WEICHSELIAN INTERSTADIAL FORAMINIFERA FROM THE SANDNES-JÆREN AREA

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The Sandnes Clay

The micropalaeontological examinations and considerations presented in the following pages deals primarily with samples from five shallow borings in the Gann area of the town Sandnes on the southwest coast of Norway, see sketch-map, fig. 3. The Gann area includes the clay pit of Gann brickworks, which closed production in 1952. On August 12th, 1963, cracks appeared in the ground and it was realised that a slide was in progress. The movement was stopped, however, by the loading of the lower part of the area with sand, and the Norwegian Geotechnical Institute, Oslo, undertook a comprehensive subsurface investigation of the sediment properties. The results of the investigation were precipitated in a series of reports in 1964 (Norwegian Geotechnical Institute, Reports F 256, 1–10), in a main report by Bjerrum, Eide & Foss (1964), and more recently by Bjerrum (1967 and 1968).

As a part of the investigations in 1963 six borings, 20.2 to 32.6 m deep, were carried out. The Geotechnical Institute's standard type of piston corer was used. It cuts out samples with a cross section of 54 mm, and almost continuous sampling was obtained from borings I–V. (Boring no. VI penetrated sandy deposits, and has not been considered in the present paper). Parts of these samples, core slices of 3 to 4 cm thickness cut at intervals of about 50 cm or even 25 cm – or at greater intervals if a shortage occurred, were handed over to the author for micropalaeontological examination. The routine examination concentrated upon boring no. I. A subdivision into zones was possible and the same zones were recognised, more or less clearly developed, in the borings nos. II–V. The foraminiferal faunas indicated a Quaternary age for the deposits. Furthermore, being overlain by a young till and with no other tills being recognised in the core samples, the age estimate was narrowed to Middle Weichselian, i.e. post Eemian but pre Main Weichselian (pre Main Wisconsin advance). A report on the micropalaeontological results was submitted to the Norwegian Geotechnical Institute in January 1964 (F 256–6, bilag 1). A chart of boring no. I with the frequencies and the distribution of 21 species of foraminifera, a similar chart for boring no. VI, a profile through the Gann clay pit and a picture

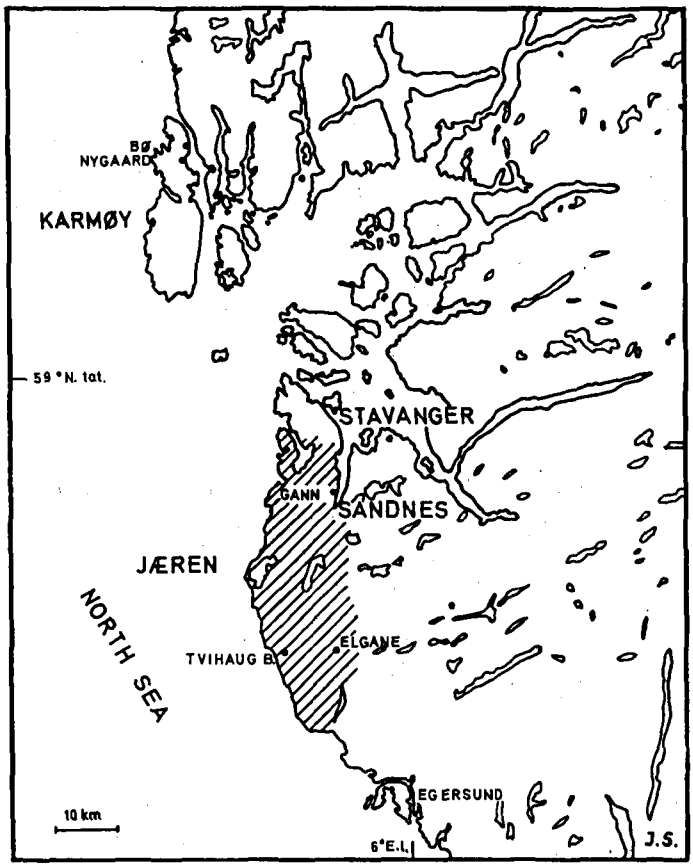

Fig. 3. The Gann area in the town Sandnes in the northern part of the district of Jæren, southwestern Norway. NNE of Sandnes is the island of Karmøy with Bø and Nygaard brickworks.

of a foraminiferal fauna from 8.85 m depth of boring no. I were published in 1966 (Feyling-Hanssen, 1966). A Paudorf interstadial age was suggested for the clay deposits. Boring no. I was mentioned again by Feyling-Hanssen (in press) and Feyling-Hanssen et al. (1970).

The intention of the present article is to give a complete account of the foraminifera in the samples from the Sandnes borings. A range chart for boring no. I has been reconstructed after re-examination of the samples and for comparison, the range chart for boring no. V is presented. The faunas from the borings are compared with faunas from surface samples from the Sandnes-Jæren area, and also with fossil faunas from Jutland in Denmark.

The Gann area forms a slope on the west side of the Gandsfjord, gently descending eastward towards the fjord (fig. 4). The original average inclina-

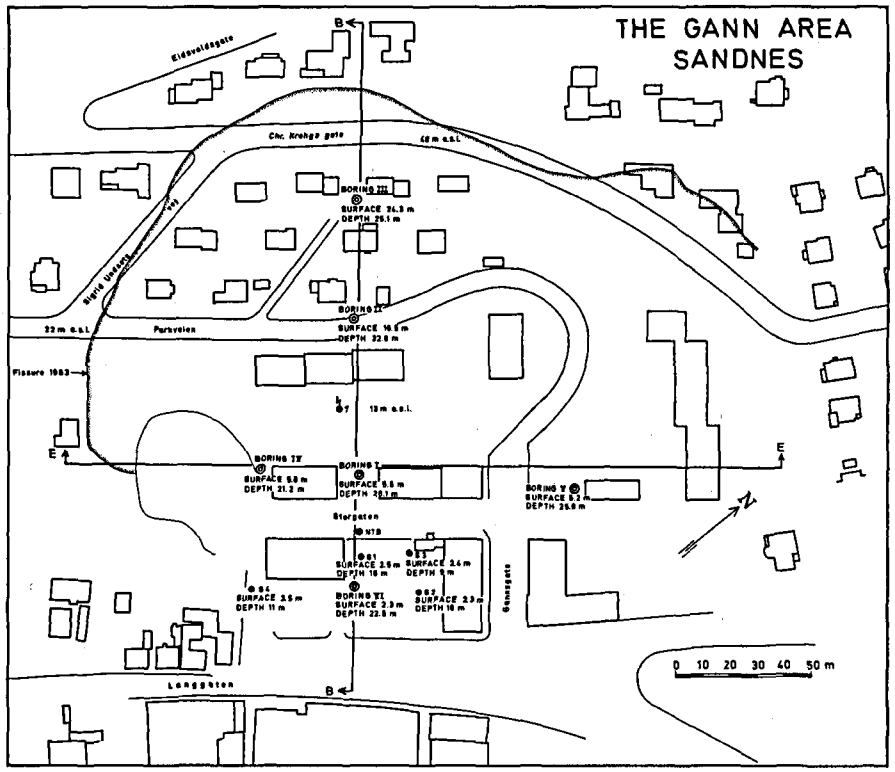

Fig. 4. The Gann area in Sandnes with location of the borings I to VI. The altitude of the terrain surface and depth of the borehole are indicated at each site. NTB, S 1, S 2, S 3 and S 4 are probe borings without samples. At 7, about the middle of the map area, a geoelectric measurement was carried out to determine the thickness of the till. BB and EE represent the profiles shown in figs. 6 and 7. Redrawn from a sketch in Bjerrum, Eide & Foss, 1964.

tion of the slope was 1:5. This was gradually changed by the activity in the clay pit at the foot of the slope. The change in slope was caused by minor failures along a gradually developed horizontal slip plane (Bjerrum, Eide & Foss, 1964; Bjerrum, 1967).

The locations of the borings are indicated on the sketch-map, fig. 4. It appears that the borings I–IV are situated within the area affected by these movements, whereas the borings V and VI are situated outside this area. However, the easy correlation of the zones in the different borings suggests that the sequence has not been seriously disturbed by the movements. This may be explained by the semi-horizontal slip surface and block-by-block failures on a minor scale of the slope above.

Lithology of boring no. I

Boring no. I, situated at the foot of the slope, was 26.1 m deep. The terrain surface at the bore site is situated 5.5 m above sea level. The lithological and geotechnical units revealed by the samples from this boring are as follows (Bjerrum, Eide & Foss, 1964, p. 39 and personal observations):

From 0 to 1.7 m depth occurred a silty sand with stones and blocks of Archaean crystalline rocks from the mountainous highland to the east of Sandnes. This represents partly filling but also a till which forms a veneer, 0.5 to 7.0 m thick, in the surrounding area. The blocks may be more than 2 m in diameter.

From 1.7 to 9.2 m occurred a 7.5 m thick layer of sandy clay with small stones. Stones and pebbles were mostly scattered throughout the layer but tended to concentrate at 2.2 m, 5.5 m, 6.4 m, 7.8 m, and in the deepest part of this unit. The clay content, particle size less than 2 μ, was 50 %–55 %, the sorting normal. Fragments of molluscan shells occurred at 2.5 m and at 3.5 m. The salt content of the pore water of the clay was measured at 2.5 m, 5.4 m, and 8.0 m depth. The result was between 9 and 10 g/l (9–10 ‰). The humus content at the same levels ranged between 0.20 % and 0.25 %.

From 9.2 to 14.7 m occurred a 5.5 m thick, fissured plastic clay. Except for the silty top of this layer the clay content was higher than in the overlying unit (between 56 % and 73 %). Only some mineral grains, mainly quartz, in the sand-silt fraction were observed. This unit was fissured throughout and in all directions, making the clay brittle and apt to collapse in pieces when under load. The fissures seemed to be composed of small, mostly curved and glistening slip surfaces. There was a difference in colour above and below 12 m depth, the upper part being light grey whereas the lower part was dark grey. Lumps of consolidated clay, stained red with iron oxide, usually occurred upon the sieves after washing of the samples from this unit. Fragments of molluscan shells occurred in the lower part of this layer, among them taxodont hinge fragments, probably representing *Yoldiella* or *Portlandia,* most probably *Portlandia arctica* (Gray). Some plant remains occurred in the upper part of this unit. Three measurements of the salt content of the pore water of the clay gave 6.0 ‰–7.5 ‰, i.e. considerably lower than for the unit above. The humus content, on the other hand, was higher, viz. 0.52 % in two of the analysed samples (9.5 and 12.3 m), and 0.2 % in the third one at 10.6 m.

