972: Étude des Foraminifères des côtes nord et ouest de Bretagne. Trav. Lab. Géologie, E.N.S. 6. 225 pp.
Walton, W. R., 1964: Recent foraminiferal ecology and paleo-ecology, 151–237. In: Imbrie, J. & Newell, N. D. (editors): Approaches to Paleoecology. Wiley & Sons, New York.
Wiegank, F., 1972: Ökologische Analyse quartärer Foraminiferen. Beitrag zur Quartärstratigraphie in der nördlichen Deutschen Demokratischen Republik. Geologie 21, Beih. 77. 111 pp.
Woszidlo, H., 1962: Foraminiferen und Ostrakoden aus dem marinen Elster-Saale-Interglazial in Schleswig-Holstein. Meyniana 12, 65–96.

Fig. 3.
Text on page 12


TORNSKOV
LITHOLOGY
DEPTH IN BOREHOLE
GRAIN SIZE DISTRIBUTION
SAMPLE NO.
CASSIDULINA RENIFORME
ELPHIDIUM ASKLUNDI
ELPHIDIUM HALLANDENSE
NONION ORBICULARE
BUCCELLA FRIGIDA
BUCCELLA FRIG. var. CALIDA
ELPHIDIUM EXCAVATUM
CIBICIDES LOBATULUS
QUINQUELOCULINA STALKERI
FISSURINA SPP.
ELPHIDIUM ALBIUMBILICATUM
ELPHIDIUM MAGELLANICUM
AMMONIA BATAVUS
NONION GERMANICUM
ELPHIDIUM WILLIAMSONI
ELPHIDIUM MARGARITACEUM
ELPHIDIUM GERTHI
ELPHIDIUM VOORTHUYSENI
NONION DEPRESSULUM
AUBIGNYNA PERLUCIDA
MIOCENE FAUNAS
Very few QUATERNARY FORAMINIFERA
Many reworked PRE-QUATERNARY FORAMINIFERA
Only few FORAMINIFERA
No FORAMINIFERA
FAUNAL DIVERSITY
NUMBER OF SPECIES
FAUNAL DOMINANCE
PIELOU INDEX P'3
NUMBER OF SPECIMENS IN 100g SEDIMENT
23,000
8,900
7,200
6,300
FORAMINIFERAL ZONATION
A
B
C
D
E
(D)
POLLEN ZONATION (After Andersen, 1963)
H1
H2
H3
H4
H5
(H3)
STAGES
M.
ELSTERIAN
HOLSTENIAN
HOLST. Dislocated

Ostracoda of the Holsteinian Interglacial in Jutland, Denmark

BY

DAVID NORMAN PENNEY

Abstract

Ostracoda are described from several marine Holsteinian deposits in Jutland, Denmark. The faunas are extremely uniform all over Jutland. Very little difference is seen between them and the faunas present in Late Elsterian deposits of the same area. They are largely boreal in aspect, but contain a few species from warmer realms. With the exception of *Callistocythere* sp and *Semicytherura* sp, all the species are extant, though *Carinocythereis whitei* and *Pterygocythereis coronata* do not live in Danish inshore waters today. The environment at all the investigated localities was one of open, shallow waters (10–30 m depth) and normal marine salinities. No shallower water facies have as yet been identified. The Holsteinian ostracod faunas of Denmark are analogous to those recorded in North Germany, and show similarities to those reported from Mid-Pleistocene deposits in Great Britain.

Introduction

In recent years detailed surveys of the marine Late Elsterian and Holsteinian deposits of Jutland, Denmark, have been made. In the course of these surveys pollen (Andersen 1963, 1965) and Foraminifera (Buch 1955, Jensen & Knudsen 1984, Knudsen 1987 and this volume, Kronborg & Knudsen 1985) have been studied, and amino acid determinations have been undertaken on marine molluscs from some of the sites (Miller & Mangerud 1986), confirming a Holsteinian age for most of them. The material examined by Dr K. L. Knudsen was also found to contain ostracods, and the residues were kindly made available to me for the analysis and description of the ostracod assemblages. The present paper thus augments Knudsen's several articles on the marine Holsteinian deposits of Denmark.

Very little work has been undertaken on Mid- to Late Pleistocene marine ostracods in Northwest Europe. The Hoxnian (Holsteinian) Ostracoda of the Brickearths of the River Nar Valley in Norfork, England, have been examined on several occasions (see e.g. Lord & Robinson 1978). The Bridlington Crag (Catt & Penny 1966, Neale & Howe 1975) and the Speeton Shell Bed (Edwards 1982) have also yielded Ostracoda. both deposits have conventionally been dated as Hoxnian, but the Bridlington Crag is clearly a cold water deposit with ostracod faunas which cannot be considered as indicating interglacial conditions. Robinson (in West et al. 1984) has described the Ostracoda of a Mid-Pleistocene (Holsteinian?) channel fill sequence at Earnley, Sussex. Ipswichian (Eemian) ostracods have been investigated at Shortalstown, Co. Wexford, Ireland (Whatley, in Colhoun & Mitchell 1971), Selsey, Sussex (Whatley & Kaye 1971), and in the Burtle Beds of Somerset (Whatley, in Kidson et al. 1978). Whittaker (in Kirby & Oele 1975) reported on the Ostracoda in the 'Late Pleistocene' graded sediments of the Sandettie-Fairey Bank in the English Channel off Ostend.

Woszidlo (1962) described a fauna from the Holsteinian deposits of Schleswig-Holstein and Esbjerg, Denmark, on the European mainland. Bassiouni (1965) has also listed the ostracods of the 'Esbjerg Yoldia Clay', but his material does not appear to constitute a complete fauna. The Esbjerg deposits were originally assigned to the Holsteinian interglacial (e.g. Hansen 1965), but recent amino-acid measurements on mollusc shells would suggest a pre-Holsteinian age (Miller & Mangerud 1986). Unfortunately, none of the material examined by the author from Esbjerg yielded any ostracods. There are no other published accounts of interglacial marine Ostracoda in Northwest Europe.

Material and methods

The sites chosen for this study are all located in Jutland (fig. 1). Tornskov and Inder Bjergum are in southwest Jutland, Kås Hoved is in the Limfjord area, and Hadsten and Rugård are in East Jutland.

The samples used are the same as those examined by Knudsen (1987, this volume, Jensen & Knudsen 1984, Kronborg & Knudsen 1985: all sites) and Buch (1955: Tornskov and Inder Bjergum). The results may, therefore, be directly compared, both qualitatively and quantitatively. The preparation techniques used on the raw samples were described in detail by Meldgaard & Knudsen (1979). The ostracods were obtained in part from the light foraminiferal concentrates and in part by picking the residues from which the Foraminifera had been obtained. The total assemblage, perfect and imperfect specimens alike, was picked in each sample in order to obtain a representative fauna, as far as was possible. Thus all immature moult stages (recorded as instars) were recorded along with the larger adult valves. Articulated valve-pairs (carapaces) were only very occasionally found in the analysed material. As studies on Quaternary and living Ostracoda have shown that certain types of population age-structure are indicative of either life- or death-assemblages (Whatley 1983), the above approach enabled the in-situ status of each species and overall fossil community to be assessed, thus facilitating palaeoenvironmental interpretation.

Fig. 1. Map of Denmark showing place names referred to in the text. Filled circles = sites examined in this study. Open circles = other sites.

Tornskov

The Tornskov boring (Danish Geological Survey, File no. 157. 243) was described in detail in Andersen (1963). A total of 68 samples were examined from the marine sediments between 94.7 m and 13.7 m depth (72.7 m below sea-level to 8.3 m above sea-level). Only 24 of the samples yielded Ostracoda (fig. 3). When compared with the occurrence of Foraminifera, which were present in all of the samples (Knudsen, this volume), the record of Ostracoda must be considered disappointing. To what extent this is a function of the palaeoenvironments in the Tornskov area during deposition cannot now be fully determined, but it could be due to the sediment accumulation rate, diagenesis, laboratory processing of the samples, or a combination of these factors. The small sample size (100 g dry weight) has definitely influenced both the number of species (18) and the number of specimens (1 carapace and 247 valves: fig. 3) present in the analysed material.

Ostracoda

Figure 3 should be examined in conjunction with Knudsen's (this volume: fig. 3) foraminiferal data. The boring penetrated a thick, dominantly argillaceous sequence. The Elsterian deposits at the base of the borehole (foraminiferal zones A and B) were sandier and contained no Ostracoda. Foraminiferal zone C contained ostracod assemblages characterized by *Robertsonites tuberculatus* and *Acanthocythereis dunelmensis*, with *Sarsicytheridea punctillata*, *S. bradii*, *Cytheropteron latissimum*, and *Elofsonella concinna*. There was a trend of increasing diversity and density upwards through the zone, to a maximum of 8 species and 108 valves in sample no. 76 (75 m).

