

Foraminifera in Late Saalian, Eemian, Early and Middle Weichselian of the Skærumhede I boring

KAREN LUISE KNUDSEN AND ANNE-LISE LYKKE-ANDERSEN



Knudsen, K. L. and Lykke-Andersen, A.-L.: Foraminifera in Late Saalian, Eemian, Early and Middle Weichselian of the Skærumhede I boring. *Bull. geol. Soc. Denmark*, vol. 30, pp. 97–109, Copenhagen, September 1st, 1982.

A foraminiferal stratigraphy primarily based on the late Axel Nørvangs material from the Skærumhede I boring has been made.

Foraminifera from the marine Skærumhede sequence show a faunal succession from an arctic environment (zone N4) to deep water boreal and boreo-lusitanian conditions (zone N3). This is succeeded by a zone (N2) containing a faunal transition from a shallow water boreal assemblage in its lower part through to boreo-arctic conditions in its upper part, and finally a zone (N1) reflecting mainly arctic environment. It is argued that zone N4 represents the Late Saalian, zone N3 the Eemian and zones N2 and N1 the Early and Middle Weichselian.

K. L. Knudsen, Department of Micropaleontology, Institute of Geology, University of Aarhus, 8000 Århus C, Denmark; A.-L. Lykke-Andersen, Labyrinten 17, 8220 Brabrand, Denmark, 1982. March, 22nd, 1982.

At Skærumhede, about 10 km west of Frederikshavn in Vendsyssel (fig. 1), three borings have been carried out by the Geological Survey of Denmark.

The Skærumhede I boring was made in 1905. This boring was 235 m deep and contained a 123 m thick marine sequence resting on 20 m of till and fluvio-glacial deposits. It was overlain by about 57 m fluvio-glacial deposits (Jessen et al., 1910).

The marine Skærumhede sequence was originally subdivided using molluscs into the *Turritella terebra* zone, the *Abra nitida* zone and the *Portlandia arctica* zone (figs. 2 and 3). Jessen et al. (1910) concluded "The changes in the climatic conditions – from temperate to high arctic – displayed by the molluscan fauna, thus show that these marine formations resting on a primary bed, which are covered by and rest upon glacial formations, were deposited during an Interglacial Period and the beginning of the next following Glacial Period".

Correlation between the *Portlandia arctica* zone and the Older *Yoldia* Clay, known from several localities in Vendsyssel, leads to the conclusion that the marine part of the Skærumhede series belongs to the last Interglacial period and the beginning of the last Glacial period. However

Jessen et al. (1910) pointed out that "The fauna in the Eem deposits, which at present are also referred to the last Interglacial Period, has a different and far too southern a character, to be brought into close connection with the Skærumhede series".

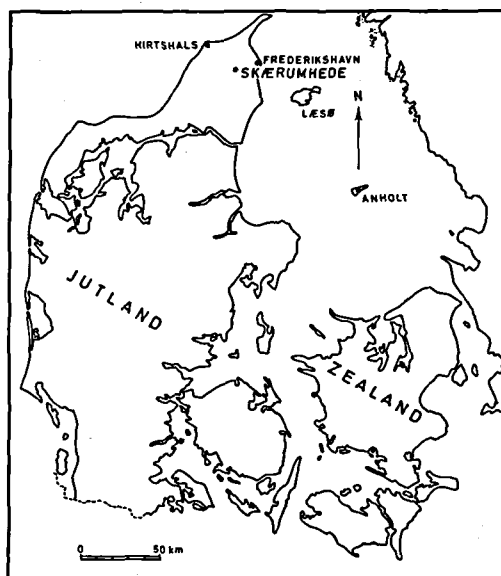


Fig. 1. Locality map.

The fact that the molluscan fauna from the temperate part of the Skærumhede series is different from that known from shallow water Eemian deposits has been the argument used by several authors to refer the marine Skærumhede sequence to different interglacial, glacial and interstadial periods in the Quaternary stratigraphy (for further discussion see Bahnson et al., 1974).

Comparison between the Older *Yoldia* clay in Hirtshals coast cliff and the *Portlandia arctica* zone of the Skærumhede I boring, based mainly upon the sediments and their content of molluscs but also on the foraminifera, shows that the Older *Yoldia* Clay at Hirtshals corresponds to the upper c. 30 m of the *Portlandia arctica* zone together with the lowermost part of the fluvio-glacial deposits (Lykke-Andersen, 1971).

Radio carbon dates of plant material and molluscs from the Older *Yoldia* Clay in Hirtshals coast cliff, gave ages which seem to prove that this deposits and therefore also the upper c. 30 m of the *Portlandia arctica* zone have been deposited exclusively in the Middle Weichselian (Lykke-Andersen, 1981, 1982 and fig. 5, this paper).

The second boring at Skærumhede was made in 1971–72. It was 122 m deep and located only a few metres from the Skærumhede I boring. This boring contained only the upper part of the marine Skærumhede sequence, i.e. the *Portlandia arctica* zone, the *Abra nitida* zone and the uppermost part of the *Turritella terebra* zone (see fig. 5).

A detailed foraminiferal zonation of the marine sequence in Skærumhede II was made by Konradi and Knudsen (1974). As this boring only contains the upper part of the marine sequence, it is obvious that the foraminiferal material from Skærumhede I provides important additional information from earlier in the stratigraphy. A rough outline of the foraminiferal stratigraphy combining the Skærumhede I and Skærumhede II borings was published in 1980 by Feyling-Hanssen and Knudsen.

The Skærumhede III boring from 1974 was only 34 m deep and did not reach the marine sequence (Bahnson et al., 1974).