From 14.7 m to the bottom of the boring occurred a silty clay with some layers of sand or fine sand. Between 20.5 and 21.0 m depth there was a nearly 0.5 m thick layer of well-sorted fine sand. Above and below this layer there were sand layers of approximately 10 cm thickness. Some stones

occurred between 15.0 and 15.5 m depth and some shell fragments at 15.0 and 24.5 m. The deposit was grey below the conspicuous sand layer, and grey with black spots above it. The clay fraction was measured at four levels within this unit and found to be approximately 50 % at 15.9 and 19.5 m, approximately 30 % at 17.3 m, and 40 % at 26.0 m depth. The salt content of the porewater varied between 5.5 g/l and 3.2 g/l. The humus content was 1.0 % at 17.3 m, 0.25 % at 15.9 m, and 0.10 % at 19.0 and 26.0 m. Many of the microfaunas from this part of the deposit showed signs of decalcification, particularly between 16.5 and 18.4 m depth, where some of the fossils were corroded or dissolved and filled with pyrite to such a degree that identification was difficult or impossible. In some of them the calcium carbonate was completely dissolved so that only a pyrite cast remained, in others only a mould of foraminifera was left in hard lumps of red-brown clay. Large forms with thick tests seemed to be overrepresented within such layers.

The clay below the conspicuous sand layer was softer than the clay above.

All the clays in boring no. I were described as stiff and overconsolidated. The pre-consolidation pressure was found to have been more than 600 t/m² for the sandy clay of the upper part of the boring. The upper part of the fissured plastic clay was also found to have been heavily pre-consolidated, whereas the pre-consolidation pressure for the clays below 12 m depth was 100–200 t/m². Most probably the pre-consolidation must be ascribed to the glacier ice which deposited the till at the top of the sequence.

Magnetite occurred with some of the mineral grains throughout the boring, most frequently in the sandy clay of the upper part of the succession.

The lithological units described from boring no. I, are present in borings II, IV and V as well. Boring no. III penetrated only the sandy clay and the uppermost part of the fissured plastic clay. Boring no. VI revealed sand deposits with little relation to the other sediments of the Gann area.

Foraminifera from boring no. I

47 samples from this boring were treated for micropalaeontological investigation. Their dry weight ranged from 50 to 150 g. The samples were taken from 1.23 to 26.08 m below the surface. The sampling was made with 40 cm or 80 cm long steel cylinders, the sample designation of the Norwegian Geotechnical Institute being F 256–01 to F 256–43 for this boring. The positions of the samples in the boring are indicated in the range chart, fig. 5. Most of the samples contained foraminifera, indicating that these deposits, or at least the major part of them, are marine. Other fossils also occurred, e.g. ostracoda, but in all instances the foraminifera were predominant.

Nevertheless, the foraminifera faunas were poor in number of species and specimens. As a rule a 100 g sample yielded less than 500 specimens. The

maximum number of specimens in this boring was 3,300–3,400 in 100 g, which occurred in the sample from 7.80 m depth. For comparison, Postglacial clays from the Oslofjord area in Norway usually contain 10,000 specimens per 100 g, 30,000 being a maximum (Feyling-Hanssen, 1964 a), and Postglacial samples from Løkken, Vendsyssel in Jutland contained up to 226,000 specimens in 100 g sediment (Knudsen, this paper). The number of different species exceeded 20 in only two samples from boring number I, viz. that from 7.80 m and 8.85 m depth. Otherwise there were, on an average, 15–20 species per sample in the upper part of the boring and less in the lower part. The samples from 9.3–12.0 m and below 19.0 m were almost barren of foraminifera.

The distribution of species and changing composition of foraminiferal assemblages through this boring permitted a subdivision of the deposits into four units, here called zones. They are, from top to bottom: zone 1, the *labradoricum-norcrossi* assemblage; zone 2, the upper zone with scattered specimens; zone 3, the *asklundi-bartletti* assemblage; zone 4, the lower zone with scattered specimens.

In the first report on boring no. I to the Norwegian Geotechnical Institute and in Feyling-Hanssen (1964 c, 1966), this boring was divided into six zones. The upper two are retained in the present account, but zone 3 now comprises the previous zones 3, 4 and 5, and the present zone 4 is identical with the previous zone 6.

Zone 1, the *labradoricum-norcrossi* assemblage

This zone coincides with the sandy clay from 1.70 to 9.20 m. The foraminiferal assemblages are all dominated by the brown, translucent form of *Elphidium clavatum,* usually with a distinct umbilical plug. In most of the samples this species accounts for more than 60 % of the assemblage. Second in number in all but one of the samples is *Cassidulina crassa,* accounting for 10–23 % of the specimens. This frequency relation between the two mentioned species is also found in many samples from zone 3. Therefore the characteristic feature of the zone 1 fauna is not the dominance of *Elphidium clavatum* and the consistent occurrence of *Cassidulina crassa,* but the presence of other species, primarily *Nonion labradoricum* and *Islandiella norcrossi,* which do not, or only occasionally, occur in the lower zones. *Nonion labradoricum* includes 2 to 13 % of the assemblages, whereas *Islandiella norcrossi* accounts for 1 to 13 %. *I. norcrossi* is usually less frequent than *N. labradoricum,* and is even absent in the uppermost sample of this boring. Other characteristic, but less frequent species in this zone are *Islandiella teretis, Virgulina loeblichi,* and *Astrononion gallowayi. Trifarina fluens* is quite common, but it also occurs in some samples from zone 3.

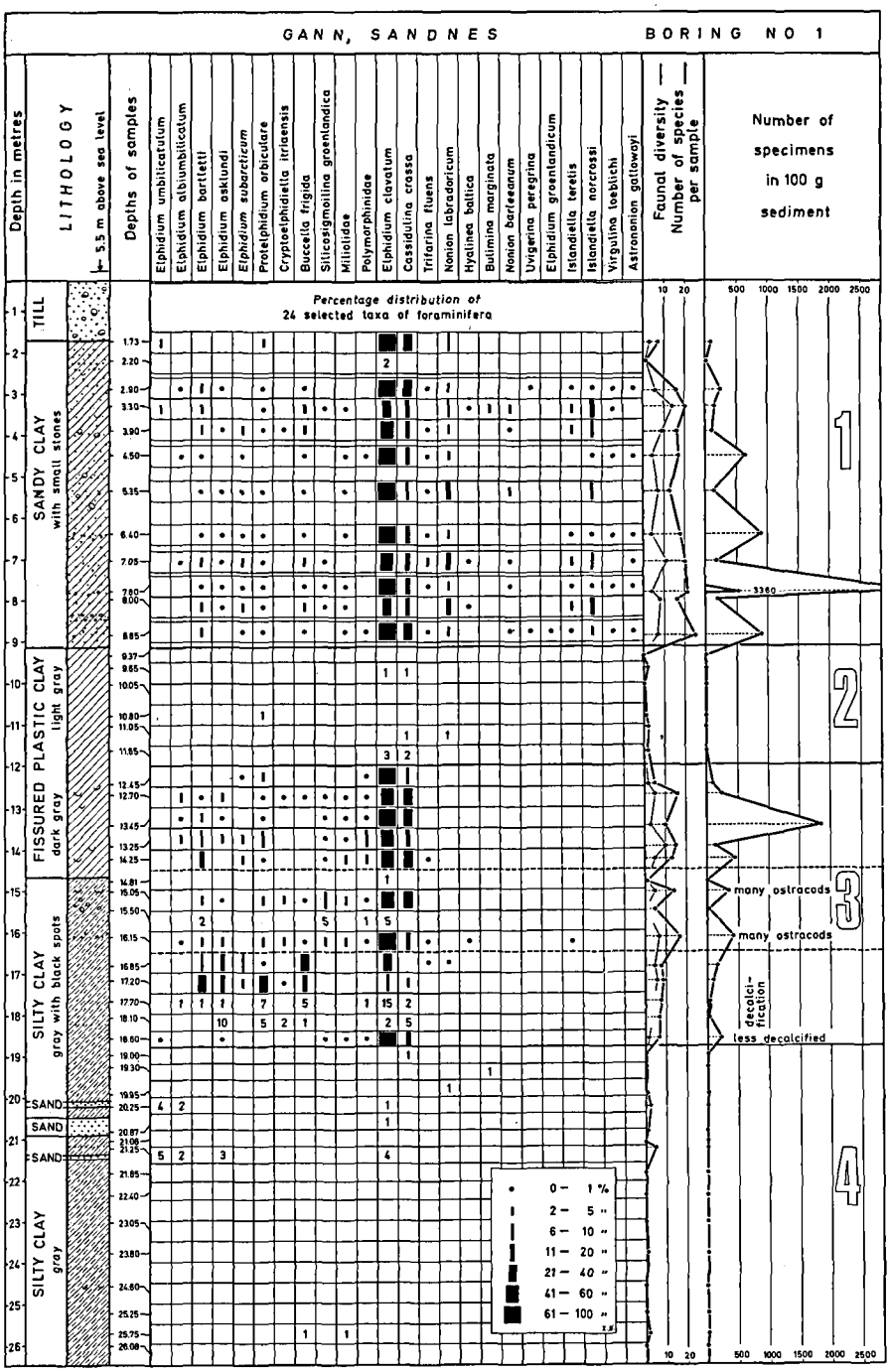

Fig. 5. Range chart for boring no. I, Sandnes. Lithology to the left, foraminiferal zonation (1–4) to the right.

Other species which occur in zone 1, but which are more frequent in zone 3, are *Elphidium bartletti, E. asklundi, E. subarcticum, Protelphidium orbiculare, Buccella frigida, Silicosigmoilina groenlandica,* and in addition some miliolid and polymorphinid species.

All the species are found today in arctic or boreo-arctic environments. But at least some of the samples from zone 1 contain a few boreal species, viz. *Hyalinea baltica, Bulimina marginata, Nonion barleeanum,* and *Uvigerina peregrina.* They seem, when first noticed, to constitute an alien element in these faunas, and some specimens may be re-worked from older deposits; this is most likely the case with a few worn *Hyalinea baltica.* Usually, however, the boreal specimens are equally well preserved as the other specimens of the *labradoricum-norcrossi* assemblage; they must be a primary element in this zone, and add another characteristic feature to it.

The analysis of the sample from 8.85 m depth is here given as an example of the faunal composition in zone 1:

Gann, Sandnes, boring no. I, 8.85 m. zone 1.