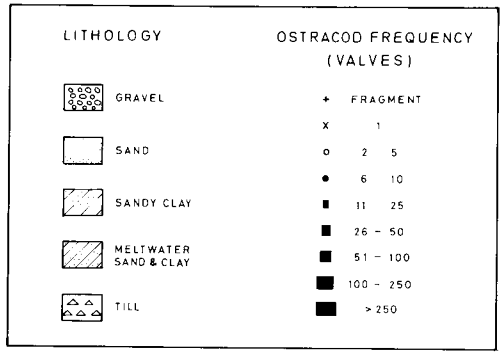
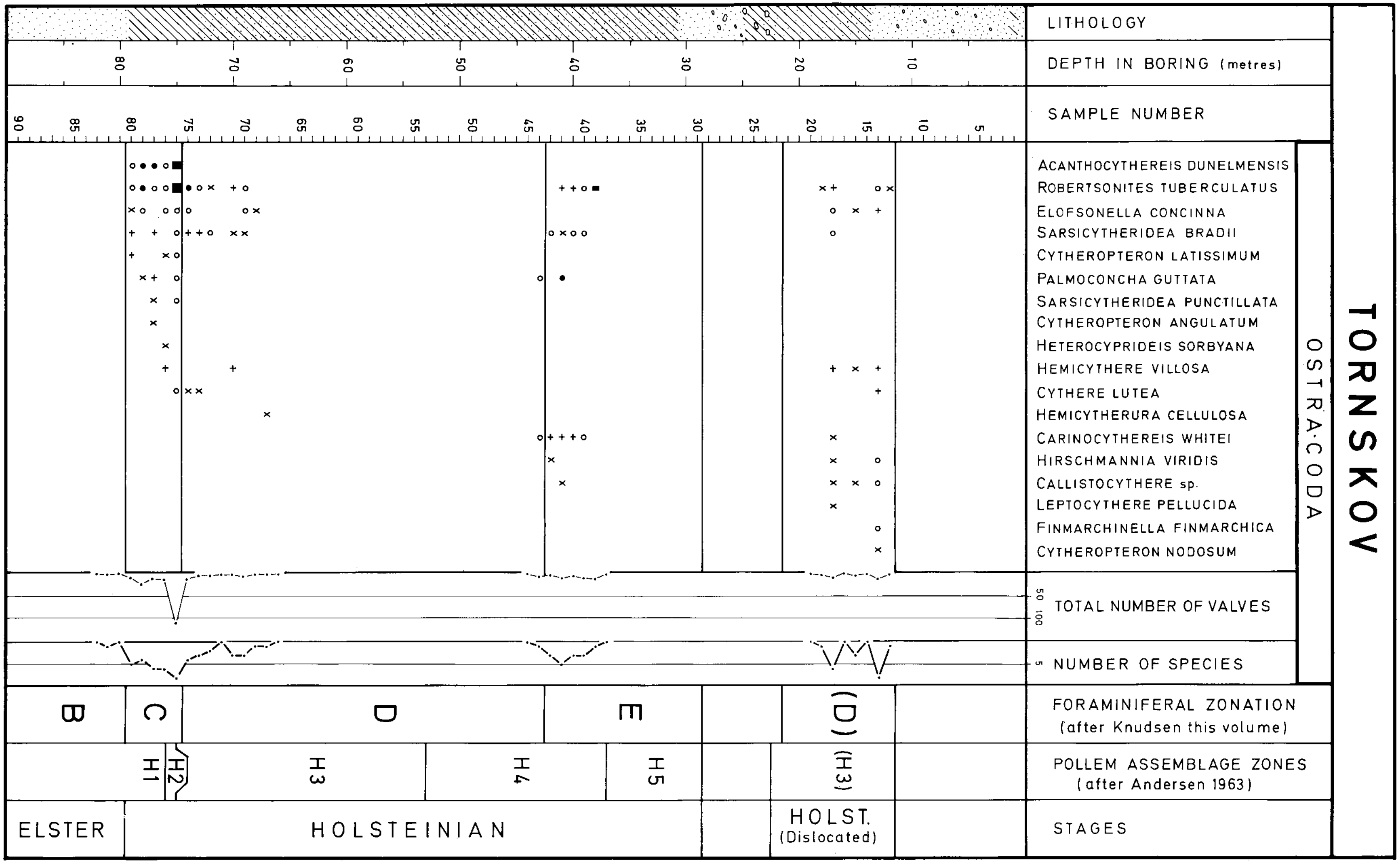


Fig. 2. Explanation of symbols used in the ostracod diagrams.

The ostracods in the remainder of the borehole distinguished themselves immediately from those in foraminiferal zone C in both their scarcity and species composition (fig. 3). Ostracoda were extremely rare in foraminiferal zone D. They occurred only sporadically and in small numbers up to 67 m (sample no. 68), and none were found between 66 m and 44 m. Knudsen's (this volume) foraminiferal assemblages were also rather sparse above 70 m (sample no. 71). The only species present were *Robertsonites tuberculatus*, *Sarsicytheridea bradii*, *Cythere*

→

Fig. 3. Distribution of Ostracoda in the Tornskov boring. The symbols used in the diagram are explained in fig. 2.



TORNSKOV
OSTRACODA
LITHOLOGY
DEPTH IN BORING (metres)
SAMPLE NUMBER
ACANTHOCYTHEREIS DUNELMENSIS
ROBERTSONITES TUBERCULATUS
ELOFSONELLA CONCINNA
SARSICYTHERIDEA BRADII
CYTHEROPTERON LATISSIMUM
PALMOCONCHA GUTTATA
SARSICYTHERIDEA PUNCTILLATA
CYTHEROPTERON ANGULATUM
HETEROCYPRIDEIS SORBYANA
HEMICYTHERE VILLOSA
CYTHERE LUTEA
HEMICYTHERURA CELLULOSA
CARINOCYTHEREIS WHITEI
HIRSCHMANNIA VIRIDIS
CALLISTOCYTHERE sp.
LEPTOCYTHERE PELLUCIDA
FINMARCHINELLA FINMARCHICA
CYTHEROPTERON NODOSUM
TOTAL NUMBER OF VALVES
NUMBER OF SPECIES
FORAMINIFERAL ZONATION (after Knudsen this volume)
B
C
D
E
(D)
POLLEM ASSEMBLAGE ZONES (after Andersen 1963)
H1
H2
H3
H4
H5
(H3)
STAGES
ELSTER
HOLSTEINIAN
HOLST. (Dislocated)

lutea, Hirschmannia viridis, Hemicythere villosa, and *Hemicytherura cellulosa. Acanthocythereis dunelmensis* did not occur above foraminiferal zone C (fig. 3).

The samples between 44 m and 39 m depth were characterized by the presence of *Carinocythereis whitei* and *Palmoconcha guttata* (as the finely punctate Scandinavian form), with *Sarsicytheridea bradii* and *Robertsonites tuberculatus.* This interval corresponded roughly to the base of foraminiferal zone E (Knudsen this volume, fig. 3). The remainder of the zone was barren of Ostracoda.

The upper marine interval between 22 m and 13.7 m contained sparse ostracod assemblages, which resembled those found at the base of foraminiferal zone D (fig. 3), with the noticeable addition of *Callistocythere* sp.

Palaeoenvironment

The ostracods present in the Tornskov boring were indicative of cold temperate, shallow waters of normal marine salinity. The four most important species in foraminiferal zone C: *Robertsonites tuberculatus, Sarsicytheridea bradii, S. punctillata,* and *Acanthocythereis dunelmensis,* are widely distributed littoral and inner neritic forms with eurythermal tolerance, and they occur commonly in North Atlantic boreal and arctic faunas (e.g. Neale 1974, Neale & Howe 1975, Lord 1980). *Elofsonella concinna, Cytheropteron latissimum,* and the finely punctate form of *Palmoconcha guttata* are also inner neritic in habit, but have their northern limit of distribution in East Finmark, at about 70°N in the eastern North Atlantic (Norman 1891, Sars 1928, Elofson 1941, Whatley & Masson 1979). *E. concinna* extends into the arctic province in the western North Atlantic, but has not been recorded live in the eastern arctic (e.g. Neale & Howe 1975). All these species are very commonly found together in the Skagerrak and Kattegat today (Elofson 1941). The assemblages lacked certain southern species that have their northern limit of distribution in the North Sea (Neale 1974). They may, therefore, indicate conditions similar to, but a little cooler than they are in the North Sea today.

The ostracod, pollen, and foraminiferal evidence are compatible in this section of the boring. Andersen (1963) recognised a typical pioneer open vegetation-type (pollen zone H1), which was succeeded by a *Pinus* dominated forest flora (pollen zone H2), and Knudsen (this volume) interpreted foraminiferal zone C as the first stage of the interglacial. She placed the Late Elsterian-Holsteinian boundary at 79.5 m depth, at the base of this zone (fig. 3).

The ostracod species found in foraminiferal zone D and the dislocated unit near the top of the borehole (fig. 3) are nearly all present in the North Sea today, and climatic conditions must, therefore, have been similar. As only immature moult stages were found, the assemblages may represent low energy death assemblages. In addition, their sparsity may have resulted from an extremely high sedimentation rate consequent on a rapid rise in sea-level, in an inshore area partially protected by a series of islands and headlands, as is the situation in the German Bight today. Some of the species are essentially euryhaline and phytal in habit (e.g. *Hirschmannia viridis* and *Hemicythere villosa*), but the majority are benthonic and require salinities greater than 30‰ outside the Baltic Sea. The *Callistocythere* species is a distinctive small, ornamented form, which is at present undescribed. Its distribution and stratigraphical significance in Northwest Europe will be returned to in the discussion.

Ostracoda reappeared in the borehole at the top of foraminiferal zone D. This coincided with a marked increase in the numbers of Foraminifera in the samples (Knudsen, this volume, fig. 3), and may indicate that the sedimentation rate had fallen. Of particular interest in the interval between 43 m (sample no. 44) and 38 m (sample no. 39) was the almost total absence of phytal, euryhaline species, and the presence of *Carinocythereis whitei*. This species inhabits Atlantic coasts from south Britain to Northwest Africa, and is widespread in the Mediterranean. It is a benthonic species, typically living on sand and silty substrates from 2–60 m depth (Athersuch et al. 1985). Its presence in foraminiferal zone E may indicate slightly warmer conditions than existed in the other foraminiferal zones. It is also noticeable that a climax forest-type vegetation (top of pollen zone H4) was being approached at this level in the borehole (Andersen 1963). The foraminiferal zone E ostracod assemblages correspond to shallow sublittoral, marine associations. Knudsen (this volume) considered the foraminiferal assemblages at the base of this zone to represent a more protected environment than either in zone D or the top of zone E. Although the ostracod assemblages included both adult valves and final moult stages, their sparsity rendered any attempt to assess whether they represented life or death assemblages highly conjectural. Knudsen's conclusions cannot, therefore, be either confirmed or rejected.

No Ostracoda were found at the top of foraminiferal zone E (fig. 3). The foraminiferal assemblages were also sparse (Knudsen this volume), and the presence of badly etched and pyritized Foraminifera in the residues was witness to the detrimental effects of diagenesis on the faunas. Any Ostracoda present were probably destroyed by these processes.

