THE QUATERNARY OF VENDSYSSEL

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Vendsyssel is the northernmost part of Jutland in Denmark. Many investigators have dealt with the Quaternary of this area, among them Jessen (1899, 1918, 1931, 1936), Madsen (1895), Jessen, Milthers, Nordmann, Hartz & Hesselbo (1910), Jessen & Nordmann (1915), Iversen (1942, 1943), Milthers (1948), Andersen (1961), Hansen (1965), and Tauber (1966).

The pre-Quaternary surface consists almost everywhere in Vendsyssel of white chalk of Upper Senonian age. Only at Skagen do layers of lower Cretaceous age underlie the Quaternary deposits. The position of the chalk surface varies a great deal even within small areas; a dominant trend is recognisable. Northeast of a line from Nørre Sundby to Saltum the chalk surface lies below the level of the sea, whereas southwest of this line it is situated above sea level. The chalk outcrops at several places towards southwest. It has been assumed that the chalk surface was exposed during a long period, and that its unevenness is due mostly to faulting, but also to erosion by running water and glaciers.

Jessen (1918, 1936) distinguished between three morphological units in Vendsyssel: The hill country, the high-lying Lateglacial plateaus, and the low-lying Postglacial plateaus.

The hill country, or the glacial highland, forms more or less distinctive units, the so-called "hill islands" (Danish: Bakkeøer) rising above an otherwise flat area. Some of these "islands" are indicated on the geological sketch map in fig. 11, viz. Hjørring, Rubjerg, Børglum, Saltum, Vester Hassing, Hammer, Nørre Sundby, and Gjøl. The hill country is composed primarily of glacifluvial sand and to a lesser degree of glacifluvial clay and of till. Glacifluvial gravel is scarce. The glacifluvial sand and clay were originally deposited as more or less horizontal strata, but in many places they now appear deformed and very often tilted. Conspicuous imbricate structures of such deposits are visible in the coast cliff of Lønstrup (Lønstrup klint), particularly about Rubjerg. Such deformation is now supposed to have been caused by ice pressure during glacier advance (Jessen, 1936). In 1918 Jessen believed that the magnitude of the distortions was too large to be explained by glacial tectonics. The distorted layers are supposed to be older than the main advance of the Weichselian glaciers. The till of the glacial highland is sandy in the northeastern part of the area and more