Recent workers have again considered that the

marine sequence at Skærumhede represents the Late Saalian, Eemian and Early and Middle Weichselian (Feyling-Hanssen et al., 1971; Bahnson et al., 1974; Knudsen, 1976; Feyling-Hanssen and Knudsen, 1980; Lykke-Andersen, 1981). For additional discussion of the stratigraphic position, the reader is referred to these authors.

Material and methods

Foraminifera from the Skærumhede I boring were studied by the late Axel Nørvang. He delivered a lecture about his results in the Geological Society of Denmark (Nørvang, 1945) but he never published the foraminiferal stratigraphy.

This paper is an attempt to publish Nørvangs results using his remaining material, viz. some sample residues, "faunal" slides, index cards and a fragmentary manuscript.

The sample material, which was at Nørvangs disposal for foraminiferal analyses consisted of casings stored for many years.

Nørvang did not analyse the faunal compositions by counting, but by use of a five level scale of relative frequency (abundant, common, scarce, rare, fragments). By comparing the estimates, made by Nørvang, with his "faunal" slides, and with faunas known from the Skærumhede II boring, it would appear that more weight was given to the larger species than actual frequencies by counting would have demonstrated. One reason for underrepresentation of smaller specimens may be the special preparation method used by Axel Nørvang, but as some of the "faunal" slides also contain many small specimens, it may partly be caused by deliberate selection of the foraminifera. Examination of Nørvangs sample remains from no. 139 and especially no. 109 show that many small specimens were left behind after preparation. To obtain a better knowledge of the complete faunas, we have processed 19 selected samples from the original Skærumhede I material. These samples were processed according to the methods described by Feyling-Hanssen et al. (1971).

Fig. 2. Relative frequencies of selected species of foraminifera in the lower part of the Skærumhede sequence, based on Nørvangs results (legend fig. 4).

Using the available information extracted from Nørvang's papers, figure 2 has been constructed showing relative frequencies of the most common species of foraminifera. Species names have been altered according to the modern day usage, and taxonomic problems have been solved by careful examination of the foraminiferal material, which was collected by Nørvang.

The upper part of the Skærumhede I boring, above 93 m depth, has been left out of this range chart (fig. 2), partly because the faunal information there was very fragmentary, but also because a foraminiferal zonation of this section of the boring has been constructed using much better material from Skærumhede II (fig. 5). The lower part of Skærumhede I (93–181 m below ground level) produced reasonably representative faunal distributions, which are shown here in fig. 2 based exclusively on Nørvang's results.

Results of our supplementary foraminiferal investigations of the original Skærumhede I material are shown in fig. 3. Seven additional species are added to the right of the diagram. Peter Konradi, Geological Survey of Denmark, kindly placed some of his faunal lists from Skærumhede I at our disposal, and his results (samples 89, 97, 101, 104, 150, 152 and 157) are entered in the range chart together with ours (fig. 3).

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

Foraminiferal zonation

The marine sequence of the Skærumhede I boring was subdivided into four assemblage zones by Nørvang, here called N1, N2, N3 and N4.

The lowermost zone, N4, which was included in the "lower glacial beds" by Nørvang, is in his material represented by only two samples (154 and 153) from 181.1 m to 180.5 m depth. The most common species in zone N4 are *Elphidium groenlandicum*, *E. excavatum*, *Islandiella helenae* (including *I. norcrossi*), *Nonion labradoricum*, *Stainforthia loeblichii* and *Quinqueloculina seminulum* (fig. 2). This composition of species together with the occurrence of *Cassidulina reniforme* show, that the zone represents an arctic

marine environment. The presence of a small number of boreal species, which are dominant in the zone above, was probably caused by contamination during sampling.

Additional samples selected from the "lower glacial beds" (199.3–180.3 m) have been analysed for foraminiferal content (fig. 3). The lowermost sample 192 (199.3–199.1 m), which consisted of coarse clayey sand and gravel, contained a rich foraminiferal fauna indicating an arctic environment. *Elphidium excavatum*, *Cassidulina reniforme* and *Islandiella helenae* dominate the assemblage and *Elphidium groenlandicum*, *Nonion labradoricum* and *Stainforthia loeblichii* are the most common accessory species (fig. 3). In spite of the fact that this marine deposit rests directly on top of the White Chalk, the content of Prequaternary foraminifera is extremely low.

Above this marine sand and gravel follows a 14.3 m thick deposit of clayey till. Five samples from this sequence have been analysed. These sediments were found to contain extremely large quantities of Prequaternary foraminifera (1000–7000 specimens per 100 g sediment), Quaternary species were however low in number (fig. 3).

The till is overlain by 0.8 m of coarse gravel followed by sand with clay layers and sandy clay containing pebbles and mollusc shells (183.4–180.5 m). Samples from this deposit contain rich Quaternary foraminiferal faunas, but in contrast to sample 192 from the lowermost part of the marine sequence, there is also a rather high content of Prequaternary specimens (from 10 to 50% of the Quaternary content). The Quaternary faunal composition in samples 154, 155, 157 and 158 is very similar to that described from the lowermost sample, except that *E. groenlandicum* is less frequent in this upper part (fig. 3). A thin layer of coarse sand (180.5–180.3 m) representing the uppermost part of the "lower glacial beds" contains only very few Quaternary as well as Prequaternary foraminifera (sample 152, fig. 3).

The present foraminiferal analysis shows that zone N4 includes two marine transgressions in an arctic environment, separated by a glacial advance.