Inder Bjergum

The Inder Bjergum No. 2 boring (Geological Survey File no. 140.82b) was described in detail by Buch (1955). It penetrated a 58 m thick sequence of marine interglacial deposits between 10.23 m and 65.23 m below sea-level (fig. 4). A total of 24 samples were examined from this sequence, fourteen of which yeilded Ostracoda.

Ostracoda

Of the 19 species present in the interglacial deposits at Inder Bjergum, 12 were also recorded at Tornskov. A total of 1865 ostracod valves were found, 1090 of which were obtained from sample no. 18 (fig. 4). No Ostracoda were present below −65.7 m (sample no. 25) and above −14.8 m (sample no. 9). Rich assemblages occurred in the interval between −38.2 m and −57.7 m (sample nos 17 to 20).

Very sparse assemblages were found below −60.46 m (fig. 4). The assemblages in the succeeding samples were reminiscent of those found in foraminiferal zone C at Tornskov (fig. 3), but there were certain striking differences. In particular, *Cluthia cluthae* occurred between −60.73 m (sample no. 21) and −39.48 m (sample no. 18), its distribution overlapping above −43.23 m (sample no. 19) with *Palmoconcha laevata, Hirschmannia viridis,* and *Leptocythere* spp. The most important species in this interval in the boring were *Robertsonites tuberculatus, Acanthocythereis dunelmensis, Cytheropteron latissimum, Sarsicytheridea punctillata, S. bradii,* and *Elofsonella concinna,* with *Palmoconcha guttata* occurring above −52.7 m (sample no. 20).

Palaeoenvironment

The Ostracoda of the Inder Bjergum No. 2 boring were indicative of cold temperate, shallow waters of normal marine salinity, i.e. similar environmental conditions as existed during the deposition of foraminiferal zone C at Tornskov. The pollen and foraminiferal evidence (Andersen 1963, Buch 1955, Knudsen this volume) would place the Elsterian-Holsteinian boundary at −42.3 m (sample no. 19). No sharp boundary could, however, be distinguished on the basis of the ostracod assemblages. Rather, there was a gradual change in the faunas between −60.7 m (sample no. 21) and −39.5 m (sample no. 18), as certain species of arctic affinity died out, to be replaced by boreal species.

The arctic species included *Cluthia cluthae,* which has its southern limit of distribution today in East Finmark, North Norway (Norman 1891, Neale 1973). Earlier records of this species from as far south as the Celtic Sea have proved to be of *Cluthia keiji,* a related but more thermophilous species (Neale 1975). Another arctic species is *Heterocyprideis sorbyana,* which was also found in foraminiferal zone C at Tornskov. This species lives today in the Baltic Sea (Hirschmann 1912, Elofson 1941, Rosenfeld 1977), but its main distribution is in the arctic, and Hirschmann (1912) considered it to be a glacial relict species in the Baltic. *Palmoconcha laevata, P. guttata, Cytheropteron latissimum, Hirschmannia viridis,* and *Leptocythere* spp., on the other hand, all have their northern limit of distribution in East Finmark (e.g. Norman 1891, Sars 1928, Elofson 1941, Whatley & Masson 1979).

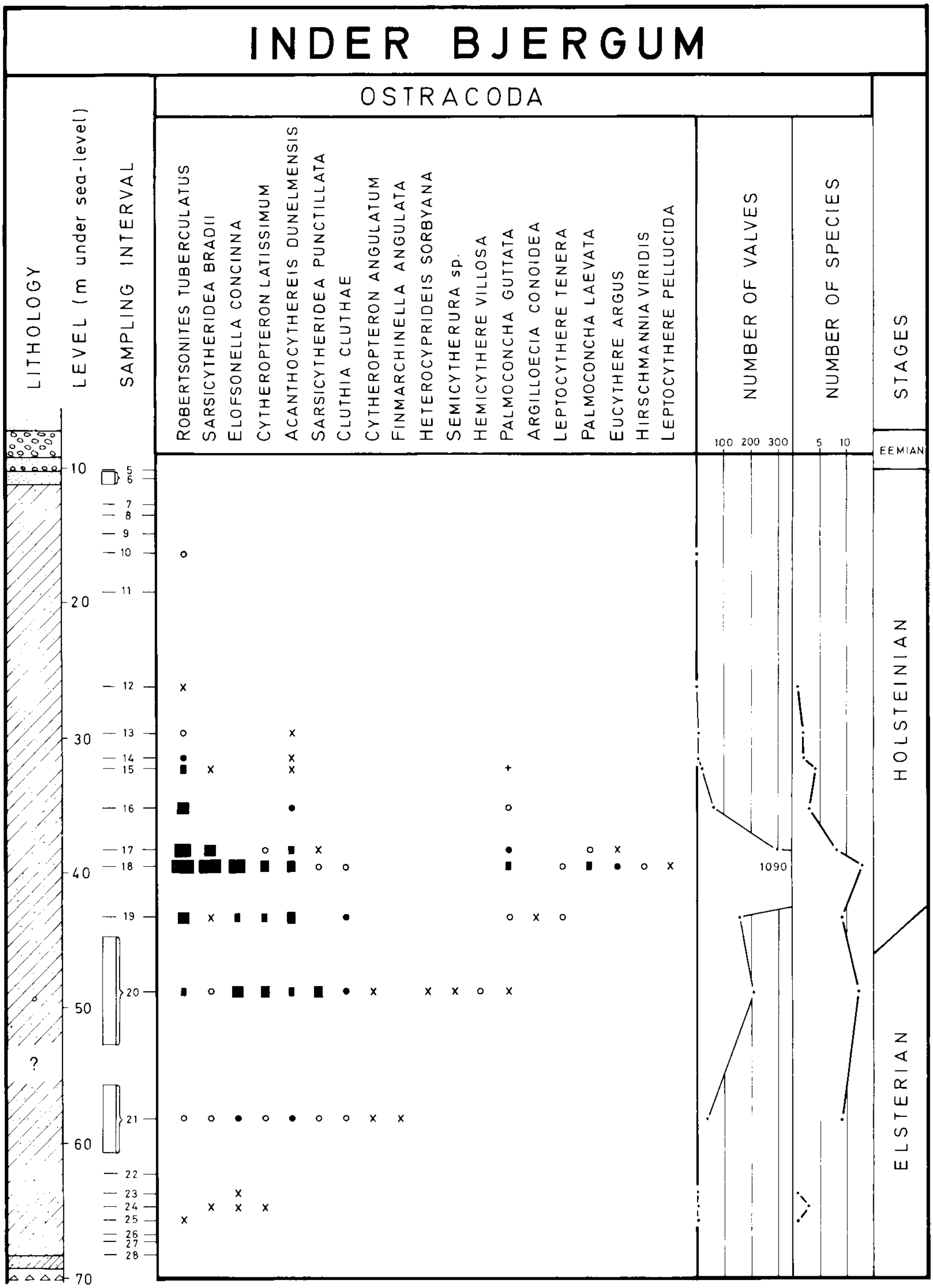


Fig. 4. Distribution of Ostracoda in the Inder Bjergum No. 2 boring. Symbols used in this diagram are explained in fig. 2.

The assemblages in sample nos 20 and 21 were, thus, comparable to the ostracod faunas of the northern Norwegian province today, whereas the faunas found above −43.2 m (sample no. 19) reflected slightly warmer conditions. The differences in the assemblages were, however, very slight, as the most important species were the same both above and below the Elsterian-Holsteinian boundary (fig. 4).

Kås Hoved

Marine deposits are exposed at the base of a cliff-section at Kås Hoved in the Limfjord (fig. 1). These massive dark grey silty clays underlie a sandy till, which was deposited from the northeast (Jensen & Knudsen 1984). The sediments are bioturbated and contain worm burrows. They are full of articulated shells of *Nuculana (Leda) pernula,* a species which lives at water depths of greater than 15–20 m. The marine sequence contains boreal shelf foraminiferal faunas, also from a water depth of more than 15 m. The deposits are considered to be Holsteinian in age (Jensen & Knudsen 1984, Miller & Mangerud 1986).

Ostracoda

A total of 4 ostracod carapaces and 2762 valves belonging to 18 species, were found in the 6 samples examined from the marine clays at Kås Hoved (fig. 5). Sample no. 755 was almost barren, but the other samples contained from 327 to 922 valves in each. The assemblages were totally dominated by

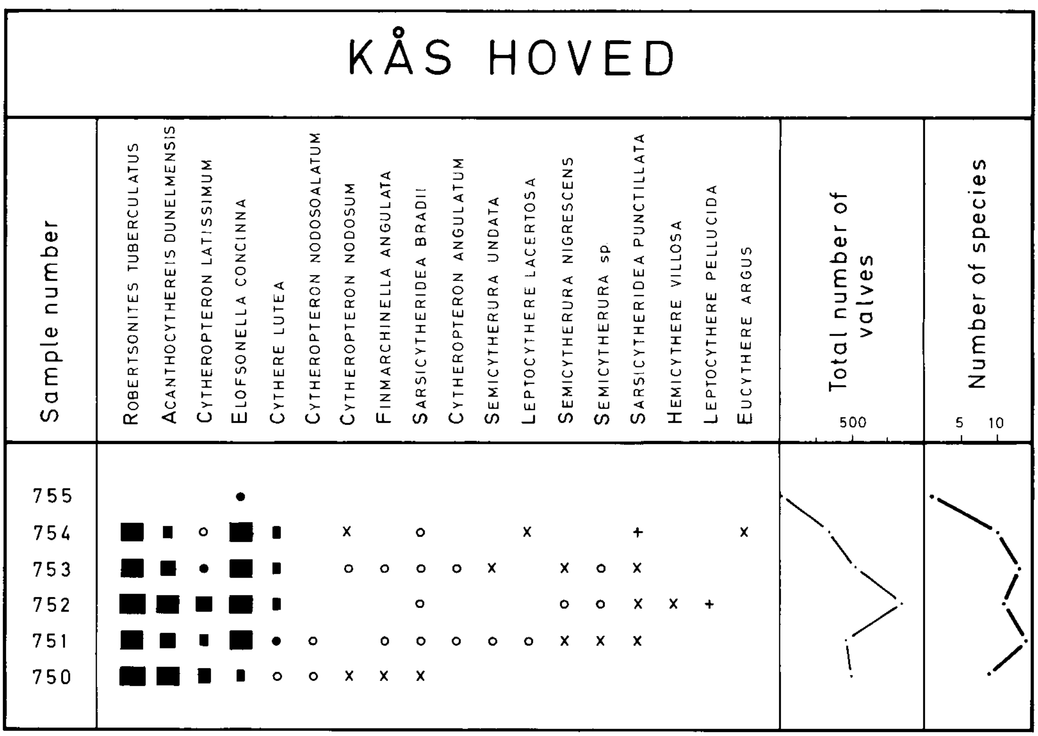


Fig. 5. Distribution of Ostracoda in the Holsteinian deposits at Kås Hoved (Limfjord). Sample numbers are the same as those used by Jensen & Knudsen 1984. The symbols used are explained in fig. 2.

adult valves and immature moult stages of *Robertsonites tuberculatus, Acanthocythereis dunelmensis, Elofsonella concinna,* and *Cytheropteron latissimum,* which together accounted for 94% to 98% of the total in each sample. The only other species of importance, *Cythere lutea,* showed an increase from 0.3% of the assemblage in sample no. 750 to 3.7% in sample no. 754. *Elofsonella concinna* also increased (4.5% to 31%), while *Acanthocythereis dunelmensis* (26% to 13%) and *Cytheropteron latissimum* (7.5% to 1%) both decreased in importance.