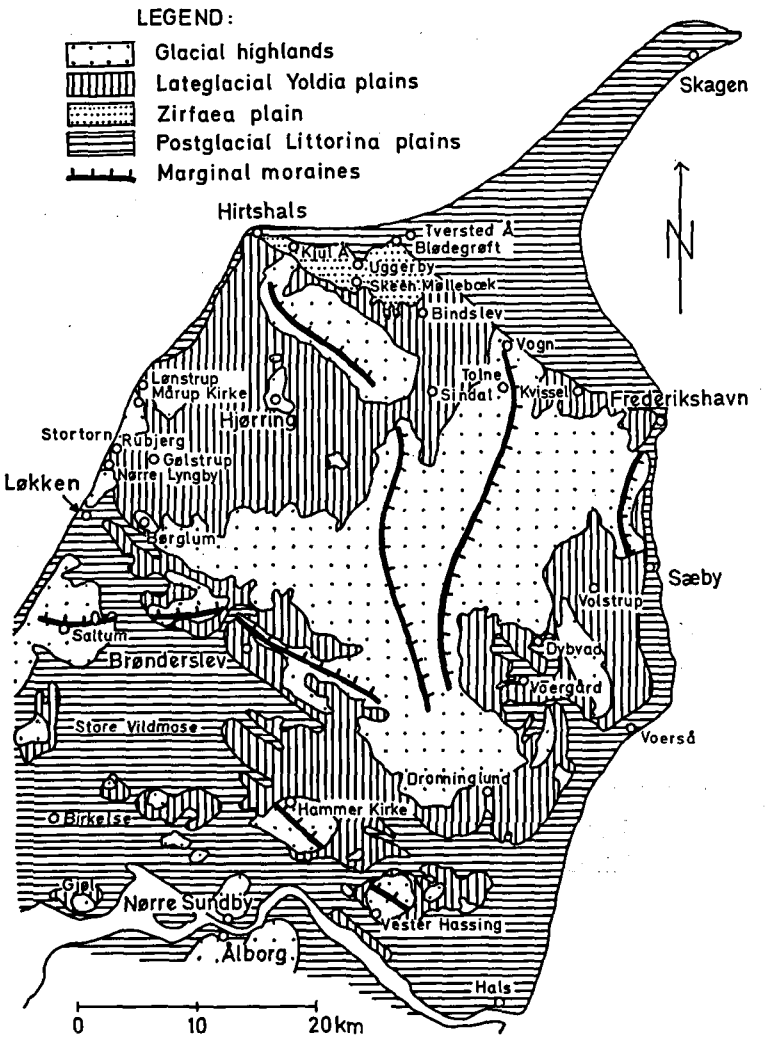

Fig. 11. Geological map of Vendsyssel. After V. Milthers, 1948 and Jessen, 1936.

clayey in the southwestern part. The major part of the boulders in the tills are of Norwegian and West-Swedish origin. The average thickness of the till deposits in Vendsyssel is 3–8 m. In a boring at Hals, however, a till deposit of 21 m thickness occurred, and at Nørre Sundby the till reached 23 m thickness. A few marginal moraines, most probably representing ice border lines, have been recognised. They have a northwest-southeast to north-south trend, as illustrated in the geological sketch map in fig. 11.

The high-lying Lateglacial plateaus, or the *Yoldia* flats, form a southwestward dipping plain. They are: The Kvissel plateau, the Sindal-Uggerby pla-

teau, the Hjørring plateau, the Volstrup plateau, the Voergaard plateau and the southern plateau, which is situated north of the Hammer hills. These plateaus are built of marine sand and clay which were deposited during a Lateglacial transgression, the highest shoreline of which is now found at 56 m to 62 m above sea level at Frederikshavn (in the northeast) descending to 13 m at Gjøl (in the southwest). The deposits contain marine molluscs of arctic habitat and have been divided into 1) Lower *Saxicava* Sand, transgressive facies with *Hiatella arctica* (Linné), 2) Younger *Yoldia* Clay, with *Portlandia arctica* (Gray), and 3) Upper *Saxicava* Sand, regressive facies with *Hiatella arctica*. The thickness of the Younger *Yoldia* Clay varies between 1 m and 20 m. Radiocarbon datings (Tauber, 1966, and H. Krog, pers. communication) of the combined unit of *Saxicava* sands and *Yoldia* Clay have given ages from 12,300 to 10,700 years B.C.

In the northern part of Vendsyssel, towards Hirtshals, Uggerby and Frederikshavn the Lateglacial *Yoldia* Clay is overlain by sandy deposits with boreo-arctic molluscs, i.a. *Macoma calcarea* (Chemnitz), *Mya truncata* Linné, *Mytilus edulis* Linné, and *Zirfaea crispata* (Linné). These deposits are called the *Zirfaea* layers. Shorelines are found up to 17–20 m above present-day sea level, and are supposed to represent a renewed transgression after the regression of the *Yoldia* Sea. Radiometric datings of shells from the *Zirfaea* layers range from 10,250 to 10,800 years B.C., i.e. they are of Bølling Interstadial age.

The low-lying Postglacial plateaus, or the *Littorina* flats, extend over much of Vendsyssel. The northernmost of these plains lies between Frederikshavn, Hirtshals and Skagen, and another one between Nørre Sundby and Løkken. A part of this latter one is occupied by the extensive bog, Store Vildmose. A third plain is situated to the east, around Hals, with branches towards north and northwest. In the western part of the region the plateau character has been obliterated by superincumbent dune sand. The *Littorina* flats are composed of sand, clay or mud, which were deposited during a Postglacial transgression with many oscillations which took place during Atlantic and Subboreal times. The highest shorelines of this transgression are now found at 15 m above sea level at Frederikshavn, 9 m at Brønderslev and about 8 m at Gjøl and Nørre Sundby. These deposits contain molluscs of boreo-lusitanian habitat, i.a. *Ostrea edulis* Linné, *Venerupis decussatus* (Linné) (= *Tapes decussatus*), *Dosinia exoleta* (Linné), *Littorina littorea* Linné, and *Nassa reticulata* (Linné). Radiometric datings of shells from different parts of these deposits range between 550 and 6,350 years B.C. (Tauber, 1966: H. Krog, pers. communication).