Zone N3, the *Quinqueloculina padana* zone, is about 40 m thick (179–139 m below surface). In this zone boreal and boreo-lusitanian species are

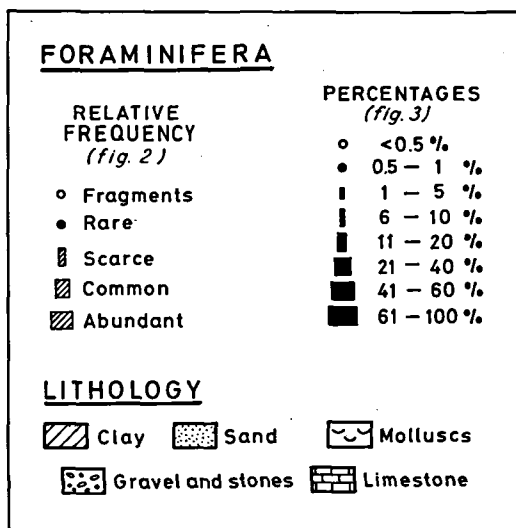


Fig. 4. Legend for the range charts, figs. 2 and 3.

however, found as single specimens within the zone. This is illustrated in our examination of the material (fig. 3), which shows increasing percentages of different species of *Elphidium* in the upper part of zone N3.

The faunal composition of zone N3 indicates marine climatic conditions at least as warm as to-day, but probably slightly warmer. *Quinqueloculina padana*, which is a characteristic species in this zone, was described from the Upper Pliocene of the Mediterranean (Perconig, 1954) and recorded by several authors from Pliocene, Pleistocene and Recent deposits of this area (Longinelli, 1956; Cita and Chierici, 1962; Lentini, 1968). The recent depth distribution of *Q. padana* is given by Cita and Chierici (1962), who recorded it from 32 m depth to the deepest sample at 835 m in the Adriatic Sea, and by Giunta (1954), who recorded it (as *Q. pentagona*, n.sp.) from depths between 75 m and 125 m near Genova. Material from 100 m water depth in the Mediterranean collected by Nørvang, 1962 also contained specimens of *Q. padana*, and in Nørvang's unpublished manuscript of the foraminiferal stratigraphy in Skærumhede I, he actually found that this lusitanian species (described as *Miliolinella interglacialis* n.sp.) was a characterizing faunal element in the assemblages between 139 m and 179 m below ground level, and he named this interval the »*Miliolinella interglacialis*« zone (see also p. 107, this paper).

Q. padana has not been found in recent faunas described from the Oslofjord (Risdal, 1964) or from the Gullmar Fjord and the Skagerrak (Höglund, 1947), and it did not occur in recent faunas from 26–80 m water depth in the Kattgat eihier. (Samples from the area around Læsø were placed at our disposal by Hans Jørgen Hansen, University of Copenhagen). Based on these occurrences *Q. padana* seems to occur exclusively in lusitanian environment.

By comparison with recent faunas the water depth of the zone N3 assemblages is estimated to be up to 60 to 100 m, probably deeper in the lower part of the zone than in the upper, because of the content of *Nonion barleeaanum*.

The faunas in the upper part of zone N3 are also comparable to Holocene faunas from deposits at about 80 m water depth in Djupa Rännan off the Swedish west coast (Fält, 1977). The content of *Elphidium excavatum* in these Holocene faunas together with the very sparse occurrence of *Nonion barleeaanum* indicates a closer correlation with the upper part than with the lower part of zone N3 (fig. 3). *Q. padana* seems not to occur in Holocene deposits of Djupa Rännan.

Zone N2, the *Islandiella helena*-*I. norcrossi* zone, is about 40 m thick (139–98.5 m). The faunal composition varies a great deal through this zone (fig. 2). *Quinqueloculina seminulum* and *Pyrgo williamsoni* are common through-out the zone N2, but *Islandiella helena*, *I. norcrossi* and *Elphidium excavatum* are only common in its upper part. Here other arctic species also gradually appears.

A comparison of the faunas of zone IX in the Skærumhede II boring with Nørvang's foraminiferal material from the corresponding levels in Skærumhede I demonstrates the underrepresentation of small specimens. This is also shown by an additional examination of samples from zone N2 (fig. 3). *Elphidium excavatum* is dominant together with the small boreal shallow water species *E. albiumbilicatum*, *E. magellanicum*, *E. margaritaceum*, *E. gerthi* and *Nonion depressula*, whilst the content of *Cassidulina reniforme* (an arctic species) increases in the upper part of the zone.

The faunal composition of zone N2 shows a transition in marine climatic conditions from a

boreal environment in the lower part to colder water conditions in the uppermost part of the zone. A subzonation of zone N2 has not been attempted based on the present material. The upper part of this zone (to 122 m depth) is represented in the Skærumhede II boring, from which a detailed foraminiferal zonation is described (Konradi and Knudsen, 1974; Knudsen, 1976; see also the correlation below).

Zone N1, the *Elphidium asklundi* zone, is about 41 m thick (98.5–57.4 m). Nørvangs material from this zone was very fragmentary, and only the lowermost part of zone N1 is included in the diagram, fig. 2. *Elphidium groenlandicum*, *Islandiella helenae*, *I. norcrossi* and some miliolids are the most common foraminifera found in Nørvangs material, but a few metres higher in the sequence *E. excavatum* is the dominant species. This assemblage is represented in additional samples, which were analysed from zone N1 (fig. 3).

Correlations and age

In spite of the rather insufficient foraminiferal material left by Nørvang from the upper part of the Skærumhede I boring, a rudimentary correlation of the foraminiferal zones of the two Skærumhede borings can be made. Of more importance is the fact that the very well preserved faunas from the deeper part of Skærumhede I and the supplementary analysis of original material from this part of the boring provides us with new information from earlier in the stratigraphy.

The arctic zone V of Skærumhede II seems to be correlatable with the *Elphidium excavatum* dominated part of zone N1 in Skærumhede I, and zones VI and VII are probably represented by the lowermost part of zone N1 (figs. 2, 3 and 5). The mainly arctic zones in Skærumhede II are included in the Weichselian by Bahnson et al. (1974) (see also Lykke-Andersen, 1981 and 1982).