The assemblages contained an as yet undiscribed *Semicytherura* species. This is a small, slightly elongated form, with a very distinctive pattern of punctae in the dorsocentral part of the valve (Plate 2, figs. 5, 6).

Palaeoenvironment

The ostracod assemblages present in the Kås Hoved deposits are cold temperate, shallow shelf faunas. They were very similar to the assemblages found in foraminiferal zone C at Tornskov, and in the Inder Bjergum No. 2 boring (figs 3 & 4). Most of the species are benthonic in habit, but a few phytal forms, including *Hemicythere villosa* and *Semicytherura nigrescens,* were present. These species may have been washed in from shallower waters. The changes in faunal composition described above may have been temperature related, suggesting a slight warming, but could also indicate a slight reduction in water depth upwards in the profile. Knudsen's (Jensen & Knudsen 1984) foraminiferal assemblages were very uniform in composition, and showed no shallowing trend.

Rugård

Kronborg & Knudsen (1985) gave a preliminary account of the Quaternary section exposed in the coastal cliff at Rugård in eastern Jutland (fig. 1). These deposits were divided up into an upper and lower glacial series, separated by marine sediments. The latter rested unconformably on the lower glacial series and were up to 2.5 m thick. They comprised a lower fine silty sand with peat inclusions and an upper oyster-rich clay (Kronborg & Knudsen 1985). The foraminiferal assemblages in the marine deposits recorded a transition from shallow brackish water conditions in the silty sands to a more open marine environment with water depths of greater than 30 m in the oyster bearing clays. These deposits were tentatively placed in the Holsteinian interglacial (Kronborg & Knudsen 1985), an interpretation which has recently been supported by thermoluminescence measurements on the marine sediments at Rugård (Knudsen 1987).

Ostracoda

No Ostracoda were present in either the brackish water horizon at Rugård, or in the lower part of the oyster-bearing clays. The Foraminifera were also very badly preserved in these layers (samples F6-F2: fig. 6). A total of 405 valves were found in sample F1, belonging to 9 species. *Elofsonella concinna* dominated (87%), and the only other species of importance was *Robertsonites tuberculatus* (10%). Of note was the presence of *Krithe praetexta* and a single adult valve of *Cytheropteron inornatum*. Neither of these two species have been found in any other Holsteinian marine deposit in Jutland.

RUGÅRD

Sample number	Elofsonella concinna	Robertsonites tuberculatus	Acanthocythereis dunelmensis	Cytheropteron latissimum	Sarsicytheridea bradii	Sarsicytheridea punctillata	Finmarchinella finmarchica	Krithe praetexta	Cytheropteron inornatum	Cytheropteron crassipinatum	Palmoconcha guttata	Leptocythere castanea	Pterygocythereis coronata	Prequaternary cytherellid	Total number of valves	Number of species
16 (NPM)*	•	■		x	o	■							x		37	6
F. 1a*	■	■	x			■								o	109	4
F. 1b	■	■			•	o				x	x	x			194	4
F. 1	■	■	x	o	o	o	x	x	x						405	9
F. 2															0	0
F. 3															0	0
F. 4															0	0
F. 5															0	0
F. 6															0	0

* = LIGHT FORAMINIFERAL CONCENTRATE ONLY

Fig. 6. Distribution of Ostracoda in the Holsteinian deposits at Rugård (East Jutland). Sample nos F1-F6 are the same as those used by Kronborg & Knudsen 1985. Nos NPM-16 and F1a are the same as those given in Knudsen 1987. The symbols are explained in figure 2.

Three further samples were examined from the upper part of the oyster-bearing clays at Rugård (fig. 6). These contained ostracod assemblages which resembled that found in sample no. F1, with some noteworthy additions. *Sarsicytheridea punctillata* was an important species in two of the samples (nos F1a and 16). In addition, three adult valves of a pre-Quaternary cytherellid were found in sample no. F1a, an adult valve of *Cytheropteron crassipinatum* in sample no. F1b, and a juvenile valve of *Pterygocythereis coronata* in sample no. 16 (fig. 6).

Palaeoenvironment

The ostracod assemblages present in the Rugård deposits resembled those present in the Tornskov and Inder Bjergum borings and at Kås Hoved, but they contained a few species which live in fairly deep waters in the North Atlantic today. These included *Krithe praetexta,* which has been found from 50 m to 500 m depth in Northwest Europe (Athersuch 1982), and *Cytheropteron inornatum*, which occurs from 25 m to 50 m depth off western Britain (Whatley & Masson 1979), but is also known from deeper waters in the Adriatic (Bonaduce et al. 1975).

Pterygocythereis coronata was also found in the Hadsten boring (see below). It is a widespread benthonic marine species in the Mediterranean, but is also found on the North Atlantic coast south of Northwest Scotland (Athersuch 1978). There are no records of *Pt. coronata* from the North Sea and it has not previously been found in interglacial deposits in Northwest Europe. *Cytheropteron crassipinatum* was classified by Whatley & Masson (1979) as a boreal species whose geographical range is between 50°N and 60°N off the west coast of Europe.

The above-mentioned taxa constitute only a small fraction of the total fauna at Rugård. While some of these species inhabit relatively deep water in the Skagerrak and Kattegat today (Elofson 1941), no modern ostracod fauna in that area exactly matched the Rugård material. Elofson, however, observed faunas which were not unlike the Rugård assemblages between 20 m and 50 m depth. The Ostracoda at Rugård may, thus, indicate cold temperate, marine waters of over 20 m to 30 m depth, but probably shallower than 50 m.

Hadsten

Marine deposits have also been recorded at the base of a 74 m deep boring at Hadsten, East Jutland (Geol. Surv. File no. 78.458) (fig. 1). These sediments, which occurred between 69 m and 74 m depth (31 m to 36 m below mean sea-level), were divided into a basal silty clay possessing arctic Foraminifera, overlain by fine sand and silty clay containing boreal foraminiferal assemblages (Knudsen 1987). Knudsen considered the basal clay to have been deposited in the Late Elsterian, and the overlying sediments to belong to the Holsteinian interglacial.

Ostracoda

Only the upper two of the four samples examined by Knudsen (1987) contained Ostracoda (fig. 7). The species composition was reminiscent of that recorded at Rugård (fig. 6). *Elofsonella concinna* dominated the assemblages (65% to 74%), and *Sarsicytheridea bradii, S. punctillata, Acanthocythereis dunelmensis,* and *Robertsonites tuberculatus* were also recorded at both sites. Of interest was the presence of *Carinocythereis whitei,* which was also found in foraminiferal zone E at Tornskov (fig. 3), and *Pterygocythereis coronata.*

HADSTEN									
Sample depth	Elofsonella concinna	Sarsicytheridea bradii	Robertsonites tuberculatus	Acanthocythereis dunelmensis	Sarsicytheridea punctillata	Pterygocythereis coronata	Carinocythereis whitei	Number of valves	Number of species
69 m	■	o	o	•	o	o	o	138	7
71 m	▮	o	x					43	3
73 m								0	0
75 m								0	0

Fig. 7. Distribution of Ostracoda in Holsteinian marine deposits in the Hadsten boring. Sample numbers are the same as those given in Knudsen 1987. The symbols are explained in fig. 2.

Palaeoenvironment

Only adult carapaces and valves were found in the Hadsten material. This, coupled with the fact that many of the specimens were etched and stained red, suggested that relatively high energy conditions existed at the site. Species composition indicated the presence of relatively open, sublittoral conditions and normal marine salinities. The marine deposits at Hadsten are probably glacially deformed, and may have been transported as a frozen block from the east. This deposit's location in East Jutland is, nonetheless, of interest, as it could indicate that an open sound existed across North Jutland during the Late Elsterian and Holsteinian, connecting the North Sea to the Kattegat.

Age and correlation

Recent advances in absolute dating techniques have meant that we can now be fairly sure of the stratigraphic position of several interglacial marine deposits in Denmark. Thus, Tornskov, Rugård, and Kås Hoved have all been assigned to the Holsteinian interglacial on the basis of amino-acid and thermoluminescence measurements (Miller & Mangerud 1986, Knudsen 1987). More traditional methods must be resorted to where absolute dates are unavailable. The interglacial deposits at Inder Bjergum have, for example, been assigned to the Holsteinian on the basis of their pollen (Andersen 1963) and foraminiferal (Buch 1955, Knudsen this volume) content, and because they are overlain by Eemian marine sediments (Buch 1955). The interglacial deposits at Hadsten have also been placed in the Holsteinian on the basis of their foraminiferal content (Knudsen 1987).