Species	Frequency	Percentage
Elphidium clavatum	366	63
Cassidulina crassa	132	22
Nonion labradoricum	20	3
Islandiella norcrossi	15	3
Elphidium bartletti	9	2
Islandiella teretis	6	1
Buccella frigida	6	1
Cibicides lobatulus	4	1
Virgulina loeblichi	3	1
Astrononion gallowayi	3	1
Elphidium subarcticum	3	1
Trifarina fluens	2	<1
Protelphidium orbiculare	2	<1
Quinqueloculina stalkeri	1	<1
Pateoris hauerinoides	1	<1
Pyrgo williamsoni	1	<1
Guttulina lacta	1	<1
Fissurina fasciata	1	<1
Fissurina laevigata	1	<1
Parafissurina tectulostoma	1	<1
Uvigerina peregrina	1	<1
Bolivina pseudoplicata	1	<1
Nonionella auricula	1	<1
Nonion barleeanum	1	<1
Cibicides refulgens	1	<1
Elphidium groenlandicum	1	<1
Total	584	

The sample weighed 125 g and the count above represents the assemblage from approximately 2/3 of the sample. The rest of the sample was searched for unregistered species, and a total of 26 different species are present. This is the highest number of species found in any of the samples from the borings in the Gann area. The faunal dominance is 63, the faunal diversity (cf. p. 71) is 7. For comparison the faunal diversity of assemblages from the Postglacial warm interval of the Oslofjord area (Feyling-Hanssen, 1964 a) could be 15 or 20, but on the other hand, Lateglacial faunas of about Younger *Dryas* age (the age of the Fennoscandian marginal moraines) from that area usually show a faunal diversity of only 2–4. The representation of *Nonion labradoricum* and *Islandiella norcrossi* in the present sample is very typical for zone 1. The specimens of *Cibicides lobatulus* are of regular form, not of the flat, modified and multimorphological forms often found in extremely shallow waters.

The sample from 6.40 m depth provided a fauna with a more pronounced dominance and a low faunal diversity:

Gann, Sandnes, boring no. I, 6.40 m. zone 1.

Species	Frequency	Percentage
Elphidium clavatum	388	73
Cassidulina crassa	93	18
Nonion labradoricum	15	3
Islandielle norcrossi	6	1
Elphidium bartletti	6	1
Virgulina loeblichi	3	1
Buccella frigida	3	1
Bolivina spathulata	2	<1
Protelphidium orbiculare	2	<1
Pyrgo williamsoni	1	<1
Fissurina sidebottomi	1	<1
Trifarina fluens	1	<1
Cassidulina laevigata	1	<1
Islandiella teretis	1	<1
Epistominella takayanagii	1	<1
Astrononion gallowayi	1	<1
Elphidium asklundi	1	<1
Elphidium subarcticum	1	<1
Total	527	

The sample weighed 150 g, and the count represents 2/5 of the assemblage. 18 species are present, but because of the high dominance, viz. 73, the diversity is only 4. The sample from 4.50 m yielded a similar fauna, in which 75 % of the specimens belong to *Elphidium clavatum*. A fauna with mode-

rate dominance and comparatively high diversity occurs in the sample from 3.30 m depth. The sample weighed, in dry state, 105 g. The entire foraminiferal content was counted, only 153 specimens are present:

Gann, Sandnes, boring no. I, 3.30 m. zone 1.

Species	Frequency	Percentage
Elphidium clavatum	53	35
Cassidulina crassa	20	13
Islandiella norcrossi	18	12
Nonion labradoricum	15	10
Cibicides lobatulus	11	7
Buccella frigida	5	3
Elphidium bartletti	5	3
Islandiella teretis	4	3
Bulimina marginata	3	2
Nonion barleeanum	3	2
Elphidium albiumbilicatum	3	2
Oolina isabella	2	1
Virgulina loeblichi	2	1
Hyalinea baltica	2	1
Protelphidium orbiculare	2	1
Silicosigmoilina groenlandica	1	1
Quinqueloculina seminulum	1	1
Pyrgo williamsoni	1	1
Elphidium asklundi	1	1
Cryptoelphidiella itriaensis	1	1
Total	153	101

There are 20 different species in this sample. The faunal dominance is only 35, the faunal diversity 14.

Except for a few re-worked specimens, the foraminifera of the *labradoricum-norcrossi* assemblage are well preserved. In addition to the foraminifera a few ostracoda occur throughout the zone. A wheel-shaped diatom and a compartment of the barnacle *Balanus crenatus* Bruguière was found at 3.30 m, and a little gastropod, probably a *Trophon,* at 5.35 m.

Zone 2, upper zone with scattered specimens

In boring no. I this zone comprises the upper part of the fissured plastic clay from 9.20 to 12.00 m. It is almost barren of fossils. Only the specimens listed in the range chart, fig. 5 occur in this zone. These few specimens are not particularly corroded. A few specimens of a *Daphnia* and one of *Difflugia capreolata* were found; they may have been brought into the sample by the water used during the washing process.

Zone 3, the *asklundi-bartletti* assemblage

In boring no. I the lower part of the fissured plastic clay and the upper part of the silty clay, from 12.00 to 18.80 m depth belong to this zone. The majority of the assemblages, like those from zone 1, are dominated by *Elphidium clavatum.* In some samples, however, there are many *Cassidulina crassa.* In a few samples *Elphidium clavatum* and *Cassidulina crassa* are outnumbered by typical, large arctic shallow-water species like *Elphidium bartletti, E. asklundi, Protelphidium orbiculare,* and moderately large *Buccella frigida.* The four species are characteristic of the whole zone, but they are most frequent (largest percentage representation) in the basal part of the zone. *Silicosigmoilina groenlandica* is relatively most frequent in the middle part of the zone, whereas members of the Polymorphinidae are fairly common in the upper part of the zone. This distribution permits a subdivision of zone 3 into a lower, a middle, and an upper subzone which are equal to the previously established zones 3, 4 and 5. Such a subdivision of zone 3 is possible also in boring no. V, but not as readily in the other borings. *Elphidium albiumbilicatum* and *Cryptoelphidiella itriaensis* n. g., n. sp. occur in zone 3 together with some miliolid species. Equally characteristic is the absence of *Nonion labradoricum, Islandiella norcrossi,* and the other species from zone 1 placed to the right in the range chart. Only single scattered specimens of this group are occasionally found in zone 3. The boreal element is also absent.

Gann, Sandnes, boring no. I, 12.70 m. Upper part of zone 3.

Species	Frequency	Percentage
Elphidium clavatum	162	55
Cassidulina crassa	100	34
Elphidium asklundi	8	3
Elphidium albiumbilicatum	5	2
Elphidium bartletti	4	1
Silicosigmoilina groenlandica	2	1
Triloculina trihedra	2	1
Pyrgo williamsoni	2	1
Miliolinella subrotunda	2	1
Elphidium incertum	2	1
Pseudopolymorphina novangliae	1	<1
Esosyrinx curta	1	<1
Patellina corrugata	1	<1
Protelphidium orbiculare	1	<1
Cryptoelphidiella itriaensis	1	<1
Buccella frigida	1	<1
Total	295	

Many of the samples from this zone were more or less decalcified, particularly the samples from 16.85 m, 17.20 m, 17.70 m, and 18.10 m. One gets the impression that the assemblages of these samples, and also of some of the other samples from zone 3, represent only remnants of the original assemblages and that smaller and more delicate forms, e.g. *Elphidium clavatum* and *Cassidulina crassa* are under-represented, as many specimens may have been completely dissolved. On the other hand, *Buccella frigida,* which is both a quite small and comparatively thin-walled form, is exceptionally frequent in two of the samples from this part of the boring.

To illustrate the composition of a fossil fauna from the upper part of zone 3, the count of the sample from 12.70 m depths is presented above.

The sample weighed 85 g and the whole assemblage was counted. There are 16 different species, the dominance is 55, and the faunal diversity 5.

The fossil assemblage from 15.05 m depth contains many specimens of *Silicosigmoilina groenlandica* and *Cryptoelphidiella itriaensis* and is presented as an example of the fauna from the middle part of zone 3. The weight of the sample was 112 g, all the foraminifera were counted:

Gann, Sandnes, boring no. I, 15.05 m. Middle part of zone 3.

Species	Frequency	Percentage
Elphidium clavatum	191	48
Cassidulina crassa	142	35
Silicosigmoilina groenlandica	26	6
Cryptoelphidiella itriaensis	11	3
Protelphidium orbiculare	10	3
Elphidium bartletti	6	2
Cyclogyra involvens	3	1
Triloculina trihedra	3	1
Pyrgo williamsoni	3	1
Buccella frigida	2	<1
Elphidium asklundi	2	<1
Guttulina lactea	1	<1
Glabratella wrightii	1	<1
Rosalina vilardeboana	1	<1
Total	402	

14 different species were found, the dominance is 48, and the diversity 5.

To demonstrate a zone 3 composition of the fauna from the lower part of the zone, the count of the sample from 17.20 m depth is given. The weight of the sample was 110 g, all the foraminifera were counted:

Gann, Sandnes, boring no. I, 17.20 m. Lower part of zone 3.

Species	Frequency	Percentage
Elphidium bartletti	30	28
Protelphidium orbiculare	23	21
Buccella frigida	22	20
Elphidium asklundi	13	12
Elphidium clavatum	9	8
Cassidulina crassa	5	5
Elphidium subarcticum	4	4
Cryptoelphidiella itriaensis	2	2
Elphidium incertum	1	1
Total	109	101

The large *Elphidium* specimens dominate the fauna together with *Bucella frigida,* whereas *Cassidulina crassa* has almost disappeared, Many of the specimens are corroded, indicating that the foraminifera have been subjected to decalcification.

Some of the samples from zone 3 contain only a few foraminifera. The occurrences of these species have been entered in the chart (fig. 5) with actual frequencies. At 18.60 m an assemblage with a very high dominance of *Elphidium clavatum* is seen. This sample is also included in zone 3.

In addition to the foraminifera sometimes a considerable number of ostracod valves were found, particularly at 15.05 m (52 valves, representing 26 animals) and at 16.15 m (19 valves). Taxodont hinge fragments of a pelecypod, probably *Portlandia arctica,* occur in some of the samples from the upper part of the zone.