Zone VIII of Skærumhede II was correlated with the *Abra nitida* zone by Bahnson et al. (1974). This zone is not distinguishable on the basis of Nørvangs foraminiferal material in Skærumhede I, but additional analyses (fig. 3) shows that this zone VIII is correlatable with the upper part of zone N2 in Skærumhede I.

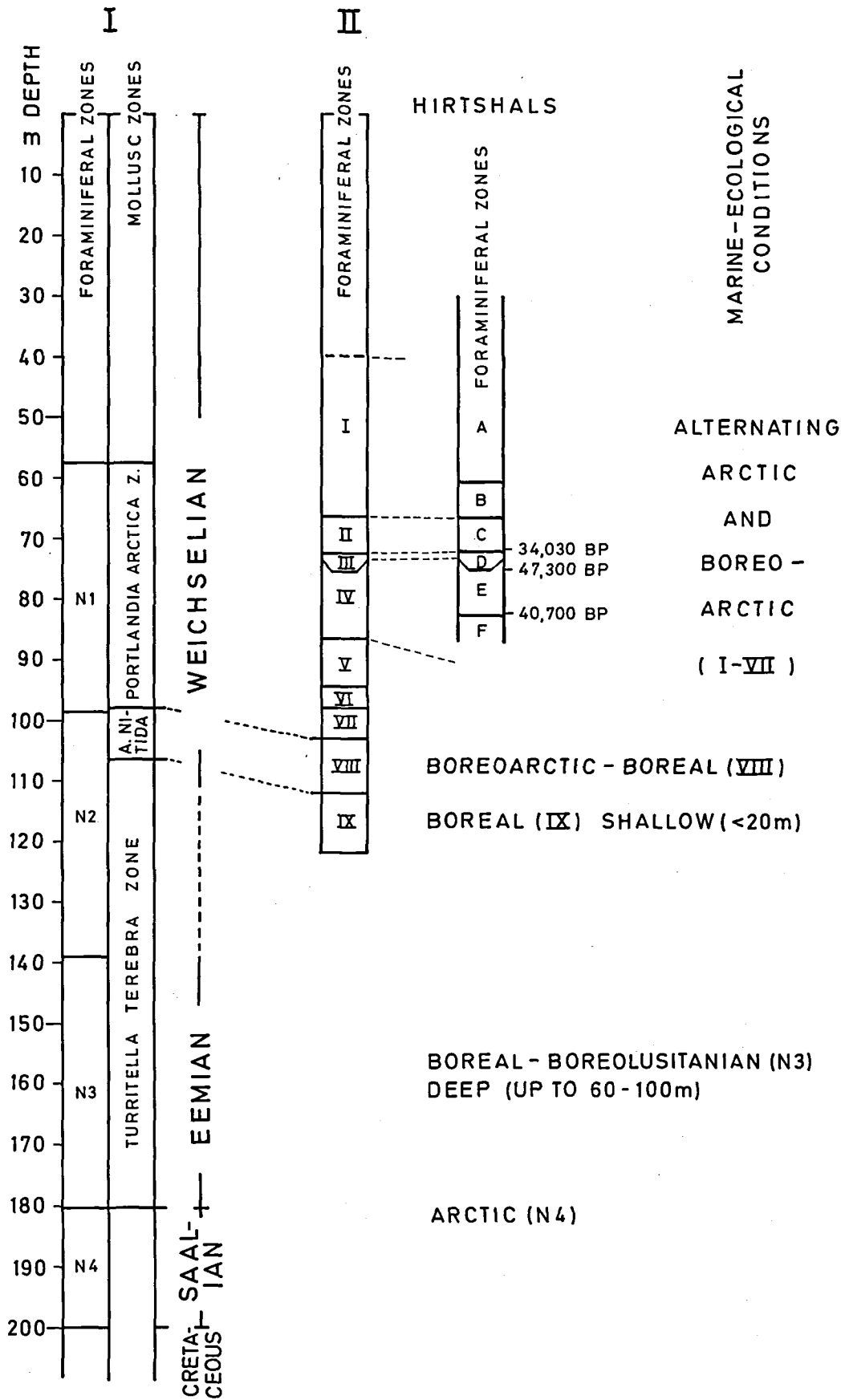
Zone IX in Skærumhede II, with its characteristic boreal shallow water element, and with a very low content of the arctic *Cassidulina reniforme* is represented in zone N2 of Skærumhede I, at a level around samples 108–112 (see discussion above). A more detailed correlation of the foraminiferal faunas in zone N2 with the zonation in the Skærumhede II boring is not possible, but it is obvious that the transition to deeper water faunas in the lower part of zone N2 and especially in zone N3 is not represented in the Skærumhede II boring.

The boreal to boreo-lusitanian faunas of zone N3 in the Skærumhede I boring undoubtedly belong to an interglacial period, and according to our opinion it must be the Eemian. Consequently zone N4 represents the Saalian Glacial period. It was not possible, based on the present material to decide, whether there has been a break in marine sedimentation between the glacial and following interglacial period, or if continuous marine sedimentation occurred. In the present area close to the Fennoscandian border zone, local tectonic movements cannot be excluded.