Considerable uncertainty lies in the use of biological correlation techniques in Quaternary stratigraphy, not least because very few genuine extinction events are recognisable in the Pleistocene. Thus, presence/absence data largely reflect environmental control rather than genetic (=evolutionary) events. The apparent similarity in the biological composition of assemblages from two or more deposits need not, therefore, necessarily mean that they are of the same age. Minor differences do, however, often occur, and these can be used productively to distinguish between interglacials. Thus, considerable steps have been made to differentiate between Eemian marine deposits and sediments belonging to earlier interglacials using Foraminifera (Knudsen 1986).

Unfortunately, no such advances have been forthcoming for Ostracoda, as they have not been examined in detail in the Danish Eemian. I have studied some borehole material from the marine Eemian embayment in Southwest Jutland (see fig. 8), but the deposits here are from the intertidal environment, and cannot, therefore, be compared directly with the shallow, sublittoral sediments of the Danish Holsteinian. Deeper water Eemian deposits occur in North Jutland (e.g. Bahnson et al. 1974), but their ostracod content remains to be examined. Two samples from a sublittoral facies of the Eemian, from a boring at Nørre

Species	Sample no. 83 c	Sample no. 83 v	Sample no. 84 c	Sample no. 84 v
Sarsicytheridea punctillata	1	61	4	150
Acanthocythereis dunelmensis	–	33	2	15
Elofsonella concinna	–	1	–	3
Krithe pernoides	–	2	1	–
Palmoconcha laevata	1	–	–	–
Normanicythere leioderma	–	–	–	2
Total	2	97	7	170

Table 1.: Nørre Lyngby Eemian deposits: species list and abundances (c = carapaces, v = valves).

OSTRACOD SPECIES / LOCALITIES	Tornskov	Inder Bjergum	Kås Hoved	Rugård	Hadsten	Earnley (Mid Pleistocene)	Nar Valley (Hoxnian)	Hamburg (Holsteinian)	Sandettie (Late Pleistocene?)	Højer (Eemian)	Skagerrak (Recent)
ACANTHOCYTHEREIS DUNELMENSIS	X	X	X	X	X			X			X
ARGILLOECIA CONOIDEA		X						X			X
CALLISTOCYTHERE sp.	X					X		X	X		
CARINOCYTHEREIS WHITEI	X				X	X	X	X			
CLUTHIA CLUTHAE		X						X			
CYTHERE LUTEA	X		X					X		X	X
CYTHEROPTERON ANGULATUM	X	X	X					X			X
CYTHEROPTERON CRASSIPINATUM				X							X
CYTHEROPTERON INORNATUM				X							
CYTHEROPTERON LATISSIMUM	X	X	X	X				X		X	X
CYTHEROPTERON NODOSOALATUM			X								
CYTHEROPTERON NODOSUM	X		X					X			X
SEMICYTHERURA sp		X	X					X			
ELOFSONELLA CONCINNA	X	X	X	X	X		X	X	X	X	X
EUCYTHERE ARGUS		X	X					X		X	X
FINMARCHINELLA ANGULATA		X	X					X	X	X	X
FINMARCHINELLA FINMARCHICA	X			X		X	X	X	X	X	X
HEMICYTHERE VILLOSA	X	X	X			X	X	X	X	X	X
HEMICYTHERURA CELLULOSA	X					X	X				X
HETEROCYPRIDEIS SORBYANA	X	X						X			
HIRSCHMANNIA VIRIDIS	X	X				X	X	X		X	X
KRITHE PRAETEXTA				X			?				X
LEPTOCYTHERE CASTANEA				X		X		X		X	X
LEPTOCYTHERE LACERTOSA			X			X		X		X	X
LEPTOCYTHERE PELLUCIDA	X	X	X			X	X	X	X	X	X
LEPTOCYTHERE TENERA		X				X		X		X	X
PALMOCONCHA GUTTATA	X	X		X		X	X	X		X	X
PALMOCONCHA LAEVATA		X						X		X	X
PTERYGOCYTHEREIS CORONATA				X	X						
ROBERTSONITES TUBERCULATUS	X	X	X	X	X		X	X	X	X	X
SARSICYTHERIDEA BRADII	X	X	X	X	X		X	X			X
SARSICYTHERIDEA PUNCTILLATA	X	X	X	X	X			X		X	X
SEMICYTHERUPA NIGRESCENS			X			X	X	X		X	X
SEMICYTHERURA UNDATA			X			X		X			X

Fig. 8. Ostracod distribution by age and site. Sources: Tornskov, Inder Bjergum, Kås Hoved, Rugård, and Hadsten – this study; Earnley – West et al. 1984; Nar Valley – Lord & Robinson 1978 and West et al. 1984; Hamburg – Woszidlo 1962 and Lord, Robinson and Moutzourides in-press; Højer – Penney unpublished data; Skaggerak – Elofson 1941 and Sars 1928.

Lyngby (fig. 1), were kindly placed at my disposal by Anne-Lise Lykke-Andersen. These contained ostracod assemblages (Table 1) which were rather similar in species composition to those recorded at Rugård (fig. 6), but which lacked *Robertsonites tuberculatus.* In addition, the Nørre Lyngby material was dominated by *Sarsicytheridea punctillata,* whereas *Elofsonella concinna* dominated the Rugård assemblages. It is not clear if these differences are of any significance in distinguishing between the Holsteinian and Eemian interglacials, as the possibility remains that they are simply the result of a combination of facies, water depth, and temperature controls.

The ecological patterns discussed in the first part of this paper are based on the evidence drawn from the vast majority of species on the faunal list (fig. 8). Nearly all of these species are alive today, but a few are not part of the living faunas in Danish inshore waters. The latter include species which have their present northern limits of distribution in South Britain, and at least one which may be extinct. Both categories may tell us something about the relative age of the Tornskov, Inder Bjergum, Kås Hoved, Rugård, and Hadsten deposits.

Of the species which can suggest an age, several bear a striking resemblance to those found in the Hoxnian (Holsteinian) Nar Valley Clays of East England (e.g. Lord & Robinson 1978) and the Holsteinian marine deposits of the Hamburg area, North Germany (Woszidlo 1962, Lord et al. in-press). One such form is *Carinocythereis whitei,* a warm water indicator, which was present at Tornskov (foraminiferal zone E) and Hadsten (figs 2 and 7). This is actually the senior synonym of both *C. aspera* (Brady) and *C. bairdii* Uliczny (see Athersuch et al. 1985). It has also been recorded in the Mid-Pleistocene (Late Cromerian-Late Hoxnian) estuarine deposits at Earnley (Robinson, in West et al. 1984), but has not been found in the Eemian deposits of Great Britain (e.g. Whatley, in Kidson et al. 1978, Whatley & Kaye 1971).

The undescribed *Callistocythere* species found in the Tornskov boring (fig. 2) has also been recorded at Earnley (Robinson, in West et al. 1984), Dockenhuden (qho 4) in the Hamburg area (Lord et al. in-press), the Red Crag of Great Britain, and the graded sediments of the ?Late-Pleistocene Sandettie-Fairey Bank in the English Channel (Whittaker, in Kirby & Oele 1975, Robinson, in West et al. 1984). It has not been recorded live, its present known stratigraphic range spanning the Early Pleistocene Red Crag to the ?Holsteinian interglacial.

The undescribed *Semicytherura* species is very close to what Lord et al. (in-press) called *Semicytherura* sp. A from the Holsteinian of Hamburg. This species has only been found in Holsteinian sediments to-date.

There are no published records of *Pterygocythereis coronata* from the Pleistocene of Northwest Europe, its known range spanning only the Sub-recent and Recent (Athersuch 1978). *Pt. coronata* is actually the senior synonym of *Pt. siveteri* Athersuch (see Malz & Jellinek 1984). As it was previously considered as either conspecific with *Pt. ceratoptera* (Bosquet), or as a sub-species or variety of *Pt. jonesii* (Baird), the possibility remains that it has been grouped under these species-names in the Quaternary. It is widespread in the Plio-Pleistocene and Recent of the Mediterranean Sea (Athersuch 1978, Breman 1976).

Palmoconcha guttata occurred as the finely punctate Scandinavian form in the Danish Holsteinian. The same finely punctate form was also recorded in the Holsteinian deposits of North Germany (Woszidlo 1962, Lord et al. in-press), in the Mid-Pleistocene deposits at Earnley (Robinson, in West et al. 1984), and the Hoxnian Nar Valley clays (Robinson, in West et al. 1984: Table 2) (fig. 8). I have found coarsely reticulate and intermediate forms of this species in the Eemian deposits of Southwest Jutland, but only the finely punctate form is part of the Danish fauna today.

The two arctic species *Cluthia cluthae* and

Species	c	v	%
Elofsonella concinna	2	512	57
Sarsicytheridea punctillata	–	222	24
Acanthocythereis dunelmensis	–	74	8
Heterocyprideis sorbyana	–	26	3
Cytheropteron latissimum	–	16	2
Finmarchinella angulata	–	15	2
Cluthia cluthae	–	14	2
Cytheropteron nodosum	–	11	1
Semicytherura sp.	–	6	–
Cytheropteron nodosoalatum	–	4	–
Robertsonites tuberculatus	–	3	–
Argilloecia conoidea	–	1	–
Total	2	904	100

Table 2. Sebberkloster, sample no. 18–21 (40 g sediment): species list and abundances (c = carapaces, v = valves).

Heterocyprideis sorbyana are not found alive in Danish waters today. They occurred both immediately below and above the Elsterian-Holsteinian boundary in the Inder Bjergum boring (fig. 3), and have also been found immediately below the same boundary in a boring at Sebberkloster in North Jutland (fig. 1). The latter material contained an ostracod assemblage which had a striking resemblance to that recorded in sample no. 20, just under the Elsterian-Holsteinian boundary at Inder Bjergum (compare fig. 4 & Table 2). Both these species have been recorded in a similar stratigraphic position at Eggstedt in North Germany (Lord et al. in-press). Another feature in common for both Eggstedt and Inder Bjergum was the overlap in distribution of *C. cluthae* with its temperate equivalent, *Leptocythere*. Indeed, the ostracod assemblages of the Danish and North German Holsteinian were very similar in both species and assemblage composition, and in their sparsity. *Acanthocythereis dunelmensis, Cytheropteron latissimum, Elofsonella concinna, Palmoconcha guttata, Robertsonites tuberculatus, Sarsicytheridea bradii,* and *S. punctillata* were important members of the faunas in both regions. In addition, the faunal succession found by Lord et al. (in-press) in the Eggstedt boring was the same as that recorded at Inder Bjergum (fig. 4), while the ostracod assemblages present in the Dockenhuden boring corresponded more closely to those found in foraminiferal zones D and E at Tornskov (fig. 2). Comparison can also be made with the Hoxnian assemblages of the Nar Valley clays (Lord & Robinson 1978), although *Carinocythereis whitei* was a much more important species in the English material.