Zone 4, lower zone with scattered specimens

This zone comprises the lowermost part of the boring, from 18.80 m downwards. Like zone 2 it is almost barren of fossils. A specimen of *Bulimina marginata* was found at 19.30 m and a *Nonion labradoricum* at 19.95 m. Close to the sand layers, above as well as below it, some specimens of the typical shallow-water species *Elphidium umbilicatulum* occurred together with a few other species usually associated with shallow water, viz. *Elphidium asklundi* and *Elphidium albiumbilicatum.* On the other hand, a broken specimen of *Bolivina* cf. *robusta* was also found. A badly preserved fragment of *Cibicides lobatulus* (?) occurred at 23.80 m, and a specimen of *Buccella frigida* and *Miliolinella subrotunda* at 25.75 m. Most of these specimens are worn. A few ostracods occurred in the upper part of the zone and at 21.08 m a single carapace.

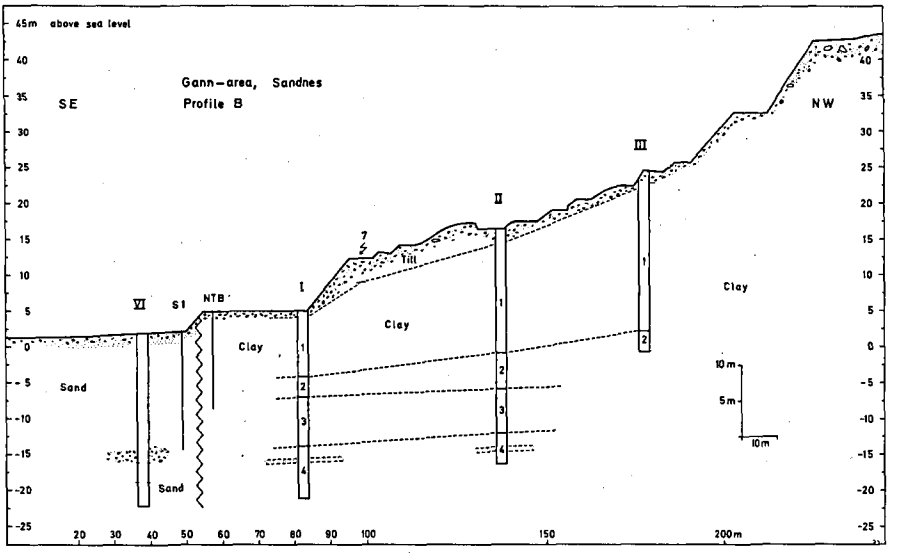

Fig. 6. Profile B, along the slope of the Gann area, Sandnes, with the foraminiferal zonation of borings I, II and III. Boring VI revealed mostly sand deposits and is only briefly discussed in the present paper. The reason for the sharp and steep boundary between clay, to the right, and sand, to the left was discussed by Jørstad (1964) and Feyling-Hanssen (1966).

Borings nos. II-VI in Sandnes

Boring no. II

The terrain surface at boring no. II is at 16.5 m altitude (see figs. 4 and 6). The boring was 32.5 m deep, and continuous samples were obtained. All the zones and lithological units from boring no. I may be recognised in boring no. II.

Zone 1, the *labradoricum-norcrossi* assemblage, is well developed down to 17.3 m. The maximum number of species is 22 at 11.55 m depth.

Zone 2, the upper zone with scattered specimens, extends down to 22.20 m, and coalesces with the fissured plastic clay. In boring no. I zone 2 comprises only the upper half of this "geotechnical" unit. A specimen of *Islandiella norcrossi* was found at 21.85 m together with 7 *Elphidium clavatum,* 5 *Cassidulina crassa,* 1 *Elphidium bartletti,* 1 *E. subarcticum,* 1 *Protelphidium orbiculare,* and 1 *Pyrulina cylindroides.* A specimen of *Silicosigmoilina groenlandica* occurred at 22.05 m.

Zone 3, the *asklundi-bartletti* assemblage, is developed in the same way as in boring no. I. Even a subdivision of the zone into an upper, a middle and a lower part is possible, although the boundary between the middle and the

lower subzone is not as conspicuous as in boring no. I. Some ostracod valves and a few pelecypod fragments (*Portlandia* or *Yoldiella*) occur in zone 3.

Zone 4, the lower zone with scattered specimens, contains a few *Elphidium clavatum*, a few *Cassidulina crassa*, 1 *Protelphidium orbiculare*, 1 *Elphidium bartletti* and 1 *Virgulina loeblichi*. The correlation of the zones in borings I and II is shown in fig. 6. The uppermost fossiliferous sample in boring no. II is found at 5.10 m depth and this assemblage has a typical zone I composition, as seen from the following analysis:

Gann, Sandnes, boring no. II, 5.10 m. Zone 1.

Species	Frequency	Percentage
Elphidium clavatum	111	52
Cassidulina crassa	33	16
Nonion labradoricum	18	9
Islandiella norcrossi	15	7
Elphidium bartletti	10	5
Cibicides lobatulus	7	3
Buccella frigida	4	2
Elphidium subarcticum	4	2
Islandiella teretis	3	1
Nonion barleeanum	2	1
Uvigerina peregrina	1	<1
Cassidulina laevigata	1	<1
Hyalinea baltica	1	<1
Elphidium asklundi	1	<1
Elphidium groenlandicum	1	<1
Protelphidium orbiculare	1	<1
Total	213	

The entire sample (130 g) was counted.

As seen from the profile, fig. 6, this sample represents a level 9.20 m above that represented by the uppermost highly fossiliferous sample from 3.3 m depth in boring no. I. A change in faunal composition has, however, not taken place.

Boring no. III

Boring no. III (see figs. 4 and 6) is situated at an altitude of 24.4 m, it is 25.1 m deep and penetrates only zone 1 and the uppermost part of zone 2. The boundary between the zones is found at 22.0 m depth, 1.5 m down in the "fissured plastic clay". As with boring no. II the uppermost part was incompletely sampled and in addition the uppermost samples available contain few foraminifera. Filling and till material extend down to 3.0 m

depth. The uppermost sample from 3.2 m is rich in sand and contains only three specimens: 1 *Nonion labradoricum,* 1 *N. barleeanum,* and 1 *Elphidium clavatum.* The next sample from 5.10 m contains 4 *Elphidium clavatum* and 1 *Islandiella norcrossi.* A sample from 6.30 m contains 29 specimens, among them 2 *Islandiella norcrossi,* 1 *Elphidium asklundi,* 1 *E. bartletti,* 1 *E. albiumbilicatum,* 1 *Buccella frigida,* but no specimens of *Nonion labradoricum.* At 6.85 m only 2 *E. clavatum* and 1 *Cassidulina crassa* were found, and at 7.60 m only 1 *E. clavatum.* At 8.75 m 28 specimens occur in the sample, among them 3 specimens of *Nonion labradoricum* and 5 of *Islandiella norcrossi.* A fairly well populated sample of typical zone 1 composition was not reached until 10.70 m depth. Between 8.75 m and 10.70 m there was no sample available. Nevertheless, boring no. III seems to indicate that there are probably poorly populated layers in the upper part of the sandy clay in the Gann area. This part may be distinguished as a separate zone, but it is a question of degree of population rather than of difference in composition. The scarce specimens in the upper part of boring no. III belong to species which all occur in zone 1, and a surface sample from the upper part of the Gann clay pit (see p. 107) contains a well developed zone 1 fauna.

Boring no. IV

The surface at boring no. IV (see figs. 4 and 7) lies 5.8 m above sea level, and the boring is 21.2 m deep. The lithological units, as described by the

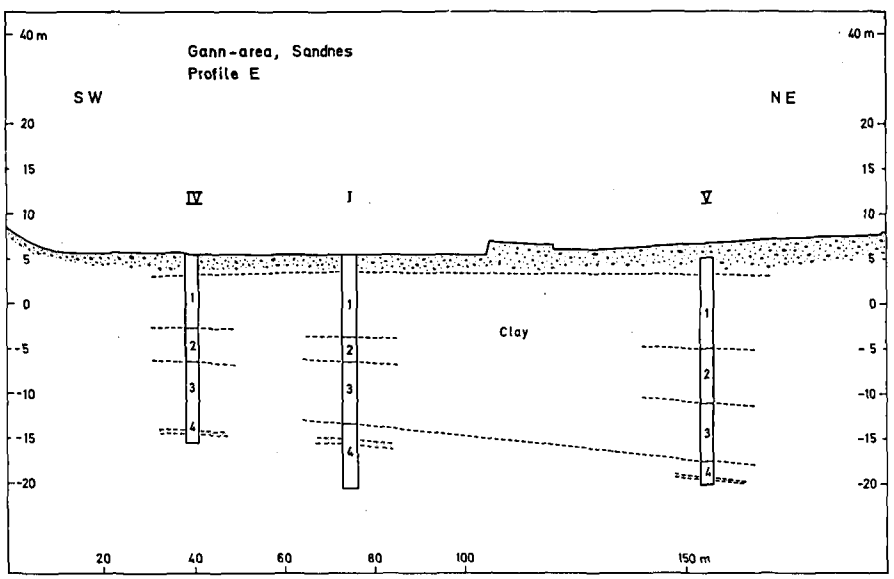

Fig. 7. Profile E, along the toe of the slope of the Gann area, Sandnes, with the foraminiferal zonation of the borings I, IV and V.

geotechnicians, were the same as in boring no. I, with the exception of the sand layer in the deeper part of the boring being thinner (fig. 7).

The zones, described from boring no. I, are readily recognisable in this boring. A subdivision of zone 3, the *asklundi-norcrossi* zone, is, however, not possible, and the boundary between zone 3 and zone 4, the lower zone with scattered specimens, is indistinct. Zone 3 merges into zone 4 as the foraminifera become rarer downwards.

Sample no. F 256–112, from 5.20 m depth weighed 135 g. A count of half its foraminiferal content reveals the following zone 1 fauna:

Gann, Sandnes, boring no. IV, 5.20 m. Zone 1.

Species	Frequency	Percentage
Elphidium clavatum	284	66
Cassidulina crassa	92	22
Nonion labradoricum	16	4
Elphidium bartletti	7	2
Islandiella norcrossi	4	1
Buccella frigida	4	1
Protelphidium orbiculare	3	1
Trifarina fluens	2	1
Cryptoelphidiella itriaensis	2	1
Triloculina trihedra	1	<1
Pyrgo williamsoni	1	<1
Miliolinella subrotunda	1	<1
Oolina acuticosta	1	<1
Fissurina danica	1	<1
Virgulina loeblichi	1	<1
Islandiella teretis	1	<1
Buccella tenerrima	1	<1
Cibicides lobatulus	1	<1
Nonion barleeanum	1	<1
Nonionella aff. *auricula*	1	<1
Pullenia subcarinata	1	< 1
Total	426	

In addition one *Heterohelix* from the Upper Cretaceous and one ostracod fragment occurred. The faunal dominance is 66, the faunal diversity 5. *Islandiella norcrossi* is poorly represented in this sample, and even poorer in the sample from 2.80 m depth, but at 6.80 m the species is more frequent.