However, corresponding very distinctive faunal changes, from the arctic Weichselian directly into relative deep water boreal faunas of Flandrian age, are also found in borings in the northern North Sea (Feyling-Hanssen, 1980) and in the Kattegatt (Fält, 1977), and this may show a very rapid change in the water masses going from a glacial into an interglacial period. According to Kellogg et al. (1978) and Kellogg (1980) warm Atlantic water penetrated northward into the Norwegian Sea during the Eemian as well as during the Flandrian (see also Sejrup et al., 1980). The rather abrupt faunal change from the arctic zone N4 to the boreo-lusitanian faunas in zone N3 in Skærumhede I probably reflects a time when the Atlantic water masses could penetrate into the deeper parts of the Norwegian Channel and also into the present Eemian basin. The same was suggested by Fält (1977 and in prep.) at the transition from the Weichselian zone D faunas to the Holocene zone C faunas in borings off the Swedish west coast. On the other hand, a transition zone between Lateglacial and Postglacial assemblages is described in short cores from the Norwegian Channel (Nagy and Ofstad, 1980).

Concerning the boundary between the Eemian

SKÆRUMHEDE BORINGS



and the Weichselian, Konradi and Knudsen (1974) mentioned that the dominance of boreal and boreo-lusitanian shallow water species in zones IX and VIII in the Skærumhede II boring suggests that these zones should be included in the Interglacial period. This would imply that the top of the Eemian in the Skærumhede I boring is found at the boundary between zones N2 and N1 (fig. 5).

New radio carbon dates from zones C and E in Hirtshals, which are correlated with zones III and IV in the Skærumhede II boring (fig. 5) suggest a Middle Weichselian age. Mollusc material from zone C gave an age of $34,030 \pm 1310/1130$ BP (K 3611), molluscs from the base of zone E gave ages of 40,700 and $40,550 \pm 900$ BP (GrN-10023 and 10024) and plant material from the upper part of the same zone gave the age $47,300 \pm 1500/1200$ BP (GrN-9707). Zone E in Hirtshals is referred to the Moershoofd Interstadial complex (Lykke-Andersen, 1981 and 1982).

Consequently the Brørup Interstadial is not represented by zone IV in the Skærumhede II boring, as suggested by Bahnon et al., 1974, but is to be found deeper in the sequence. It is possible that a part of zone N2 in Skærumhede I belongs in the Brørup Interstadial, and the Eemian-Weichselian boundary could thus be represented by the zone N3-N2 boundary (figs. 2, 3 and 5).

A faunal succession corresponding to that described above from the Skærumhede sequence, is also found in other deep borings north and east of Skærumhede (Knudsen, in prep.). In a boring from Frederikshavn, however, a sequence with boreal deepwater faunas correlatable with zone N3 of Skærumhede I, is found at a much higher level. Its lower boundary is 100 m higher in Frederikshavn than in Skærumhede, and the supposed Eemian sequence in Frederikshavn is less than 10 m thick (Knudsen, in prep.). In another deep boring located on the island of Anholt (fig. 1), a similar sequence with boreal deep water foraminifera, occurs at about the same level as in Frederikshavn, and the thickness is also here less than 10 m (Lykke-Andersen, in prep.). Such very pronounced differences in level as well as in the thickness of the Eemian deposits in this area suggest, that tectonic movements may have been active.

The geographical extension of the marine Skærumhede series is not known in detail. A deep water facies of Eemian age (zone N3) has not been found from other localities in Denmark (cf. Lykke-Andersen, in prep. and Knudsen, in prep.), but a similar fauna is described from the northern North Sea (Feyling-Hanssen, 1980). A shallower Eemian fauna is found at Fjøsanger in SW Norway (Mangerud et al., 1981).

The Eemian of the Skærumhede I boring and the localities mentioned above represent deep water deposits in a basin, which occurred from the present Kattegatt, through Vendsyssel to the Skagerrak and the northern North Sea.

Foraminiferal species

Nørvang distinguished 47 different species of foraminifera in his material from the Skærumhede I boring. The relative frequencies of the 26 most common of these species are shown in the diagram, fig. 2, and 7 additional species are included in fig. 3. These 33 species are listed alphabetically below together with their original references and a few comments:

Ammonia batavus (Hofker)

1951 *Streblus batavus* Hofker: *Siboga Exped., Monogr.* 4b (3), p. 492, 501, fig. 340.

Buccella frigida (Cushman)

1922 *Pulvinulina frigida* Cushman: *Contr. to Canadian Biology* 1921, p. 12 (144).

Bulimina elongata d'Orbigny

1826 *Bulimina elongata* d'Orbigny: *Ann. Sci. nat. Paris, ser. 1* (7), p. 269, no. 9.

Our analysis of Nørvangs material suggests that he may have referred some specimens of *Bulimina gibba* Fornasini to *B. elongata*.

Bulimina marginata d'Orbigny

1826 *Bulimina marginata* d'Orbigny: *Ann. Sci. nat. Paris, ser. 1* (7), p. 269, pl. 12, figs. 10–12.

Cassidulina laevigata d'Orbigny

1826 *Cassidulina laevigata* d'Orbigny: *Ann. Sci. nat. Paris, ser. 1* (7), p. 282, pl. 15, figs. 4, 5.

Cassidulina reniforme Nørvang

1945 *Cassidulina crassa* d'Orbigny var. *reniforme* Nørvang: *The zoology of Iceland, Foram. Munksgaard* (Copenhagen and Reykjavik) 2 (2), p. 41, text-figs. 6 c-h.

Cibicides lobatulus (Walker and Jacob)

1798 *Nautilus lobatulus* Walker and Jacob, in Adams, G.: *Essays on the Microscope*. Kanmacher. Ed. 2, London, p. 642, pl. 14, fig. 36.

Elphidium albiumbilicatum (Weiss)

1954 *Nonion pauciloculum* Cushman, subsp. *albiumbilicatum* Weiss: *U.S. Geol. Survey, Prof. Paper* 254-G, p. 157, pl. 32, figs. 1, 2.