The species considered above as possible characteristic species for the Holsteinian of Denmark constitute only 15% of the total fauna, the remainder ranging on to be part of the living ostracod fauna of Denmark. My preliminary investigations of the Eemian sequence in Southwest Jutland have not yielded a single 'extinction' to-date. These figures correspond closely to those given by Robinson (in West et al. 1984) for the Mid-Pleistocene, Eemian, and Recent of southern Britain. It is interesting to note that in the faunas of the Danish and North German Holsteinian, species that are not now part of the living fauna of the region are to be found either off southern Britain to the south or East Finmark to the north. As Robinson (in West et al. 1984) stated, to some extent this may be a response of climatic changes, resulting in faunal displacements north and south, with some species failing to migrate and readjust ecologically.

Species list

The ostracod species present in the marine Holsteinian deposits of Jutland are listed alphabetically below. A total of 35 species were found, nine of which are illustrated in Plates 1 and 2.

Acanthocythereis dunelmensis (Norman 1865) – Pl. 2, figs. 9, 10
Argilloecia conoidea Sars 1928
Callistocythere sp. – Pl. 1, figs 1, 2
Carinocythereis whitei (Baird 1850) – Pl. 1, figs 3–6
Cluthia cluthae (Brady, Crosskey and Robertson 1874) – Pl. 1, figs 7, 8
Cythere lutea O. F. Müller 1785
Cytheropteron angulatum Brady and Robertson 1872
Cytheropteron crassipinatum Brady and Norman 1888 – Pl. 1, fig. 9
Cytheropteron inornatum Brady and Robertson 1872 – Pl. 1, fig. 10
Cytheropteron latissimum (Norman 1865)
Cytheropteron nodosoalatum Neale and Howe 1973
Cytheropteron nodosum Brady 1868
Elofsonella concinna (Jones 1856)
Eucythere argus (Sars 1866)
Finmarchinella (Barentsòvia) angulata (Sars 1866)
Finmarchinella (Finmarchinella) finmarchica (Sars 1866)
Hemicythere villosa (Sars 1866)
Hemicytherura cellulosa (Norman 1865)
Heterocyprideis sorbyana (Jones 1856)
Hirschmannia viridis (O. F. Müller 1785)
Krithe praetexta (Sars 1866)
Leptocythere castanea (Sars 1866)
Leptocythere lacertosa (Hirschmann 1912)
Leptocythere pellucida (Baird 1850)
Leptocythere tenera (Brady 1868)
Palmoconcha guttata (Norman 1865) – Pl. 2, figs 7, 8
Palmoconcha laevata (Norman 1865)
Pterygocythereis coronata (Roemer 1838) – Pl. 2, figs 1–4
Robertsonites tuberculatus (Sars 1866)
Sarsicytheridea bradii (Norman 1865)
Sarsicytheridea punctillata (Brady 1865)
Semicytherura nigrescens (Baird 1838)
Semicytherura sella (Sars 1866)
Semicytherura undata (Sars 1866)
Semicytherura sp. – Pl. 2, figs. 5, 6

Conclusions

Evidence from the ostracod faunas indicates convincingly that the Holsteinian marine sediments at the five sites considered above were all deposited under relatively open water, sublittoral conditions and normal marine salinities. Brackish water ostracod assemblages have not been recorded in the Danish Holsteinian to-date. The oyster-bearing clays at Rugård were deposited in slightly deeper waters than at the other sites.

Although the examined material contained mainly sparse ostracod assemblages, certain distinct characteristics were observed which may prove to be useful for correlation purposes.

(1) Arctic and boreal-arctic species occurred together with some temperate species both above and below the late Elsterian-Holsteinian boundary, thus making it difficult to position the boundary exactly using Ostracoda. Of particular interest, however, was the overlap in distribution of the arctic *Cluthia cluthae* with its temperate equivalent, *Leptocythere,* and the occurrence of both *Palmoconcha guttata* and *Cytheropteron latissimum* below the boundary.

(2) Boreal-arctic and boreal species dominated the Danish Holsteinian faunas. These included *Robertsonites tuberculatus, Elofsonella concinna, Sarsicytheridea bradii, S. punctillata,* and *Cytheropteron latissimum,* while *Acanthocythereis dunelmensis* died out early on in the interglacial.

(3) Certain temperate species, which have their present northern limits of distribution in southern Britain, occurred later in the interglacial. These included *Carinocythereis whitei, Pterygocythereis coronata,* and *Callistocythere* sp. The latter species has a known range from the Early Pleistocene to the Holsteinian. An undescribed *Semicytherura* species has only been found in the Holsteinian of North Germany and Denmark.

(4) The finely punctate form of *Palmoconcha guttata* has been found in both the Holsteinian and Recent of Denmark, whereas the coarsely reticulate form of this species has only been recorded in the Eemian of Southwest Jutland.

(5) The ostracod assemblages of the Danish Holsteinian are similar to those present in the Holsteinian of North Germany (Woszidlo 1962, Lord et al. in-press), and are not unlike those found in the Hoxnian Nar Valley clays of East England (e.g. Lord & Robinson 1978). Eemian deposits in Northwest Europe do not contain the same faunas, but there are problems in comparing the two interglacials, as the Eemian ostracod lists have largely been derived from intertidal deposits, whereas the Holsteinian lists are from shallow, sublittoral environments. Moreover, very few ostracod studies have been undertaken on marine interglacial deposits in Northwest Europe in general, thus making it very difficult to compare and correlate between sites.

These characteristics may be specific for the Holsteinian, and may, therefore, be useful in Quaternary stratigraphical studies of interglacial marine deposits. In particular, the proportion of extant species absent from Danish waters today can probably be used as a guideline to differentiate between interglacials.

Acknowledgements

I would like to thank the Geological Survey of Denmark for providing most of the material studied. Thanks also to Karen Luise Knudsen (Århus) and Anne-Lise Lykke-Andersen (Århus) for placing material at my disposal. I am grateful to Karen Luise Knudsen, Alan Lord (University College London), and Eric Robinson (University College London) for advice and discussion, and for allowing access to unpublished data. Jette Gissel Nielsen prepared the figures and Svend Meldgaard Christiansen the photographs for the plates.

Dansk sammendrag

Ostrakoder i Holstein Interglaciale aflejringer i Jylland, Danmark.

Der er undersøgt ostrakod-faunaer fra fem forskellige Holstein Interglaciale lagserier i Jylland: Tornskov og Inder Bjergum i SV Jylland, Kås Hoved i Limfjordsområdet og Rugård og Hadsten i Øst-Jylland (fig. 1).

Der findes kun meget få ostrakoder i Tornskov boringen. Sen Elster aflejringerne ved bunden af boringen (Foraminifer-zonerne A og B), samt en stor del af foraminifer-zone D er tomme (fig. 3). Ostrakoder blev først truffet i zone C, hvor faunasammensætningen svarer nogenlunde til recente faunaer i den nordlige Nordsøregion. Mere typiske Nordsø-faunaer er fundet i bunden af foraminifer-zone D. Ostrakod-sammensætningen ved zone D-E grænsen indikerer lidt varmere forhold end i Nordsøen i dag, idet der forekommer en del arter, som har deres nuværende nordligste udbredelse syd for England.

Relativt åbne marine forhold er afspejlet gennem hele lagserien. Dette passer godt med de faunistiske tolkninger baseret på foraminifererne.

Det glacialt forstyrrede lag ved toppen af boringen indeholder ostrakod-faunaer, som ligner de faunaer, der er fundet ved bunden af foraminifer-zone D. Ostrakoderne i den marine Holstein lagserie ved Inder Bjergum (fig. 4) svarer til dem, som er fundet i den nedre del af Tornskov serien, men ved Inder Bjergum forekommer desuden ostrakoder under Elster-Holstein grænsen. De sidstnævnte viser, at et ret koldt miljø har eksisteret i området før interglacialens begyndelse. Fauna-sammensætningen er næsten den samme under og over grænsen, og det er derfor vanskeligt at placere grænsen nøje med ostrakoder alene. Små ændringer viser dog, at der er en gradvis ændring fra et subarktisk til borealt miljø.

Et tilsvarende borealt miljø er repræsenteret i Holstein aflejringer ved Kås Hoved i Limfjordsområdet (fig. 3).

De ostrakod-faunaer, som er fundet ved Rugård i Øst-Jylland (fig. 6), er lidt forskellige fra faunaerne ved de andre lokaliteter. Her er fundet arter, der tyder på lidt dybere vand, måske mellem 30 og 50 m dybde. Her, og i Hadsten boringen (fig. 7), er der også fundet arter, som indikerer et lidt varmere miljø end i det nuværende Kattegat.

Det er meget vanskeligt at sammenligne Holstein ostrakod-faunaer med faunaer fra andre interglacialer, fordi kun få undersøgelser er publiceret indtil nu, men der forekommer nogle specielle fauna-sammensætninger og arter i de danske marine Holstein lag, som kan være af biostratigrafisk betydning.

Følgende punkter kan fremhæves på nuværende tidspunkt:

1. Arktiske og boreal-arktiske ostrakoder er fundet sammen ved Elster-Holstein grænsen. Af speciel interesse er tilstedeværelse af den arktiske *Cluthia cluthae* sammen med de tempererede *Leptocythere* spp., *Palmoconcha guttata* og *Cytheropteron latissimum.*
2. Boreal-arktiske og boreale arter dominerer det danske Holstein. Vigtige arter er *Robertsonites tuberculatus, Elofsonella concinna, Sarsicytheridea bradii, S. punctillata* og *Cytheropteron latissimum,* mens *Acanthocythereis dunelmensis* kun er fundet tidligt i interglacialen.