A sample from 12.53 m depth contains a typical zone 3 fauna. The sample weighed 110 g; ⅓ of the foraminiferal content was counted:

Gann, Sandnes, boring no. IV, 12.53 m. Zone 3.

Species	Frequency	Percentage
Elphidium clavatum	118	47
Cassidulina crassa	95	38
Protelphidium orbiculare	9	4
Elphidium bartletti	8	3
Pyrgo williamsoni	6	2
Elphidium asklundi	3	1
Silicosigmoilina groenlandica	2	1
Guttulina lactea	2	1
Pyrulina cylindroides	2	1
Miliolinella subrotunda	1	<1
Guttulina austriaca	1	<1
Guttulina dawsoni	1	<1
Pseudopolymorphina novangliae	1	<1
Esosyrinx curta	1	<1
Oolina acuticosta	1	<1
Fissurina marginata	1	<1
Cibicides lobatulus	1	<1
Total	253	

The dominance is 47, the diversity 6. Pelecypod fragments of *Portlandia* also occur. The common occurrence of specimens belonging to the families Polymorphinidae and Glandulinidae is characteristic of the sample; they account for 3.2 % of the assemblage.

A few specimens of *Globigerina pachyderma* and *Globigerina bulloides* were found at 11.50 m depth, i.e. in the lowest part of zone 2, and at 15 m, 17 m, and 18 m all in zone 3. They do not appear to be natural members of the assemblages in which they were found, but may have drifted into the biotope during a storm at that time.

Boring no. V

The terrain surface at boring no. V is at 5.2 m altitude, and the boring is 25 m deep. The lithological units and the zones described from the other borings are all recognised in boring no. V. Zone 1, the *labradoricum-norcrossi* assemblage, is 8 m thick; zone 2, the upper zone with scattered specimens, which here coincides with the fissured, plastic clay, is almost 6 m thick; and zone 3, the *asklundi-bartletti* assemblage, which may be divided into three subzones is 6.5 m thick. Of zone 4, the lower zone with scattered specimens, only about 3 m is represented in this boring.

At the top of this boring there was more fill material than till. The profile of the boring and the most important members of the foraminiferal assem-

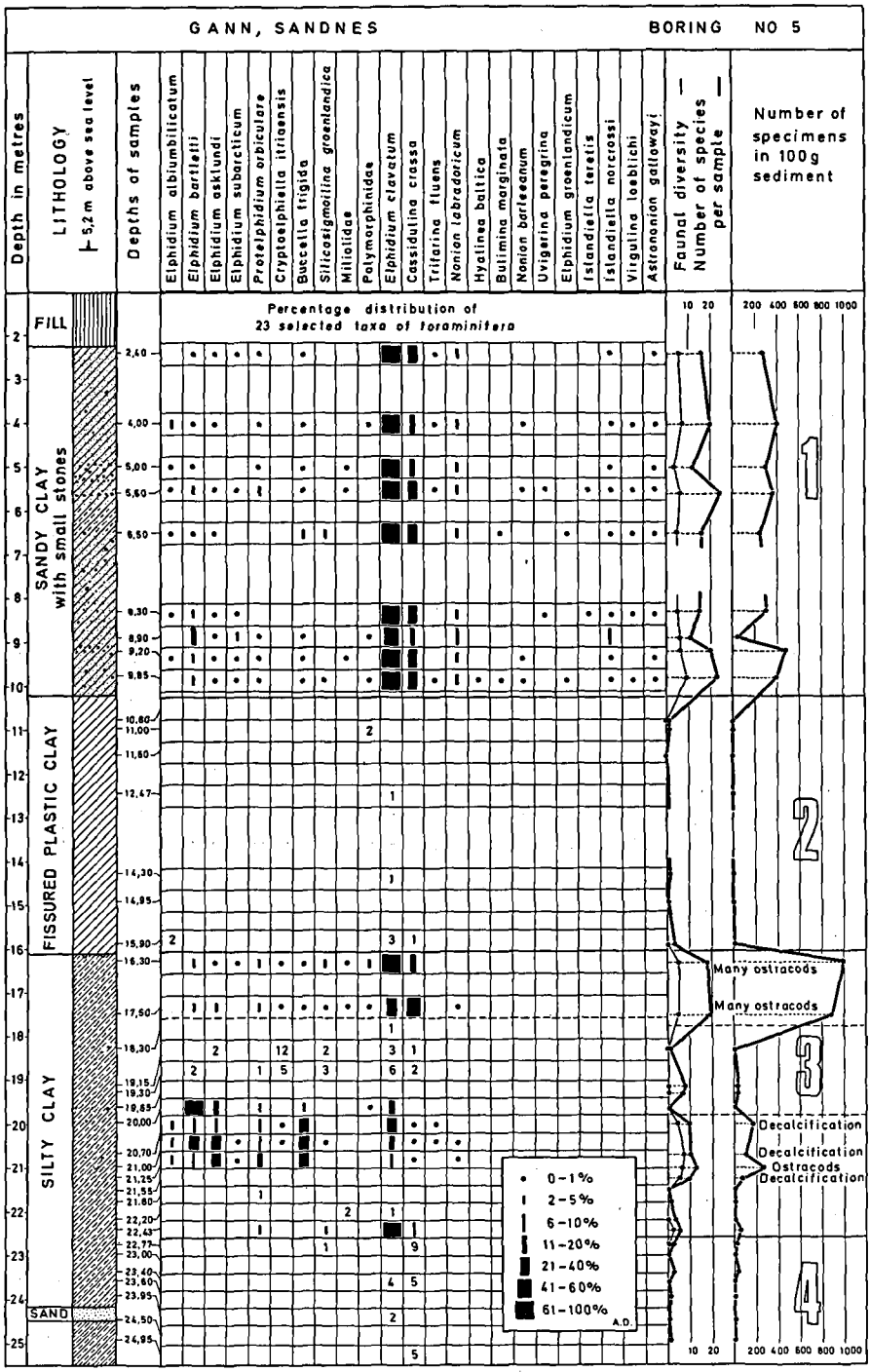

Fig. 8. Range chart for boring no. V, Sandnes. Lithology to the left, foraminiferal zonation to the right.

blages are shown in the range chart, fig. 8. The zones are easily correlated with those of the two other borings at the toe of the slope (fig. 7). There are no essential differences between the zones in the three borings, and thus no serious disturbance of the stratification seems to have taken place in any of them.

The clay deposits now described from the Gann area in Sandnes, are here termed the Sandnes Clay. The type section is designated as boring no. V, the profile of which is shown in fig. 8.

Boring no. VI

Boring no. VI reveals a sequence quite different from that of the other borings, although it is located close to boring no. I. The core samples from boring no. VI consist mostly of sand, and fossils do not occur in any abundance before the deepest part of the boring is reached. Jørstad (1964) and Feyling-Hanssen (1966) discussed possible reasons for this difference.

The Sandnes Interstadial

Dating

The fossil assemblages from the Sandnes Clay are of Quaternary age, and, as they seem to represent natural faunas with no indication of post-mortem sorting and transportation, the Sandnes Clay itself must be of Quaternary age. A few scattered Upper Cretaceous specimens, most probably Maastrichtian, occur in some samples. They obviously are reworked and in a state of preservation different from that of the Quaternary specimens. Otherwise, nothing older than the Quaternary is represented in the assemblages. Furthermore, the presence of *Nonion labradoricum* and the absence of *Elphidiella hannai* indicate an Upper Quaternary age for the deposits. *Nonion labradoricum* is known from the Tertiary, e.g. from the Pliocene of Japan (Ishiwada, 1964; Matoba, 1967) but around the North Sea basin this species has not been recorded from the early Quaternary (Fisher, Funnell & West, 1969). There is one record from the Holsteinian (Hoxnian), Madsen (1895) found it to be rare in the clay of Esbjerg brickworks in Jutland, and this clay is supposed to be of Holsteinian age. The species is not known from the Eemian, except for a few specimens which occur in the Skærumhede series in Vendsyssel. The absence of *N. labradoricum* in the Eemian of Stensigmose (Konradi, in press), however, and its absence in the Eemian and Holsteinian of Schleswig-Holstein (Lafrenz, 1963; Woszidlo, 1962), may be

explained by local extreme shallow-water conditions during the deposition of the sediment and probably also by low salinity. Shallow water may also account for its absence, or only occasional occurrence in zone 3 of the Sandnes Clay. *N. labradoricum* is not usually found in water shallower than c. 20 m (Risdal, 1964; Feyling-Hanssen, 1964 a, p. 144). *Elphidiella hannai* is characteristic of the Lower Quaternary, especially of the Icenian (van Voorthuysen, 1949 b, 1950 b; Funnell, 1961; Fisher, Funnell & West, 1969).

On the other hand, no Postglacial faunas from the Holocene were encountered in the Sandnes borings. The assemblages are all arctic or boreo-arctic, and the overlying till together with the marked pre-consolidation of the clay and disturbance of its upper part, suggest that the deposit was overridden by ice, most probably during the latest large advance of the Weichselian glaciation. Radiocarbon dating of mollusc shell fragments from zone 1 of the Gann area, submitted by F. Jørstad of the Norwegian Geotechnical Institute, and dated by R. Nydal of the Radiological Dating Laboratory of the Norwegian Institute of Technology, gave a minimum age of 30,000 years before present (personal information from Jørstad). Fragments of *Portlandia arctica* from Sandnes Clay at Lura, a short distance north of Gann, were dated at $>$ 23,000 B.P. (Nydal, 1960, p. 89, 90; Holtedahl, 1960, p. 364). A definite radiocarbon age of the Sandnes Clay has, as yet, not been available.