Elphidium asklundi Brotzen

1943 *Elphidium asklundi* Brotzen, in Hessland, I.: *Bull. geol. Inst. Uppsala* 31, p. 267, fig. 109-1. Nørvang probably included the two species *Elphidium bartletti* Cushman and *Elphidiella arctica* (Parker and Jones) in *E. asklundi* (fig. 2).

Elphidium excavatum (Terquem)

1875 *Polystomella excavata* Terquem: *Essay sur le Classement des Animaux qui vivent sur la Plage et dans les environs de Dunkerque*. Pt. 1, Paris, p. 25, pl. 2, fig. 2.

Most specimens of *E. excavatum* in the present foraminiferal material belong to the forma *clavata* Cushman, but forma *selseyensis* (Heron-Allen and Earland) also occurs (see Feyling-Hanssen, 1972).

Elphidium gerthi van Voorthuysen

1957 *Elphidium gerthi* van Voorthuysen: *Med. geol. Sticht., N. ser.* 11, p. 32, pl. 23, fig. 12.

Elphidium groenlandicum Cushman

1933 *Elphidium groenlandicum* Cushman: *Smithsonian misc. Coll.* 89 (9), p. 4, pl. 1, fig. 10.

Elphidium macellum (Fichtel and Moll)

1798 *Nautilus macellus* Fichtel and Moll: *Tes-*

tacea Microscopica. Vienna (Second ed. 1803), p. 66, var. B, pl. 10, figs. h-k.

Elphidium magellanicum Heron-Allen and Earland

1932 *Elphidium magellanicum* Heron-Allen and Earland: *Discovery Rep., Cambridge*, 4, p. 440, pl. 16, figs. 26-28.

Elphidium margaritaceum Cushman

1930 *Elphidium advenum* (Cushman), var. *margaritaceum* Cushman: *U.S. Nat. Mus., Bull.* 104 (7), p. 25, pl. 10, fig. 3.

Globobulimina turgida (Bailey)

1851 *Bulimina turgida* Bailey: *Smithsonian Contr. Know.* 2 (3), p. 12, figs. 28-31.

Hyalinea balthica (Schroeter)

1783 *Nautilus balthicus* Schroeter: *Einleitung in die Conchylienkenntniss nach Linné*. Gebauer (Halle) 1, p. 20, pl. 1, fig. 2.

Islandiella helenae Feyling-Hanssen and Buzas

1976 *Islandiella helenae* Feyling-Hanssen and Buzas: *Journ. of Foram. Res.* 6 (2), p. 156, figs. 1-4.

Nørvang grouped the two species *I. helenae* and *I. norcrossi* together. Therefore they can not be separated in the diagram, fig. 2.

Islandiella islandica (Nørvang)

1945 *Cassidulina islandica* Nørvang: *The zoology of Iceland, Foram. Munksgaard* (Copenhagen and Reykjavik) 2 (2), p. 42, fig. 7.

Islandiella norcrossi (Cushman)

1933 *Cassidulina norcrossi* Cushman: *Smithsonian misc. Coll.* 89 (9), p. 7, pl. 2, fig. 7.

See comments for *I. helenae*.

Nonion barleeaanum (Williamson)

1858 *Nonionina barleeaanum* Williamson: *On the Recent Foram. of Great Britain. Roy. Soc. Publs.*, p. 32, pl. 3, figs. 68, 69.

Nonion depressula (Walker and Jakob)

1798 *Nautilus depressulus* Walker and Jakob, in

Adams, G.: *Essays on the Microscope*. Kanmacher. Ed. 2, London, p. 641, fig. 33.

Nonion labradoricum (Dawson)

1960 *Nonionina labradorica* Dawson: *Canadian Nat.* 5, p. 191, fig. 4.

Nonion orbiculare (Brady)

1881 *Nonionina orbicularis* Brady: *Ann. Mag. Nat. Hist. London ser. 5* (8), 45, p. 415.

Planorbulina distoma Terquem

1876 *Planorbulina distoma* Terquem: *Essay sur les Classement des Animaux qui vivent sur la Plage et dans les environs de Dunkerque*. Pt. 2, Paris, p. 73. (Deuxieme Fascicule, *Mém. Soc. Dunkerq. Encour. Sci.*, 20, 1877, p. 164, pl. 8, fig. 11).

Planulina ariminensis d'Orbigny

1826 *Planulina ariminensis* d'Orbigny: *Ann. Sci. nat. Paris ser. 1* (7), p. 280, pl. 14, figs. 1–3.

Pyrgo williamsoni (Silvestri)

1923 *Biloculina williamsoni* Silvestri: *Accad. Pont. Romana Nuovi Lincei, Atli* 76, p. 73.

Quinqueloculina padana Perconig

1954 *Quinqueloculina padana* Perconig: *Contr. Sci. Geol. Rome* 3, p. 96, figs. 1–4.

Q. padana occurs only in zone N3 of the Skærumhede I boring. It was described by Nørvang as a new species "*Miliolinella interglacialis*" in his manuscript from 1940. His original drawings are shown in fig. 6. The chamber arrangement is quinqueloculine, but Nørvangs figures show a broad apertural flap, and not a bifid tooth as in the genus *Quinqueloculina* d'Orbigny, 1826. In a part of his manuscript Nørvang in fact suggested a new genus *Quinqueloculinella* should be erected for species with quinqueloculine chamber arrangement and an apertural flap. His description was, however, not published, and such a genus was later described with the name *Scutoloris* by Loeblich and Tappan (1953). We decided to refer the present species to *Quinqueloculina* and not to *Scutoloris*, because there is often a tendency towards a narrower flap, which in some cases is slightly bifid.