Between the deposition of the Lateglacial and Postglacial marine sequences Vendsyssel was above sea level for a period of almost 4,000 years. Lateglacial and Postglacial marine deposits are therefore easily distinguished

in borings as well as in outcrops, as continental deposits usually occur between them.

In 1905 the Geological Survey of Denmark had a 235 m deep boring carried out at Skærumhede, 10 km west of Frederikshavn. The terrain surface at the bore site was 23 m above sea level. The upper 57 m consisted of glacifluvial sand, and below this a 123 m thick marine sequence occurred. The marine sequence was called the Skærumhede series (Jessen, Milthers, Nordmann, Hartz & Hesselbo, 1910). The upper 41 m of this series was called the *Portlandia arctica* Zone. A similar deposit known as the Older *Yoldia* Clay is recognised at several places in Vendsyssel, e.g. in the coastal cliff at Hirtshals. Below the *Portlandia arctica* Zone an 8.5 m thick unit with boreo-arctic molluscs occurred. It was called the *Abra nitida* Zone because of the presence of the species *Syndosmya nitida* (Müller) (= *Abra nitida*). Below this zone a 74 m thick clay unit with boreo-lusitanian molluscs was found. It was called the *Turritella terebra* Zone after *Turritella communis* Lamarck (= *T. terebra* (Linné)). The Skærumhede series was supposed to belong to the later part of the Eemian. Later authors, i.a. Rasmussen (1966), have placed it in the Brørup Interstadial of the Weichselian. The age of the Skærumhede series is discussed in other parts of the present paper (Feyling-Hanssen, p. 101; Knudsen p. 151; Andersen, p. 182). Below the *Turritella terebra* Zone 19 m of till occurred, resting on Maastrichtian limestone.

Foraminifera from classical localities in Vendsyssel

Frederikshavn, Older *Yoldia* Clay

From the Geotechnical Institute of Denmark (the Århus department) the present author received four samples of shell-bearing clay from central Frederikshavn which was referred to Older *Yoldia* Clay. They were collected at 6.2 m, 6.1 m, 5.7 m and 4.2 m above sea level. The locality is the same as that described by Jessen (1936, p. 44). The samples are quite rich in foraminifera, containing 3,500, 3,200, 3,600 and 2,900 specimens respectively per 100 g sediment. *Elphidium clavatum* is dominant in all samples and *Cassidulina crassa* is second in abundance. *Virgulina loeblichi* and *Islandiella teretis* are quite frequent. The average percentages of these four species in the four samples are shown in fig. 12. Accessory species, which are species accounting for at least 2 % of the fauna in one or more of the samples, are *Nonion labradoricum* and *Buccella frigida*. Less frequent species are *Quinqueloculina seminulum, Q. stalkeri, Pyrgo williamsoni, Lagena sulcata, Guttulina austriaca, G. lactea, Oolina melo, Fissurina danica, F. laevigata, F. serrata, Bulimina marginata, Virgulina concava. Uvigerina*