Comparison of the Sandnes Clay faunas with interglacial faunas from around the North Sea basin, Eemian and Holsteinian (Hoxnian) faunas from Jutland (Buch, 1955; Konradi, 1971), from Schleswig-Holstein (Lafrenz, 1963; Lafrenz & Woszidlo, 1963; Woszidlo, 1962), from the Netherlands (van Voorthuysen, 1957), from Clacton (Baden-Powell, 1955) and East Yorkshire in England (Catt & Penny, 1966) and the westernmost North Sea (Fisher, Funnell & West, 1969), shows that no fossiliferous interglacial layers were penetrated by the borings of the Gann area. This is confirmed by comparison with the foraminifera from a recently detected Eemian deposit at Fjøsanger, near Bergen in Norway (Mangerud, 1970), and, again, by comparison with the late Dr. Nørvang's collection of foraminifera from the *Turritella terebra* Zone of the Skærumhede series in Vendsyssel. The authors of the present papers consider the *Turritella terebra* Zone to be of interglacial age. A stony or bouldery layer, which might suggest an earlier glacier advance than that indicated by the upper till, was not found in the clays of the Gann area.

Assuming that the upper till represents the late main Weichselian glacier advance, the Sandnes Clay belongs entirely to the Weichselian. The clay was deposited after the last interglacial, and probably after any eventual early Weichselian glacier advance. In any case, the clays must have been deposited

in a phase of the Weichselian during which the area was continuously ice free and open to the sea, most probably during an interstadial.

Such an interstadial is the complex Würmian Interpleniglacial of Central Europe which occurred about 24,000–50,000 B.P., (Gross, 1960, 1964) or the Upton Warren Interstadial complex in England at about 23,000–50,000 B.P. (Coope & Sands, 1966) or even the North American Port Talbot Interstadial complex, 24,000–50,000 B.P. (Dreimanis, Terasmae & McKenzie, 1966), or the Plum Point complex of approximately the same age and duration (Flint, 1963) or the Russian Karuküla (Serebryanny, 1969). There are many other records, see Gross (1964), and Woldstedt (1969).

Deposits of a similar age have been recognised in Sweden, viz. the Götaälv Interstadial (Brotzen, 1961), dated at approximately 26,000–30,000 B.P., the Younger Dösebacka-Ellesbo Interstadial (Hillefors, 1969), dated at 24,000–30,000 B.P., all included in the Glumslöv Interstadial, introduced by Mörner (1969) as a collective name for interstadial sediments from many places in Sweden.

Brotzen's Götaälv Interstadial is represented by a marine clay containing foraminifera. Unfortunately, Brotzen did not describe the foraminifera, he only stated that the fauna was arctic and had a dominance of *Cassidulina crassa*. The deposits of the Götaälv Interstadial are located near Gothenburg and a faunal comparison with the Sandnes Clay would be of great interest.

Shell fragments of *Mya truncata* from a shelly till at Bö brickworks, about 65 km NNW of Sandnes (fig. 3), were dated at 34,000 ± 3,000 B.P. Shell fragments were collected in 1905 by F. Øvrebø and in 1958 by H. Holtedahl. Holtedahl, who submitted the shells for dating, collected the fragments 4 m below the terrain surface at an altitude of approximately 7 m above sea level. He believed that the shell fragments were interstadial and already Øyen (1905, p. 15) wrote that these deposits should be dated from before the beginning of the latest glaciation, i.e. the main Weichselian advance. Ringen (1964, p. 216), who dealt with tills and drumlins on the island of Karmøy, thought, in connection with this dating that *Mya truncata* must have lived in this area at some time between 31,000 and 37,000 years before present which would prove that Norway was not entirely covered by ice during the whole of the Weichselian ice age and that considerable climatic variations must have occurred. He also made a comparison with climatic curves for the Weichselian, published by Flint & Brandtner (1961), and concluded that Norway must have had an interstadial which compares with others in Europe and North America.

Øyen, who visited Bö brickworks 1904 (Øyen, 1905, pp. 4–5) found the boulder-strewn surface at the clay pit at 11 m above sea level. Below an upper 0.2–0.3 m thick soil he found approximately 6 m of sandy clay with stones up to 1 m in diameter. This was underlain by 2 m of sandy clay con-

taining fragments of *Mya truncata* and *Chlamys islandica* (Müller) (= *Pecten islandicus*). According to this Holtedahl must have collected his shell fragments in the lower part of the sandy clay with stones. The exact position of the shells collected in 1905 by Øvrebø was not indicated. The shells were mixed with the others in order to provide enough CO_2 for the radiometric age determination.

The author has not visited any clay pits on Karmøy, and in the Paleontological Museum of Oslo found only a very small piece of sandy clay from Bø clay pit, collected by Øyen in 1904. It weighed 15 g and contained only a few badly preserved foraminifera: 14 specimens of *Cibicides lobatulus*, 7 *Cassidulina crassa*, 5 *Trifarina fluens*, 2 *Islandiella teretis*, 2 *I. islandica*, 2 *Buccella frigida*, 2 *Astrononion gallowayi*, 2 *Nonionella auricula*, 1 *Oolina acuticosta*, 1 *Bulimina marginata*, 1 *Elphidium albiumbilicatum*, 1 *E. margaritaceum*, 1 *E. owenianum*, and 1 *Protelphidium orbiculare*. Most of the species are known from zone 1 in Sandnes.

Øyen also visited in 1904 the clay pit of Nygaard brickworks, 2 km south of Bø, and two good samples which he collected there were kept in the Paleontological Museum of Oslo. Øyen (1905, p. 5) and later Ringen (1964, pp. 212, 217) emphasised the similarity of the deposits on the two localities. At Nygaard the terrain surface is situated at 11 m above sea level. Øyen (1905, pp. 6–14) recorded the following profile: Gravel and sand (6 and 5 in his designation) at the top, c. 0.5 m thick, horizontally stratified and disconformably deposited upon a 1–4 m thick unit of strongly distorted clay and sand layers (4) with crushed shells, among them many *Portlandia arctica*. Below this unit there were two layers (3 and 2) of sandy and even gravelly clay with many fragments of *Mya truncata* among other species. The combined thickness of these layers was approximately 1 m, wedging out towards east in the profile. Below these layers, and resting upon bedrock, was gravel with stones and boulders (1), which Øyen considered to be a till, the upper part of which had been washed and sublittorally reworked. It contained an abundance of *Mya truncata*, often complete specimens with united valves. Øyen called this layer a shell bed.

One of the two samples from this locality was collected in unit 4 of the profile, the strongly distorted clay and sand, it was labelled "Yoldiaførende ler 27/7 1904". 100 g of the sample was washed; all the foraminifera were counted, the contained relatively poor fauna is listed on p. 95.

All the species are known from the Sandnes Clay, and there is a good representation of *Elphidium asklundi*. The composition of the assemblage is more like that of zone 3 in Sandnes than that of zone 1, but *Islandiella teretis*, *I. norcrossi*, *Astrononion gallowayi*, and *Nonion labradoricum* are present. It is a shallow-water assemblage with zone 1 elements.

The other sample was from the combined unit 2 and 3, sandy and even

Nygaard brickworks, Karmøy, distorted layer. Coll. Øyen 1904.

Species	Frequency	Percentage
Elphidium clavatum	89	48
Protelphidium orbiculare	25	13
Cassidulina crassa	20	11
Elphidium bartletti	18	10
Elphidium asklundi	7	4
Elphidium incertum	6	3
Islandiella teretis	5	3
Astrononion gallowayi	4	2
Buccella frigida	3	2
Islandiella norcrossi	2	1
Nonion labradoricum	2	1
Guttulina austriaca	1	1
Oolina lineata	1	1
Oolina williamsoni	1	1
Elphidium subarcticum	1	1
Total	183	102

gravelly clay with many shell fragments. It was labelled "Fossilførende mellemlag"; 140 g of this sample was washed, it yielded a fauna which was rich in number of species, see the list on p. 96.

All the foraminifera of the sample were counted, and in addition to the foraminifera, ostracod valves, echinoid spines, bryozoan fragments and holothurian skeletal remains occur. There are 36 different species of Quaternary foraminifera in the sample, and the diversity is 23, i.e. remarkably high in comparison with most of the assemblages from the Sandnes clay. Nevertheless, all of these species are known from the Sandnes Clay. The distribution of the most common species may recall zone 3, but the high diversity points to ameliorated, real interstadial conditions. In fact, this assemblage may represent a shallow-water facies of the same age as zone 1 of the Sandnes Clay. Considering, however, the sediment structure of the Nygaard sample, the possibility of a mixture of faunal elements should not be ignored. The fossil molluscs from the pits of Bø and Nygaard, as recorded by Øyen, have most of the species in common with those from zone 1 of the Sandnes Clay (cf. p. 105) and from sub-morainic clay in the district of Jæren.

It is, therefore, assumed that the dated sample from Bø brickworks, 34,000 ± 3,000 B.P., may be within the range of the age of zone 1 of the Sandnes Clay.

In the southern part of Jæren, between Lerbrekk (Lerbræk) and Hobberstad, marl clay outcrops in the erosional cliffs of the brook Tvihaugbekken, 26 km SSW of Sandnes. Bjørlykke (1908, p. 22) described the clay as compact and brecciated and collected fragments of the following species, probab-

Nygaard brickworks, Karmøy, sandy clay. Coll. Øyen 1904.

Species	Frequency	Percentage
Protelphidium orbiculare	91	23
Elphidium clavatum	51	13
Elphidium asklundi	40	10
Elphidium subarcticum	35	9
Elphidium albiumbilicatum	27	7
Elphidium bartletti	21	5
Cassidulina crassa	14	3
Astrononion gallowayi	14	3
Cibicides lobatulus	13	3
Cryptoelphidiella itriaensis	11	3
Elphidium incertum	10	2
Oolina borealis	7	2
Nonionella auricula	7	2
Oolina acuticosta	6	1
Islandiella teretis	6	1
Islandiella norcrossi	5	1
Buccella frigida	5	1
Nonion labradoricum	5	1
Fissurina marginata	3	1
Nonionella aff. *auricula*	3	1
Elphidium gerthi	3	1
Elphidium magellanicum	3	1
Elphidium umbilicatulum	3	1
Guttulina austriaca	2	<1
Guttulina lactea	2	<1
Guttulina problema	2	<1
Oolina melo	2	<1
Buccella tenerrima	2	<1
Silicosigmoilina groenlandica	1	<1
Pseudopolymorphina suboblonga	1	<1
Globulina landesi	1	<1
Oolina hexagona	1	<1
Oolina williamsoni	1	<1
Trifarina fluens	1	<1
Virgulina loeblichi	1	<1
Elphidiella arctica	1	<1
Total	401	

ly between 15 and 5 m above sea level: *Mya truncata, Arctica islandica, Macoma calcarea, Hiatella arctica, Chlamys islandica, Astarte elliptica* (Brown), *Astarte montagui* (Dillwyn), *Panopaea norvegica, Balanus hameri* Ascanius, and *Balanus crenatus* Bruguière. Danielsen (1912, pp. 360–361) added *Mytilus modiolus* Linné to the fossil fauna of this locality. Fragments of *Arctica islandica* from Bjørnlykkes collection from Tvihaug-

bekken have been radiocarbon-dated at more than 36,000 years B.P. (Nydal, 1960, p. 90), and a preliminary dating by ionium of shells from the same deposit gives a maximum age of about 80,000 years (B. G. Andersen, 1965, p. 113).