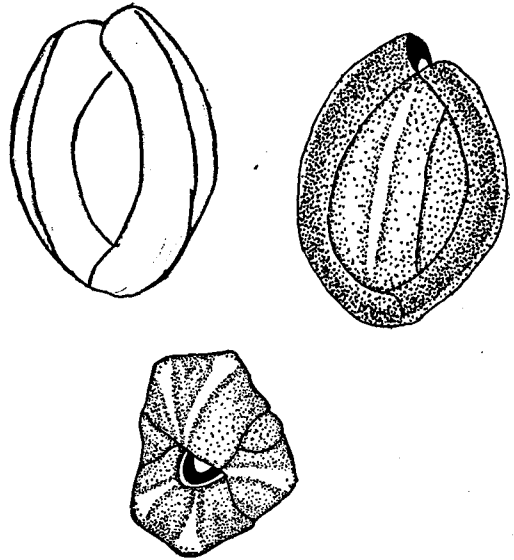


Fig. 6. *Quinqueloculina padana* Perconig. Axel Nørvang's original drawings.

A short description of *Quinqueloculina padana* was first given by Enrico Perconig in 1952 at a congress in Taormina, Sicily (Perconig, 1952, p. 137, figures and a full description published in 1954). He has kindly donated to us specimens from the Pliocene (Calabrian) of Valle del Tenna, Foglio Ferma, Italy, which confirm our reference of Nørvangs material to this species.

In 1954 Giunta described the species *Quinqueloculina pentagona* from the recent fauna of the Mediterranean (75 to 125 m water depth). According to the description and figures this species is undoubtedly synonymous with *Q. padana*.

As Nørvangs species description was never published, the species name *padana* Perconig, 1954 has priority and is used here. This name is also generally used in literature about the Pliocene, Pleistocene and Recent deposits in the Mediterranean area.

Quinqueloculina seminulum (Linné)

1758 *Serpula seminulum* Linné: *Systema naturae*. Ed. 10. *Lipsiae* 1, p. 786, pl. 2, fig. 1.

Sigmoilina schlumbergeri Silvestri

1904 *Sigmoilina schlumbergeri* Silvestri: *Accad. Pont. Nuovi Lincei, Mem.* 22, p. 267.

Stainforthia loeblichii (Feyling-Hanssen)

1954 *Virgulina loeblichii* Feyling-Hanssen: *Norsk geol. Tidsskr.* 33, p. 191, pl. 1, figs. 14–18, text-fig. 3.

Triloculina trigonula (Lamarck)

1804 *Miliolites (trigonula)* Lamarck: *Ann. Nat. Hist. Mus. Paris* 5, p. 351, no. 3, pl. 17, fig. 4 (no. 9, 1807).

Uvigerina peregrina Cushman

1923 *Uvigerina peregrina* Cushman: *U.S. natl. Mus., Bull.* 104 (4), p. 166, pl. 42, figs. 7–10.

Acknowledgments. We are grateful to the Geological Survey of Denmark for placing samples, foraminiferal collections, index cards, a rough draft of a manuscript and a range chart, left by the late Axel Nørvang, at our disposal. In that connection we owe special thanks to Arne Buch for arranging and providing most of this material for us and to Peter Konradi for assistance with additional faunal analyses, and thanks also to Hans Jørgen Hansen for kindly helping us during our work with Axel Nørvangs material.

We want to thank Rolf W. Feyling-Hanssen, Department of Micropaleontology, University of Aarhus for valuable discussions and for critically reading the manuscript, Jette Gissel Nielsen for making the drawings, and Lissi Østerhaab Mogensen for preparing the manuscript, and we are grateful to David N. Penney, University of Dublin, Trinity College, Dublin, Ireland for correcting the English of our manuscript.

Dansk sammendrag

Der er foretaget en foraminifer-stratigrafisk sammenstilling af den marine lagserie i Skærumhede I boringen fra 1905 baseret på en foraminifer-samling, enkelte prøver og et ufuldendt manuskript efterladt af afdøde Axel Nørvang. Resultaterne af denne er fremstillet i fig. 2 så nær Axel Nørvangs egne intentioner som muligt, og selve zonationen er taget direkte ud af hans optegnelser. Som supplement til disse undersøgelser er et udvalg af råprøver fra Skærumhede I boringen analyseret, og resultaterne er fremstillet i fig. 3.

Foraminifer-faunaerne i den marine Skærumhede Serie viser en faunistisk udvikling fra en nedre arktisk zone N4 til en boreal-boreolusitansk zone N3 med faunaer, som tyder på vanddybder på op til 60–100 m og temperaturer lidt højere end i dette område i dag. Derefter følger zone N2 med boreale lavtandsfaunaer i den nedre del og en overgang til boreoarktiske faunaer i den øvre del, og zone N1 med hovedsagelig arktiske faunaer.

Denne marine lagserie ved Skærumhede formodes at repræsentere Sen Saale, Eem, samt Tidlig og Mellem Weichsel. Den øvre del af den marine lagserie kan korreleres med foraminifer-zonerne, som er beskrevet i detaljer fra Skærumhede II boringen og fra Hirtshals Kystklint, mens foraminifer-faunaerne i den nedre del giver et udmærket supplement til denne stratigrafi.

Det nuværende kendskab til udbredelsen af det dybe Eem basin, som er repræsenteret ved zone N3 i Skærumhede I, tyder

på, at dette har strakt sig fra området omkring Anholt over Vendsyssel til Skagerrak og den nordlige Nordsø.