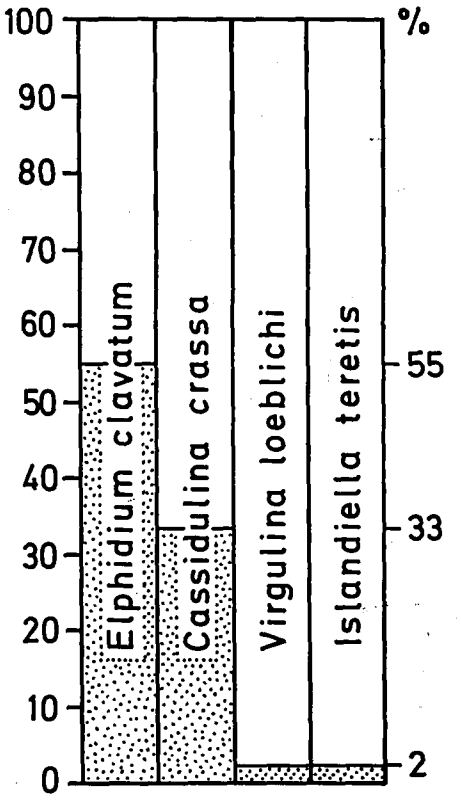

Fig. 12. Average frequency of four characteristic species in Older *Yoldia* Clay from Frederikshavn.

peregrina, Trifarina fluens, Cassidulina laevigata, Islandiella norcrossi, Hyalinea baltica, Cibicides lobatulus, Nonionella iridea, Astrononion gallowayi, Elphidium albiumbilicatum, E. asklundi, E. groenlandicum, E. incertum, E. subarcticum, Protelphidium anglicum, and *P. orbiculare.* The number of species per sample varies from 18 to 25, and a total of 33 different species occur in the four samples.

Stortorn, Older *Yoldia* Clay

Stortorn is situated just north of Rubjerg Knude Lighthouse at the coastal cliff of Lønstrup. At this locality Jessen (1936, p. 41) found Older *Yoldia* Clay. A section of the cliff, drawn by Jessen, is shown in fig. 13.

Eight samples from this locality were examined. They contain 23 to 3,500 specimens in 100 g of the dried sample. *Elphidium clavatum* was dominant in all of the samples, whereas *Cassidulina crassa* was second in abundance in three of them, and *Elphidium asklundi* in two of them. Three of the

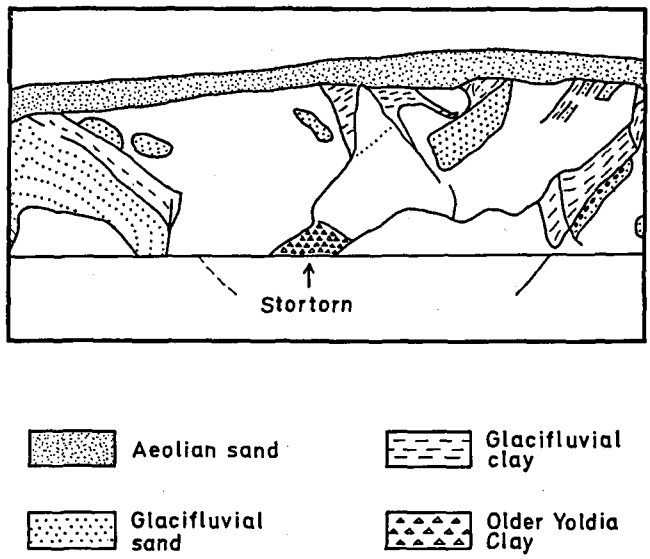

Fig. 13. Section of the cliff with Older *Yoldia* Clay at Stortorn. After Jessen, 1936.

samples contained less than 50 specimens in 100 g, and are not considered here. The average frequency distribution of the most common species is shown in fig. 14. Accessory species are *Buccella frigida, Nonion labradoricum, Protelphidium orbiculare,* and *Virgulina schreibersiana.* Among the rarer species are *Silicosigmoilina groenlandica, Pyrgo williamsoni, Pateoris haunerinoides, Lagena gracillima, L. laevis, L. sulcata, Guttolina austriaca, G. lactea, Laryngosigma hyalascidia, Parafissurina tectulostoma, Bulimina marginata, Virgulina loeblichi, Trifarina fluens, Islandiella norcrossi, I. teretis, Cibicides lobatulus, Nonion barleeanum, Elphidium bartletti, E. incertum, E. subarcticum* and *Ammonia batavus.* The richest of the samples contained 18 different species whereas a total of 30 species occur in the samples from Stortorn.