A sample of clay from Tvihaugbekken at Lerbrekk, collected by B. G. Andersen in 1966 and generously presented to the author contains a microfauna which also compares well with some of those from the Sandnes Clay. In 200 g of the sample (dry weight) the following species occur:

Tvihaugbekken at Lerbrekk. Coll. B. G. Andersen, 1966.

Species	Frequency	Percentage
Elphidium clavatum	128	58
Cassidulina crassa	63	28
Protelphidium orbiculare	8	4
Elphidium asklundi	3	1
Cibicides lobatulus	3	1
Trifarina fluens	2	1
Elphidium albiumbilicatum	2	1
Virgulina fusiformis	1	<1
Virgulina loeblichi	1	<1
Uvigerina peregrina	1	<1
Trifarina angulata	1	<1
Islandiella teretis	1	<1
Buccella tenerrima	1	<1
Cibicides refulgens	1	<1
Nonion labradoricum	1	<1
Nonionella auricula	1	<1
Astrononion gallowayi	1	<1
Pullenia subcarinata	1	<1
Elphidium groenlandicum	1	<1
Elphidium magellanicum	1	<1
Elphidiella arctica	1	<1
Total	223	

All the foraminifera were counted, representing 21 different species. The assemblage has affinity to zone 1 of Sandnes, but *Islandiella norcrossi* is absent and *Nonion labradoricum* represented only by one specimen. It compares with some of the zone 3 assemblages of Sandnes, e.g. from the uppermost part of zone 3, but *Elphidium bartletti* is absent and many of the species occurring in zone 1 of Sandnes are present. It is, furthermore, similar to the assemblage from the distorted clay and sand at Nygaard brickworks, Karmøy, but the representation of shallow-water species is poorer in the sample from Tvihaugbekken.

On the whole, all the faunas of fossil foraminifera now considered, and the radiocarbon dates directly or indirectly connected with them, illustrate that at least zone 1 of the Sandnes Clay is most probably of upper middle Weichselian interstadial age. At the present state of knowledge the complex interstadial during which the Sandnes Clay and its equivalents in Karmøy and Jæren were deposited is here termed the Sandnes Interstadial.

It compares, at least partly, with the Swedish Götaälv Interstadial of Brotzen and the Swedish Younger Dösebacka-Ellesbo Interstadial of Hillefors. It includes the period of the Weichselian ice age during which herds of mammoths and woolly rhinoceros lived on the Siberian plains. Fossil remains of these animals, from permanently frozen ground in Siberia, were dated by radiocarbon at 32,000–38,500 B.P. (Heintz & Garutt, 1965, pp. 73–79; dated by Nydal, 1962, pp. 178–180), whereas two other samples were somewhat older, viz. 40,500–47,500 B.P. and another one much younger: 11,200–11,700 B.P. (Allerød Interstadial). Heintz (1955, 1956) who described a number of finds of mammoth remains from central Norway, submitted material from two finds for dating. The bones turned out to be remarkably young, viz. 19,000 ± 1,200 B.P. and 24,400 ± 900 B.P. (Heintz, 1965, 1969). According to these datings ice free areas existed even in central Norway during, at least parts of, the Sandnes Interstadial, and the mammoths seem to have lived in the mountain regions during that same interstadial. Some of the finds from Denmark (Nordmann, 1921, 1942; Jørgensen, 1940) probably represent mammoths which inhabited Denmark during that interstadial. A tree stump, described by Sollid (1969) from Ringerike in southeastern Norway and dated at the 48,000 $\pm \frac{4,000}{2,000}$ B.P. by one standard diviation and at 48,000 $\pm \frac{11,000}{4,000}$ B.P. by two standard deviations, may belong in the earliest part of this interstadial, or in an earlier one.

Palaeoenvironment

The foraminiferal assemblages from the Sandnes Clay of the Gann area indicate an arctic or boreo-arctic environment, as most of the species represented in the assemblages occur today in arctic and boreo-arctic waters. This is emphasised by the high faunal dominance and relatively low faunal diversity of the assemblages from the Sandnes Clay. High dominance and low diversity indicate extreme ecological conditions, in this case presumably caused primarily by low temperature, but, as mentioned on page 80 still higher dominance and lower diversity are seen in high-arctic Lateglacial faunas from the Oslofjord area and in Younger *Yoldia* Clay faunas from Vendsyssel (see Jørgensen, and Knudsen, this paper). These faunas consist almost exclusively of *Elphidium clavatum* with some *Cassidulina crassa*. The species which occur in the Sandnes Clay, and the dominance and diversity

of the assemblages which they form, indicate that the marine-climatic conditions at the time during which zone 1 of the Sandnes Clay was deposited were not high-arctic but rather low-arctic to high boreal (see zoogeographical map in Feyling-Hanssen, 1955, p. 25).

The Sandnes Clay was deposited before and probably up to the time when the Welchselian glaciers covered the area. In adition to arctic immigrants, which during the post Eemian deterioration of the climate found suitable biotopes in southerly areas like Sandnes and Jæren, the faunas of the Sandnes Clay may contain relics from an earlier Weichselian interstadial and even from the previous Eem Interglacial. Some of the boreal species in the faunas may be considered as such relics, whereas other immigrated because of the amelioration of the climate during the Sandnes Interstadial itself. Therefore the Sandnes Clay is comparatively rich in species. The Lateglacial faunas from the Oslofjord area and from Vendsyssel in Denmark, on the other hand, represent a faunal reestablishment after obliteration by the glaciers from the Weichselian maximum advance. These faunas, therefore, contain few species, one or two of which show a pronounced dominance.

The different zones and subzones of the Sandnes Clay may be explained by differences in depth, in temperature and salinity.

Papers on depth distribution of recent arctic and boreo-arctic foraminifera by Buzas, Cushman, Funnell, Göes, Höglund, Ishiwada, Leslie, Loeblich & Tappan, Nagy, Nørvang, F. L. Parker, Phleger, Risdal, Saidova, Todd and many others have been consulted in order to reach an interpretation of the depth indication of the Sandnes Clay assemblages. Such considerations are always difficult, as some species inhabit different depth zones in different biotopes. It was clearly demonstrated by Funnell (1967) that many factors influence the depth distribution of the foraminifera. Details should not be expected as result of such an interpretation, but some broad concepts seem to be of general importance. According to these concepts the assemblages of the Sandnes Clay indicate:

Zone 1, the *labradoricum-norcrossi* assemblage, indicates moderate depth of water, probably more than 20 m because of the common occurrence of *Nonion labradoricum* and *Islandiella norcrossi. Virgulina loeblichi* and *Trifarina fluens* are also scarce in the shallowest water. On the other hand, the occurrence of shallow-water species, such as *Elphidium bartletti, E. subarcticum, Protelphidium orbiculare* and *Bucella frigida* in zone 1 restricts the water-depth. These species may occur at depths greater than 100 m, but they are much more common in the shallowest water. It is most likely that the depth of the water in which the zone 1 faunas of the Sandnes Clay lived did not exceed 100 m. The salinity seems to have been favourable throughout the zone, and the temperature corresponded to that of low-arctic or boreo-arctic regions.

Zone 2, the upper zone with scattered specimens, contained very few foraminifera. This may be a secondary feature caused by decalcification, for example in connection with a local regression of the sea and subaerial weathering of the sediment. The few foraminifera are well preserved, however, and the sediment shows no trace of weathering. The scarcity of fossils may be explained by unfavourable conditions during sedimentation: some sort of isolation of the local basin of sedimentation, rich supply of mud in suspension, i.e. turbid water with decreased salinity and transparency and consequently decreased food supply. This is analogous to the conditions described for zone D of the Lateglacial in the Oslofjord area (Feyling-Hanssen, 1964 a, pp. 212–213) or to the so-called shell-free *Yoldia* Clay of southwestern Vendsyssel (Jessen, 1918, 1936).

Zone 3, the *asklundi-bartletti* assemblage, characterised by the frequent occurrence of large *Elphidium, Protelphidium orbiculare* and *Buccella frigida,* indicates cold and shallow water. This indication is emphasised by the occurrence of polymorphinids and miliolids. Furthermore, the deeper water species of zone 1 are absent or only occasionally present in zone 3. The water depth was less than 20 m for he entire zone 3. The assemblage in the lower subzone of zone 3 probably lived even in the tidewater zone. The decalcification which has taken place particularly within this subzone may suggest that short, temporary regressions occurred, giving access to atmospheric oxygen and percolation of acid fresh-water in a recently elevated sea bottom sediment. The sediment itself does not, however, fully support this view. Silty clay dominates in the lower as well as in the middle subzone of zone 3 in boring no. I. The upper subzone of this boring consists of fissured plastic clay, in accordance with the less frequent occurrence of pronounced shallow-water species. However, in some of the other borings silty clay persisted throughout zone 3. Some kind of lagoonal conditions may have existed during deposition of the arctic zone 3 of the Sandnes Clay.

Zone 4, the lower zone with scattered specimens, offers very little for palaeoecological interpretation. Some of the specimens are worn and most probably reworked, whereas others are reasonably well preserved. Some specimens of the pronounced shallow-water species *Elphidium umbilicatulum* occur close to the sand layers of zone 4 in boring no. I, demonstrating agreement between sediment, fossils and environment. This species may also indicate raised temperature. A broken specimen of the deep-water species *Bolivina* cf. *robusta* was found associated with the shallow-water *Elphidium,* but the *Bolivina* fragment may be considered to be allochthonous. It is probable that zone 4 represents a marine deposit and for some unexplained reason, perhaps the same as for zone 2, it contains very few fossils.