References

- Bahnson, H., Petersen, K. S., Konradi, P. B. and Knudsen, K. L. 1974: Stratigraphy of Quaternary deposits in the Skærumhede II boring: lithology, molluscs and foraminifera. *Danm. geol. Unders., Årbog* 1973, 27–62.
- Cita, M. B. and Chierici, M. A. 1962: Crociera talassografica adriatica 1955. V. Ricerche sui foraminiferi contenuti in 18 carote prelevate sul fondo del Mare Adriatico. *Arch. Oceanogr. Limnol.*, 12 (3), 297–359.
- Feyling-Hanssen, R. W. 1972: The foraminifer *Elphidium excavatum* (Terquem) and its variant forms. *Micropaleontology*, 18 (3), 337–354.
- Feyling-Hanssen, R. W. 1980: Foraminiferal indication of Eemian interglacial in the northern North Sea. *Bull. geol. Soc. Denmark*, 29, 175–189.
- Feyling-Hanssen, R. W., Jørgensen, J. A., Knudsen, K. L. and 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. and Knudsen, K. L. 1980: Foraminiferer og deres betydning i skandinavisk kvartær geologi. *Dansk Natur Dansk Skole, Årsskrift* 1979, 3–45.
- Fält, L.-M. 1977: Gränsen Pleistocen/Holocen i marina sediment utanför svenska västkusten. *Chalmers Tekn. Högskola och Göteborgs Univ., Geol. Inst., Publ. A* 14, 1–39.
- Giunta, M. 1954: *Quinqueloculina pentagona* n. sp. *Riv. Ital. Pal. Strat.*, Milano, 60, no. 1, p. 33.
- Hedberg, H. D. ed. 1976: *International stratigraphic guide. A guide to stratigraphic classification, terminology and procedure.* Wiley and Sons, New York, 1–200.
- Höglund, H. 1947: Foraminifera in the Gullmar Fjord and the Skagerak. *Zool. Bidr. från Uppsala*, 26, 1–328.
- Jessen, A., Milthers, V., Nordmann, V., Hartz, N. and Hesselbo, A. 1910: En boring gennem de kvartære Lag ved Skærumhede. *Danm. geol. Unders.*, II Række, 25, 1–175.
- Kellogg, T. B. 1980: Paleoclimatology and paleo-oceanography of the Norwegian and Greenland seas: glacial-interglacial contrasts. *Boreas*, 9, 115–137.
- Kellogg, T. B., Duplessy, J. L. and Shackleton, N. J. 1978: Planktonic foraminiferal and oxygen stratigraphy and paleoclimatology of Norwegian Sea deep-sea cores. *Boreas*, 7, 61–73.
- Knudsen, K. L. 1976: Foraminifer faunas in Weichselian stadial and interstadial deposits of the Skærumhede boring, Jutland, Denmark. *Maritime sediments, Spec. Publ. 1, B – Paleocology and Biostratigraphy, Halifax*, 431–449.
- Konradi, P. B. and Knudsen, K. L. 1974: Foraminifera in the Skærumhede II boring, 43–57. In: Bahnson, H., Petersen, K. S., Konradi, P. B. and Knudsen, K. L. 1974.
- Lentini, F. 1968: Stratigrafia micropaleontologica dei terreni plio-pleistocenici di Sant' Arcangelo (Potenza). *Atti Acc. Gioenia Sci. Nat. Catania*, VI (19), *Suppl. Sci. Geol.*, 255–344.
- Loeblich, A. R. and Tappan, H. 1953: Studies of Arctic Foraminifera. *Smithsonian Misc. Coll.*, 121 (7), 1–150.
- Longinelli, A. 1956: Foraminiferi del Calabriano e del Piacenziano di Rosignano Marittimo e della Val di Cecina. *Paleont. Italica*, 49, 99–214.
- Lykke-Andersen, A.-L. 1971: Foraminifera from the Older Yoldia Clay in Hirtshals, 159–184. In: Feyling-Hanssen, R. W., Jørgensen, J. A., Knudsen, K. L. and Lykke-Andersen, A.-L. *Bull. geol. Soc. Denmark*, 21 (2–3), 67–317.

- Lykke-Andersen, A.-L. 1981: En ny C-14 datering fra Ældre Yoldia Ler i Hirtshals Kystklint. *Dansk geol. Foren. Årsskrift for 1980*, 1-5.
- Lykke-Andersen, A.-L. 1982: Nogle nye C-14 dateringer fra Ældre Yoldia Ler i Hirtshals Kystklint. *Dansk geol. Foren. Årsskrift for 1981*.
- Mangerud, J., Sønstegaard, E., Sejrup, H.-P. and Haldorsen, S. 1981: A continuous Eemian-Early Weichselian sequence containing pollen and marine fossils at Fjøsanger, western Norway. *Boreas*, 10, 137-208.
- Nagy, J. and Ofstad, K. 1980: Quaternary foraminifera and sediments in the Norwegian Channel. *Boreas*, 9, 39-52.
- Nørvang, A. 1945: Foraminiferer fra Skårumhedeboingen. *Meddr. dansk geol. Foren.*, 10, 645.
- Perconig, E. 1952: La stratigrafia del sondaggio profondo n. 29 di Cortemaggiore. *Atti del VII Convegno Nazionale del Metano e del Petrolio, Ires, Palermo*.
- Perconig, E. 1954: Note paleontologiche sulla zona costiera di Agrigento (Sicilia). *Contr. Sci. Geol., Rome*, 3, 91-98.
- Risdal, D. 1964: Foraminiferfaunaenes relasjon til dybdeforholdene i Oslofjorden, med en diskusjon av de senkvartære foraminifersoner. *Norges geol. Unders.*, 226, 1-142.
- Sejrup, H.-P., Holtedahl, H., Norvik, O. and Miljeteig, I. 1980: Benthonic foraminifera as indicators of the paleoposition of the Subarctic Convergence in the Norwegian-Greenland Sea. *Boreas*, 9, 203-207.