There were more specimens of *Elphidium asklundi* in the samples from Stortorn than in those from Frederikshavn, otherwise the assemblages from the two localities are much alike. They are arctic with a boreal element. The boreal species include *Bulimina marginata, Nonion barleeanum,* and *Ammonia batavus.* The Stortorn material compares well with assemblages from the Sandnes Clay in southwestern Norway and from Older *Yoldia* Clay from Hirtshals and Løkken.

Madsen (1895, p. 97) recorded 9 species of foraminifera from the Older *Yoldia* Clay at Frederikshavn, among them *Elphidium clavatum* (some of them referred to *Nonionina depressula*), *Cassidulina crassa, Elphidium ask-*

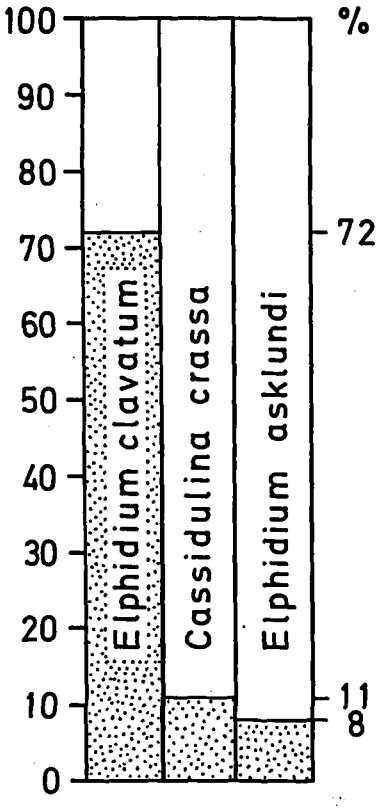

Fig. 14. Average frequency distribution of three characteristic species in Older *Yoldia* Clay at Stortorn.

lundi (recorded as *Polystomella striatopunctata* var. *incerta*), *Nonion labradoricum,* and *Bulimina marginata.* He did not investigate samples from Stortorn, but in Older *Yoldia* Clay from the coastal cliff of Hirtshals he found 26 different species.

The present author collected and examined a sample of sandy clay from the bank of the rivulet Kjul Å, 3 km ESE of the town of Hirtshals. It contained 1,800 specimens of foraminifera per 100 g of the sample. One-sixth of this content was counted and gave the distribution shown on p. 124.

This is a typical Older *Yoldia* Clay assemblage and suggests that the deposit at Kjul Å is Older *Yoldia* Clay, as mentioned by Jessen (1899, 1918, 1936). This deposit has, however, also been referred to the Lateglacial *Zirfaea* layers because K.J.V. Steenstrup (see Madsen 1895, p. 137) found *Zirfaea crispata* among the molluscs. But this species also occurs in the Older *Yoldia* Clay at Stortorn (Jessen 1899, 1918, 1936) as well as in the Older *Yoldia* Clay of the coastal cliff at Hirtshals (Jessen 1899; Andersen, this paper). On the other hand, foraminiferal assemblages from samples of *Zirfaea* layers, e.g. those from Skeen Møllebæk (see below) are quite similar to those of the

Kjul Å, 8 m above sea level.

Species	Frequency	Percentage
Elphidium clavatum	240	77
Cassidulina crassa	36	12
Elphidium asklundi	14	5
Nonion labradoricum	7	2
Pyrgo williamsoni	1	<1
Bulimina marginata	1	<1
Virgulina loeblichi	1	<1
Virgulina schreibersiana	1	<1
Uvigerina peregrina	1	<1
Cassidulina laevigata	1	<1
Islandiella norcrossi	1	<1
Islandiella teretis	1	<1
Buccella frigida	1	<1
Cibicides lobatulus	1	<1
Elphidium groenlandicum	1	<1
Elphidium incertum	1	<1
Elphidium subarcticum	1	<1
Total	310	

Older *Yoldia* Clay, and a single fauna like that from Kjul Å is insufficient as a basis for stratigraphical correlation. Five other samples from Kjul Å were almost barren.