3. I det danske Holstein optræder nogle tempererede arter som ikke er fundet i dag nord for Syd- og Vest-England. Vigtige arter er *Carinocythereis whitei, Pterygocythereis coronata* og en ubeskrevet art af *Callistocythere*. Sidstnævnte art og en ubeskrevet *Semicytherura* art er mulige ledefossiler for det Nord-Europæiske Holstein.
4. Den fint-punkterede form af *Palmoconcha guttata* er udbredt i Holstein og i recente aflejringer i Danmark, mens den groft-punkterede form af arten kun er fundet i Eem.
5. De danske ostrakod-faunaer ligner de faunaer, der er fundet i tilsvarende lagserier i Nord-Tyskland, og de kan også sammenlignes med mellem-Pleistocæne interglaciale faunaer i England.

Man skal imidlertid være forsigtig med at anvende ovennævnte karakteristika som eneste baggrund for en stratigrafisk tolkning. Men når resultaterne koordineres med foraminifer- og pollenanalyser og støttes at nogle dateringer, er der gode muligheder for at få et rimeligt sikkert stratigrafisk resultat.

References

Andersen, S. T., 1963: Pollen Analysis of the Quaternary Marine Deposits at Tornskov in South Jutland. Danm. geol. Unders. IV Række 4 (8), 1–23.

Andersen, S. T., 1965: Interglacialer og interstadialer i Danmarks kvartær. Medd. dansk geol. Foren. 15 (4), 486–504.

Athersuch, J., 1978: On *Pterygocythereis siveteri* Athersuch sp. nov. Stereo-Atlas Ostracod Shells 5 (1), 1–8.

Athersuch, J., 1982: Some ostracod genera formerly of the Family Cytherideidae Sars. 231–275 *in:* Bate, R. H., Robinson, E. & Sheppard, L. M. (editors): Fossil and Recent Ostracods. Ellis Horwood, Chichester.

Athersuch, J., Horne, D. J. & Whittaker, J. E., 1985: G. S. Brady's Pleistocene ostracods from the Brickearth of the Nar Valley, Norfolk, U.K. J. micropalaeontol. 4 (2), 153–158.

Bahnson, H., Petersen, K. S., Konradi, P. B. & Knudsen, K. L., 1974: Stratigraphy of Quaternary deposits in the Skærumhede II boring: lithology, molluscs and foraminifera. Danm. geol. Unders., Årbog 1973, 27–62.

Bassiouni, M. el A. A., 1965: Über einige Ostracoden aus dem Interglazial von Esbjerg. Medd. dansk geol. Foren. 15 (4), 507–518.

Bonaduce, G., Ciampo, G. & Masoli, M., 1975: Distribution of Ostracoda in the Adriatic Sea. Pubbl. Staz. zool. Napoli 40, 1 Suppl., 1–154.

Breman, E., 1976: The distribution of ostracodes in the bottom sediments of the Adriatic Sea. Academisch Proefschrift, Vrije Universiteit, Amsterdam, 1–165.

Buch, A., 1955: De marine interglaciale lag ved Inder Bjergum. Foraminiferfauna og stratigrafi. Medd. dansk geol. Foren. 12 (6), 593–652.

Catt, J. A. & Penny, L. F., 1966: The Pleistocene Deposits of Holderness, East Yorkshire. Proc. Yorks. Geol. Soc. 35, 375–420.

Colhoun, E. A. & Mitchell, G. F., 1971: Interglacial marine formation and Late-glacial freshwater formation in Shortalstown Townland, Co. Wexford. Proc. R. Ir. Acad. 71B, 211–245.

Edwards, C. A., 1982: The Speeton Shell Bed. Quat. Newsletter 36, 3–9.

Elofson, E., 1941: Zur Kenntnis der marinen Ostracoden Schwedens mit besonderer Berücksichtung des Skagerraks. Zool. Bidr. Upps. 19, 215–534.

Hansen, S., 1965: The Quaternary of Denmark. 1–90 in: Rankama, K. (editor): The Geological Systems. The Quaternary 1. International publishers, New York.

Hirschmann, N., 1912: Beiträge zur Kenntnis des Ostracoden-Fauna des Finnischen Meerbusen. Acta. Soc. Fauna Flora fenn. 36 (2), 3–65.

Jensen, J. B. & Knudsen, K. L., 1984: Kvartærstratigrafiske undersøgelser ved Gyldendal og Kås Hoved i det vestlige Limfjordsområde. Dansk geol. Foren., Årsskrift for 1983, 35–54.

Kidson, C., Gilbertson, D. D., Haynes, J. R., Heyworth, A., Hughes, C. E. & Whatley, R. C. 1978: Interglacial marine deposits of the Somerset Levels, South-west England. Boreas 7 (4), 215–228.

Kirby, R. & Oele, E. 1975: The Quaternary History of the Sandettie-Fairey Bank area, southern North Sea. Phil. Trans. R. Soc. Lond. A279, 257–267.

Knudsen, K. L., 1986: Middle and Late Quaternary foraminiferal stratigraphy in the southern and central North Sea area. Striae 24, 201–205.

Knudsen, K. L., 1987: Elsterian-Holsteinian foraminiferal stratigraphy in the North Jutland and Kattegat areas, Denmark. Boreas, in-press.

Kronborg, C. & Knudsen, K. L. 1985: Om Kvartæret ved Rugård: En foreløbig undersøgelse. Dansk geol. Foren., Årsskrift for 1984, 37–48.

Lord, A. R., 1980: Weichselian (Late Quaternary) ostracods from the Sandnes Clay, Norway. Geol. Mag. 117 (2), 227–242.

Lord, A. R. & Robinson, J. E., 1978: Marine Ostracoda from the Quaternary Nar Valley Clay, West Norfolk. Bull. geol. Soc. Norfolk 30, 113–118.

Lord, A. R., Robinson, J. E. & Moutzourides, S. G., in-press: Ostracoda from Holsteinian deposits in the Hamburg area. Geol. Jb.

Malz, H. & Jellinek, J., 1984: Marine Plio-/Pleistozän-Ostracoden von SE-Lakonien (Peloponnes, Griechenland). Senckenbergiana biol. 65 (1/2), 113–167.

Meldgaard, S. & Knudsen, K. L., 1979: Metoder til indsamling og oparbejdning af prøver til foraminiferanalyser. Dansk Natur-Dansk Skole, Årsskrift 1979, 48–57.

Miller, G. H. & Mangerud, J., 1986: Aminostratigraphy of European Marine Interglacial deposits. Quaternary Science Reviews 4 (4) (for 1985), 215–278.

Neale, J. W., 1973: *Cluthia* (Crustacea, Ostracoda), a new Pleistocene and Recent Leptocytherid Genus. J. Paleont. 47 (4), 683–688.

Neale, J. W., 1974: Ostracod faunas from the Celtic Sea. Geoscience & Man 6, 81–98.

Neale, J. W., 1975: On *Cluthia keiji* Neale, sp. nov. Stereo-Atlas Ostracod Shells, 2 (3), 141–148.

Neale, J. W. & Howe, H. V., 1975: The marine ostracoda of Russian Harbour, Novaya Zemlya and other high latitude faunas. Bull. Amer. Paleont. 65, 381–431.

Norman, A. M., 1891: Notes on the marine Crustacea Ostracoda of Norway. Ann. Mag. nat. Hist. ser. 6, 7, 108–121.

Rosenfeld. A., 1977: Die rezenten Ostracoden-Arten in der Ostsee. Meyniana 29, 11–49.

Sars, G. O., 1928: An Account of the Crustacea of Norway, Vol. 9: Ostracoda. 1–277. Bergen Museum.

West, R. G., Devoy, R. J. N., Funnell, B. M. & Robinson, J. E., 1984: Pleistocene Deposits at Earnley, Bracklesham Bay, Sussex, Phil. Trans. R. Soc. Lond. B306, 137–157.

Whatley, R. C., 1983: The Application of Ostracoda to palaeoenvironmental analysis. 51–77 in: Maddocks, R. F. (editor): Applications of Ostracoda. University of Houston, Geoscience.

Whatley, R. C. & Kaye, P., 1971: The Palaeoecology of Eemian (Last Interglacial) Ostracoda from Selsey, Sussex. Bull. Centre Rech. Pau-SNPA. 5 Suppl. 311–330.

Whatley, R. C. & Masson, D. G., 1979: The ostracod Genus *Cytheropteron* from the Quaternary and Recent of Great Britain. Revista Española Micropaleont. 11 (2), 223–278.

Woszidlo, H., 1962: Foraminiferen und Ostracoden aus dem marinen Elster-Saale-Interglazial in Schleswig-Holstein. Meyniana 12, 65–96.

Plates 1–2

PLATE 1
Scale = 100 μm

Fig. 1. *Callistocythere* sp. Left valve, external lateral view, adult (450 μm long). Tornskov 159.243, sample No. 14.
Fig. 2. *Callistocythere* sp. Left valve, internal lateral view, adult (460 μm long). Tornskov 159.243, sample No. 18.
Fig. 3. *Carinocythereis whitei* (Baird, 1850). Right valve, external view, juvenile A-1 (757 μm long). Tornskov 159.243, sample No. 44.
Fig. 4. *Carinocythereis whitei* (Baird, 1850). Left valve, external lateral view, juvenile A-1 (767 μm long). Tornskov 159.243, sample No. 44.
Fig. 5. *Carinocythereis whitei* (Baird, 1850). Right valve, external lateral view, male (838 μm long). Hadsten 78.458, sample No. 69.
Fig. 6. *Carinocythereis whitei* (Baird, 1850). Left valve, external lateral view, male (862 μm long). Hadsten 78.458, sample No. 69.
Fig. 7. *Cluthia cluthae* (Brady, Crosskey & Robertson, 1874). Right valve, external lateral view, female (385 μm long). Inder Bjergum 140.82b, sample No. 18.
Fig. 8. *Cluthia cluthae* (Brady, Crosskey & Robertson, 1874). Left valve, external lateral view, female (359 μm long). Sebberkloster 33.481, sample No. 18.21.
Fig. 9. *Cytheropteron crassipinatum* Brady & Norman, 1888. Right valve, external lateral view, adult (382 μm long). Rugård, sample No. 1b.
Fig. 10. *Cytheropteron inornatum* Brady & Robertson, 1872. Right valve, external lateral view, adult (436 μm long). Rugård, sample No. Fl.