The majority of the examined samples of Older *Yoldia* Clay contains some reworked specimens from the Upper Cretaceous (Maastrichtian). A few ostracods from the Quaternary also occur.

Gølstrup, Lateglacial *Yoldia* Clay

Three samples were collected from the clay pit of Gølstrup brickworks, northeast of Løkken. The samples were taken between 15 m and 16 m above sea level, and two of them contained shells of *Hiatella arctica.* Jessen (1936, p. 99) referred this deposit to the Lateglacial, or Younger *Yoldia* Clay. The samples contained 221, 1,000 and 1,100 specimens in 100 g dry sediment. In all the three samples there is a pronounced dominance of *Elphidium clavatum,* this species accounting for 78 % to 96 % of the fauna. *Cassidulina crassa* is second in abundance in one of the samples, whereas *Elphidium albiumbilicatum* ranks as second in the two others. The three species account for almost 100 % of the assemblages; their frequency in the three samples is shown in fig. 15.

A few other species were observed, viz. *Fissurina marginata, Bulimina*

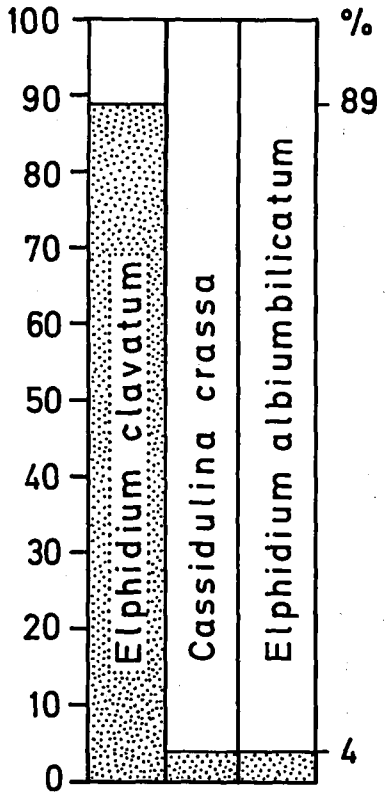

Fig. 15. Average frequency distribution of three characteristic species in Lateglacial *Yoldia* Clay at Gølstrup.

marginata, Virgulina schreibersiana, Uvigerina peregrina, Trifarina fluens, Islandiella norcrossi, Buccella frigida, Nonion labradoricum, Elphidium asklundi, E. incertum, and *E. subarcticum.* One or two specimens of each of these species occurred. The faunal diversity varies between 1 and 3 for these samples.

Nørre Lyngby, Lateglacial *Yoldia* Clay

Three samples were collected from Younger *Yoldia* Clay exposed in the coastal cliff at Nørre Lyngby, 120 m north of the descent to the beach. The samples were taken at 17 m above sea level and contained from 59 to 600 specimens of foraminifera in 100 g sediment. *Elphidium clavatum* accounts for 61 % to 97 % of the faunas, whereas *Cassidulina crassa* includes 1 % to 17 %. The average frequency of these two species in the three samples is shown in fig. 16.

Additional species observed in the samples are *Lenticulina gibba, Bulimina fossa, B. marginata, Virgulina schreibersiana, Cassidulina laevigata,*

Cibicides lobatulus, Nonion labradoricum, Elphidium albiumbilicatum, E. bartletti, E. incertum, and *E. subarcticum.*

A sample from Lateglacial *Yoldia* Clay at Bindslev, between Frederikshavn and Hirtshals contains the following assemblage in 100 g sediment:

Bindslev, 8.3 m above sea level. Geotechn. Inst.

Species	Frequency	Percentage
Elphidium clavatum	322	87
Cassidulina crassa	33	9
Elphidium subarcticum	8	2
Elphidium bartletti	1	<1
Lagena sulcata	1	<1
Pseudopolymorphina suboblonga	1	<1
Virgulina schreibersiana	1	<1
Astrononion gallowayi	1	<1
Indeterminate species	4	1
Total	372	

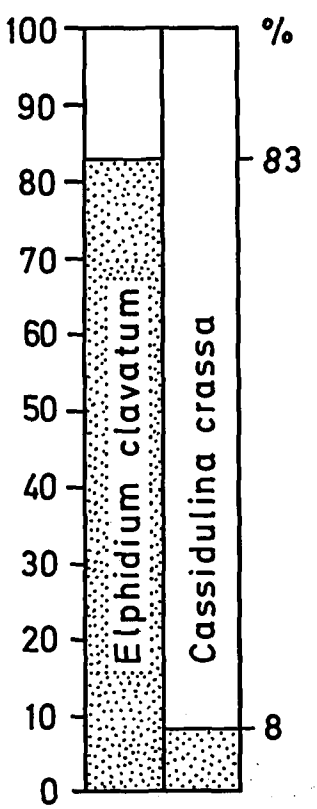

Fig. 16. Average frequency distribution of two characteristic species in Lateglacial *Yoldia* Clay at Nørre Lyngby.

All these samples from the Lateglacial *Yoldia* Clay are distinguished by high dominance of *Elphidium clavatum* and by very low faunal diversity. The number of different species is lower than in the Older *Yoldia* Clay and a boreal element of any significance is lacking in the assemblage.

Skeen Møllebæk, *Zirfaea* layers

Six samples of sandy clay from the *Zirfaea* layers were collected from the banks of the rivulet Skeen Møllebæk, east-southeast of Hirtshals. The sampled layer is 12–13 m above sea level. The mollusc species *Hiatella arctica, Mytilus edulis* and *Arctica islandica* (Linné) (= *Cyprina islandica*) occur in the samples, otherwise *Mya truncata* and *Macoma calcarea* are common at this locality.

All the samples contain foraminifera, from 263 to 3,700 specimens per 100 g. The number of species ranges from 12 to 24; a total of 41 different species were observed in the six samples. As would be expected with Lateglacial samples *Elphidium clavatum* dominates in all of them, comprising

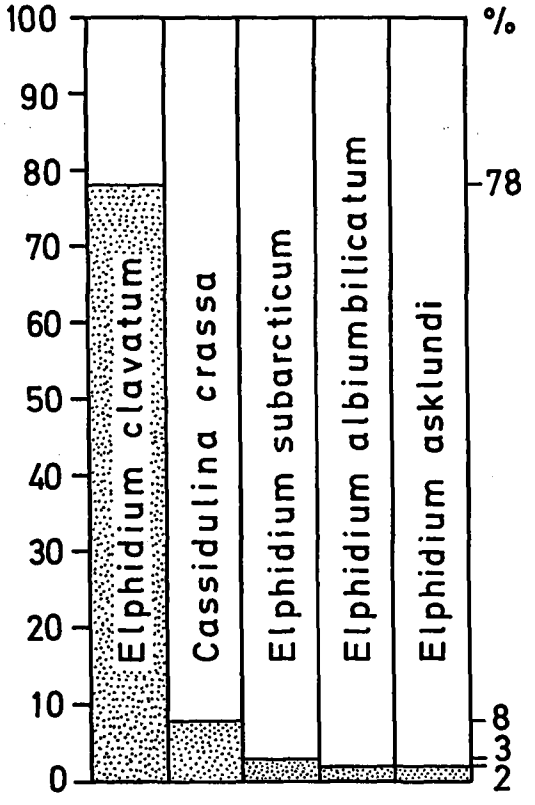

Fig. 17. Average frequency distribution of five characteristic species in *Zirfaea* deposits at Skeen Møllebæk.