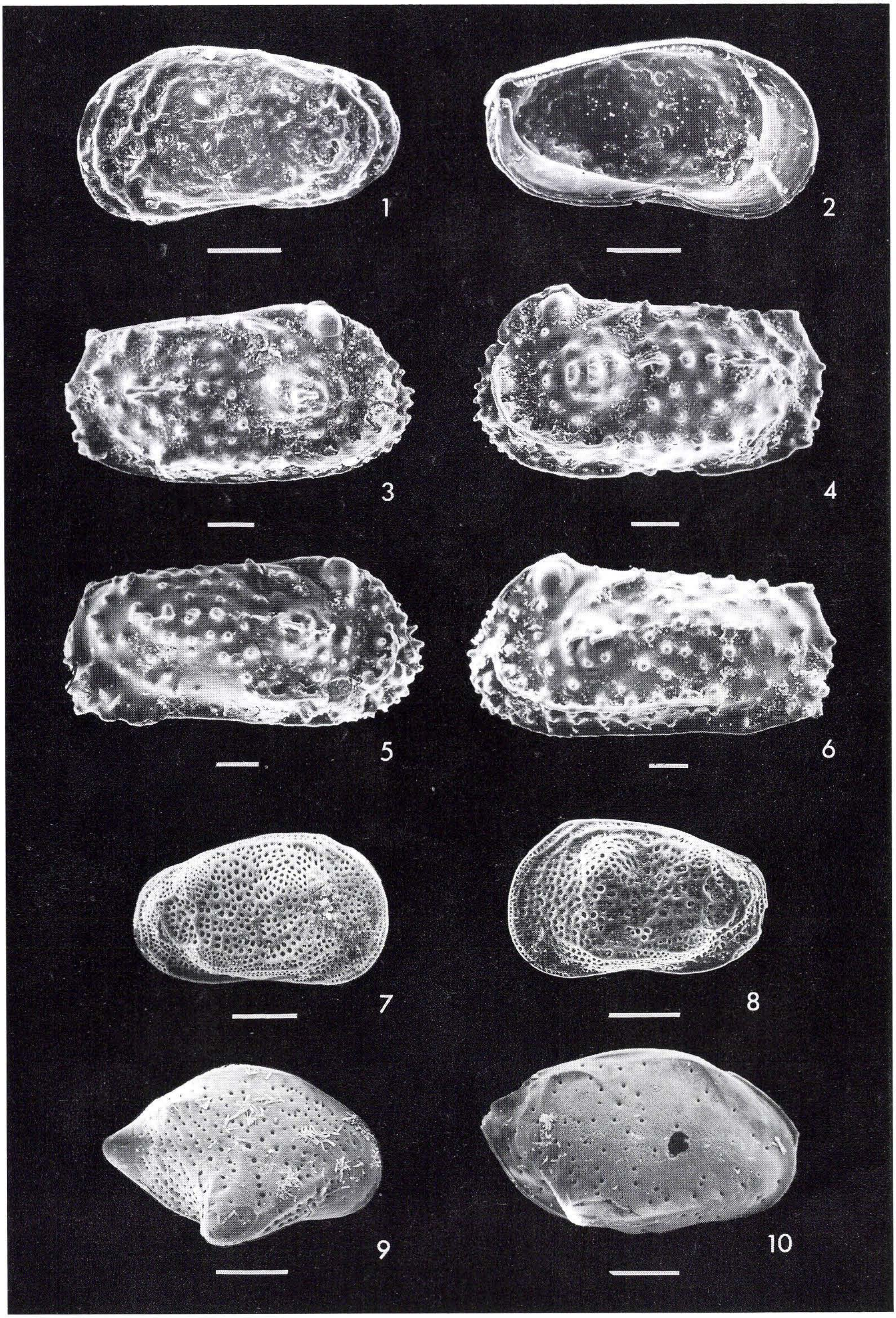
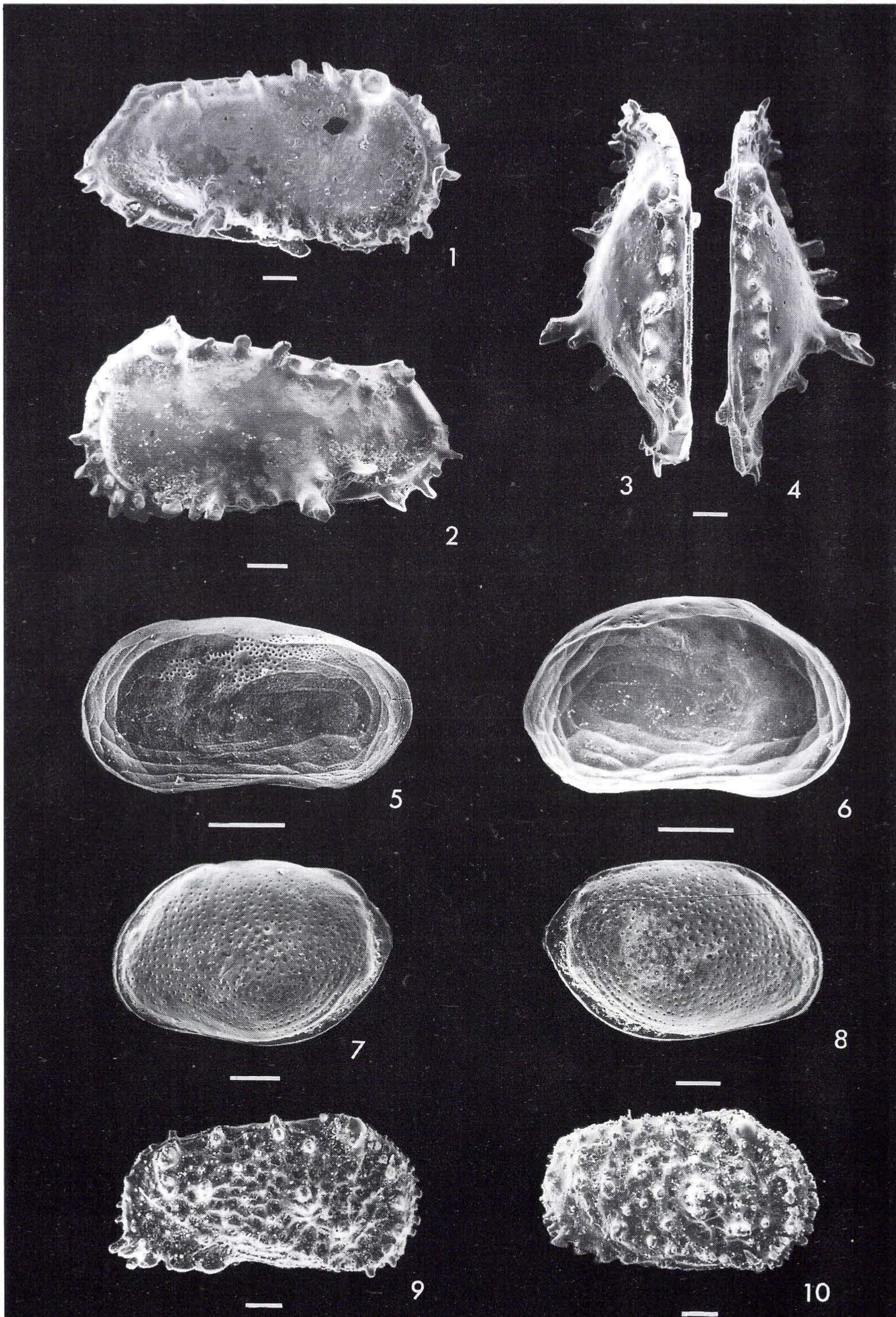

1
2
3
4
5
6
7
8
9
10

PLATE 2
Scale = 100 μm

Fig. 1. *Pterygocythereis coronata* (Roemer, 1838). Left valve, external lateral view, ?male (1045 μm long). Hadsten 78.458, sample No. 69.
Fig. 2. *Pterygocythereis coronata* (Roemer, 1838). Right valve, external lateral view, ?male (1054 μm long). Hadsten 78.458, sample No. 69.
Fig. 3. *Pterygocythereis coronata* (Roemer, 1838). Left valve, external dorsal view, ?male (1045 μm long). Hadsten 78.458, sample No. 69.
Fig. 4. *Pterygocythereis coronata* (Roemer, 1838). Right valve, external dorsal view, ?male (1054 μm long). Hadsten 78.458, sample No. 69.
Fig. 5. *Semicytherura* sp. Left valve, external lateral view, ?male (445 μm long). Inder Bjergum 140.82b, sample No. 20.
Fig. 6. *Semicytherura* sp. Right valve, external lateral view, ?female (441 μm long). Sebberkloster 33.481, sample No. 18–21.
Fig. 7. *Palmoconcha guttata* (Norman, 1865). Left valve, external lateral view, female (600 μm long). Tornskov 159.243, sample No. 42.
Fig. 8. *Palmoconcha guttata* (Norman, 1865). Right valve, external lateral view, female (607 μm long). Tornskov 159.243, sample No. 42.
Fig. 9. *Acanthocythereis dunelmensis* (Norman, 1865). Right valve, external lateral view, male (930 μm long). Inder Bjergum 140.82b, sample No. 20.
Fig. 10. *Acanthocythereis dunelmensis* (Norman, 1865). Right valve, external lateral view, juvenile A-1 (830 μm long). Inder Bjergum 140.82b, sample No. 17.


1
2
3
4
5
6
7
8
9
10

This book describes the Foraminifera and Ostracoda of the marine Late Elsterian-Holsteinian deposits in South West Jutland. The deposition occured during a transgressive phase in this period. Apparently the sedimentation took place within areas where the pre-Quaternary surface is deep-lying.

ISBN 87-421-0736-9
ISSN 0901-0289