from 75 % to 80 % of the fauna. *Cassidulina crassa* is second with 5 % to 11 %. In addition a characteristic element of large *Elphidium* species occur, viz. *Elphidium subarcticum, E. asklundi,* and *E. albiumbilicatum.* The average frequency distribution of the most common species in the six samples is shown in fig. 17. Additional characteristic species are *Virgulina schreibersiana, Buccella frigida,* and *Elphidium incertum.* Rare species are *Lagena aspera, L. hexagona, L. laevis, L. striata, L. sulcata, Guttulina austriaca, G. lactea, Globulina inaequalis, Oolina globosa, O. melo, Fissurina danica, F. laevigata, Parafissurina himatiostoma, Bulimina fossa, B. marginata, Virgulina concava, V. loeblichi, Uvigerina peregrina, Trifarina angulosa, T. fluens, Islandiella norcrossi, I. teretis, Cibicides lobatulus, Nonion labradoricum, Elphidium bartletti, E. groenlandicum, E. macellum, E. umbilicatulum,* and *Protelphidium orbiculare.*

This assemblage has thus much in common with those from the Older *Yoldia* Clay. They reflect a reestablishment of interstadial conditions (Bølling Interstadial) after the severe environmental deterioration during the advance and early retreat of the Weichselian glaciers. A difference is provided by the quite common occurrence of large, flat specimens of *Elphidium subarcticum* in the *Zirfaea* layers.

Birkelse, Postglacial *Littorina* deposits

This locality is situated southwest of Store Vildmose, where the main road west of Birkelse crosses a small watercourse. Jessen (1936, p. 155) refers the deposit to the Postglacial *Littorina* layers. Seven samples were collected from the banks of the watercourse at 1.7 m above sea level. They contained from 4,400 to 11,800 specimens of foraminifera per 100 g sediment.

Ammonia batavus dominates the assemblages in all of the samples, accounting for 45 % to 64 %. Second in abundance is a form of *Elphidium clavatum.* This form of *Elphidium clavatum* may differ from that found in the Lateglacial and Pleniglacial deposits. To the present author it seems, however, that transitional forms occur between the glacial and the postglacial representatives, and therefore they have not been separated. A third species commonly occurring in the samples is *Protelphidium anglicum.* The frequency distribution of these three species in the seven samples is shown in fig. 18. Accessory species are *Anomalina globulosa, Elphidium albiumbilicatum, E. macellum, E. subarcticum,* and *E. umbilicatulum.* Rare species are *Psammosphaera fusca, Miliammina fusca, Trochammina inflata, Eggerella scabra, Lagena hexagona, L. hispida, L. laevis, L. semilineata, L. sulcata, Guttulina lactea, Laryngosigma hyalascidia, Oolina melo, Fissurina laevigata, Buliminella elegantissima, Bulimina fossa, B. marginata, Virgulina fusiformis, V. loeblichi, Trifarina angulosa, T. fluens, Cassidulina crassa,*

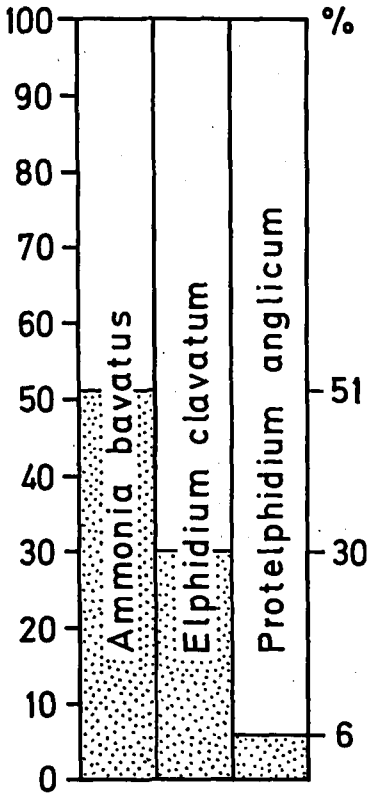

Fig. 18. The average frequency distribution of three characteristic species in Postglacial *Littorina* deposits at Birkelse.

C. laevigata, Buccella frigida, Eoeponidella laesoensis, Nonion barleeanum, Astrononion gallowayi, and *Elphidium incertum.*

The number of different species ranges from 12 to 21 per sample; 37 different species have been recorded in the seven samples from Birkelse.