Correlation

The foraminiferal assemblages of the Sandnes Clay have much in common with assemblages from Older *Yoldia* Clay in Vendsyssel in northern Jutland, as presented by Jørgensen and Knudsen in this paper. Jørgensen's analyses of samples of Older *Yoldia* Clay in Frederikshavn show the same characteristic species, with almost the same frequency distribution, as those from zone 1 in Sandnes. *Elphidium clavatum* dominates, *Cassidulina crassa* is second in number and *Virgulina loeblichi, Islandiella norcrossi* and *Nonion labradoricum* characterise the assemblages. Among the other species from Frederikshavn *Elphidium asklundi, E. groenlandicum,* and *Hyalinea baltica* may be mentioned. From Stortorn, near Rubjerg Knude on the west coast of Vendsyssel, Jørgensen describes faunas of a composition quite close to that of zone 3 in Sandnes. Knudsen has found layers with Older *Yoldia* Clay assemblages at Kodals Rende, Løkkens Blånæse and Furreby Å further south on the west coast of Vendsyssel. Some of these faunas are comparable with zone 1, some with zone 3 in Sandnes. The faunas from Vendsyssel reflect ecological conditions similar to those which prevailed during deposition of zone 1 and zone 3 in Sandnes.

Andersen (this paper) records Quaternary faunas from Hirtshals on the northwest corner of Vendsyssel, some of which have a striking resemblance with those from Sandnes. She establishes a zonal succession of assemblages from A to F, A being the youngest and F the oldest. Zone A, which is developed as clay with some sand and small stones, is characterised by *Islandiella norcrossi, Nonion labradoricum* and *Virgulina loeblichi. Elphidium clavatum* and *Cassidulina crassa* dominate the fauna, and other characteristic species are *Elphidium asklundi, E. groenlandicum, Uvigerina peregrina, Nonion barleeanum,* and *Hyalinea baltica.* The faunal diversity and number of different species are of approximately the same magnitude as for zone 1 in Sandnes. Below zone A there is a zone B, consisting of very plastic clay, and which contains very few foraminifera, a feature also characteristic of zone 2 in Sandnes. Zone C, developed as partly sandy clay, is characterised by *Elphidium asklundi, E. subarcticum, Protelphidium orbiculare* and *Buccella frigida. Elphidium clavatum* dominates, *Cassidulina crassa* seldom constitutes more than 15 % of the fauna, also *Silicosigmoilina groenlandica* is found. Certainly, *Nonion labradoricum* and *Islandiella norcrossi* are represented in some zone C layers at Hirtshals, but as a whole the zone is a shallow-water deposit comparable with zone 3 in Sandnes. Even the polymorphinids occur in zone C of Hirtshals. *Elphidium bartletti,* which is very common in zone 3 in Sandnes, does not occur at all in many

of the samples from zone C at Hirtshals. This may indicate that the water was shallower at least during deposition of the lowest part of zone 3 in Sandnes, than it was at Hirtshals during deposition of zone C.

The two sets of zones, 1 and 3 in Sandnes, A and C in Hirtshals, thus show a high degree of similarity in composition of foraminiferal assemblages which appear in the same order at the two localities. Even a zone with scattered fossils occurs between the two fosiliferous zones at both localities. This does not, however, necessarily involve anything else than a similar development of ecological conditions at the two places. The Sandnes zones originate from the Weichselian, whereas the Hirtshals zones may belong to another ice age. There is till above zone 1 in Sandnes and an abundance of residual boulders above zone A in Hirtshals.

There is, however, little reason to believe that the Older *Yoldia* Clay of Hirtshals belongs in an earlier ice age. As reviewed by Andersen (this paper), this formation was previously (Jessen et al. 1910) correlated with the *Portlandia arctica* Zone of the Skærumhede Series and placed in the Eem interglacial. In the subsequent discussions it has mainly been debated whether the *Portlandia arctica* Zone really belongs in the Eem interglacial (Hansen, 1965, p. 39) or in a Weichselian interstadial (S. A. Andersen, 1966, pp. 216, 217; Rasmussen, 1966, p. 113). Wolff (1918), Wennberg (1949), Halicki (1951) and Woldstedt (1969, p. 8) suggested that the Skærumhede Series is of Holsteinian age. A. L. Andersen (this paper) concludes that the Older *Yoldia* Clay (zone A to F) in the coast cliff of Hirtshals represents the upper 30 m of the *Portlandia arctica* Zone of the Skærumhede Series and emphasises the similarity between her zones A-C and the zones 1–3 in Sandnes.

Many years ago I got a sample of Basement boulder clay from Holderness, East Yorkshire, collected by Dr. J. A. Catt of Harpenden. The Basement boulder clay is termed the Basement Till or Basement Series by Catt & Penny (1966), and is believed to have been deposited during the Saale (Illinoisan) ice age. This sample should contain a foraminiferal assemblage from a pre-Weichselian interstadial. For the purpose of comparison with the Sandnes- and the Older *Yoldia* Clay faunas, and with the kind permission of Dr. Catt and Mr. Penny, I analysed 140 g of the sample from Holderness.

Foraminifera from 20 % of the washed sample were counted. The sample contains 38 different species (including 3 polymorphinids and 2 *Globigerina* species). The assemblage is listed on p. 103.

In the Sandnes Clay and in the Older *Yoldia* Clay of Vendsyssel the number of species per sample is usually less than 30, very often less than 20. The faunal diversity of the Holderness assemblage is 15, whereas in the Sandnes Clay and in the Older *Yoldia* Clay it is less than 10 in most

Holderness Basement Till. Coll. J. A. Catt.

Species	Frequency	Percentage
Elphidium clavatum	175	44
Cassidulina crassa	53	13
Protelphidium orbiculare	53	13
Elphidium albiumbilicatum	17	4
Quinqueloculina stalkeri	11	3
Elphidium asklundi	10	3
Elphidium subarcticum	10	3
Elphidium ustulatum	9	2
Elphidium groenlandicum	7	2
Bulimina marginata (forma *gibba*)	7	2
Buccella frigida	6	2
Trifarina fluens	4	1
Islandiella islandica	4	1
Protelphidium anglicum	4	1
Buccella tenerrima	3	1
Polymorphinidae	3	1
Oolina acuticosta	2	1
Oolina melo	2	1
Virgulina loeblichi	2	1
Astrononion gallowayi	2	1
Cibicides lobatulus	2	1
Globigerina ssp.	2	1
Quinqueloculina seminulum	1	<1
Pyrgo williamsoni	1	<1
Lagena striata	1	<1
Oolina caudigera	1	<1
Oolina lineata	1	<1
Oolina squamosa	1	<1
Fissurina danica	1	<1
Fissurina laevigata	1	<1
Fissurina marginata	1	<1
Trifarina angulosa	1	<1
Nonion barleeanum	1	<1
Nonionella auricula	1	<1
Elphidiella arctica	1	<1
Total	401	

samples. Certainly, one of the samples from Nygaard brickworks on Karmøy yielded almost the same number of species as the Holderness sample and also had high diversity, and one zone D sample from Hirtshals contained 50 different species. These assemblages differ, however, from the Holderness assemblage in other respects, i.e. by the presence of *Nonion labradoricum, Islandiella norcrossi,* and *I. teretis.*

The Holderness assemblage indicates cold and shallow water, however, neither extremely cold nor extremely shallow. Like the Sandnes faunas it reflects interstadial rather than interglacial conditions. Many of the species from the Sandnes Clay and from the Older *Yoldia* Clay of Vendsyssel are represented in the sample from Holderness, even many of the characteristic ones like *Elphidium asklundi* and *E. groenlandicum*. The assemblage recalls zone 3 in Sandnes and zone C in Hirtshals by its frequency of *Protelphidium orbiculare*, or zone D in Hirtshals by the frequent occurrence of *Elphidium albiumbilicatum*. However, *Nonion labradoricum, Islandiella norcrossi,* and *I. teretis* are absent. These species are also absent in the late Hoxnian (late Holsteinian) assemblages from Inner Silver Pit in the western part of the North Sea, described by Fisher, Funnell & West (1969). They are also absent in Holsteinian assemblages described by Buch (1955) from Inder Bjergum, near Ribe, in southwestern Jutland.

Another difference between the Sandnes – Older *Yoldia* Clay assemblages and that from the Holderness sample is the relatively high frequency of *Quinqueloculina stalkeri* and *Elphidium ustulatum* in the latter. These species are very rare in the interstadial deposits in Sandnes and in the Older *Yoldia* Clay of Vendsyssel, but at least *Q. stalkeri* is very frequent in two of the five Hoxnian samples from Inner Silver Pit. The species is frequent in a sample from Esbjerg clay pit, the clay of which is also considered to be of Holsteinian age.

These comparisons, although few in number, demonstrate nevertheless a closer faunistic interrelation between the Sandnes Clay and Older *Yoldia* Clay than between these formations and similar ones known to be older. They infer not only similarity in ecological conditions during deposition but also similarity in age of the two deposits. Therefore, as the Sandnes Clay has been shown to represent a complex interstadial of Weichselian age, the upper part of the Older *Yoldia* Clay (zones A-C) in Vendsyssel, and the uppermost part of the *Portlandia arctica* Zone of the Skærumhede Series are of similar age.

The older zones in the coast cliff of Hirtshals, i.e. zones D-F, do not seem to have been reached by the borings in Sandnes, or marine formations were not deposited in the Sandnes region at that time. Indication of an earlier glacier advance has been found in the gravel pit of Foss-Eigeland 6 km south of Sandnes where marine interstadial clay of zone 1 type rests upon periglacially distorted till. Such an advance may have covered at least parts of Jæren and may be the Sandnes region, which are situated quite close to the glaciation centre, without reaching Vendsyssel and probably only affecting that region by an increase in the influx of ice-rafted stones in the marine sediments.

Interstadial assemblages from the adjacent area

Sandnes and Ganddalen

For almost a century many samples have been collected from the pits of the brickworks in the Sandnes region. Following fossil molluscs have been recorded (Bjørnlykke, 1905, 1908; Milthers, 1913; Isachsen, 1943; Jørstad, 1964): *Portlandica arctica* (Gray) (= *Yoldia arctica*), *Nuculana pernula* (Müller) (= *Leda pernula*), *Chlamys islandica* (Müller) (= *Pecten islandicus*), *Astarte borealis* (Chemnitz), *A. elliptica* (Brown), *A. montagui* (Dillwyn) (= *Nicania banksii* Leach) or rather *A. laurentiana* Lyell in these deposits, *Arctica islandica* (Linné) (= *Cyprina islandica*), *Lyonsia arenosa* Møller, *Macoma baltica* Linné, *M. calcarea* (Chemnitz) (= *Tellina calcarea*), *Hiatella arctica* (Linné) (= *Saxicava arctica*), *Mya truncata* Linné, *Astarte* sp., *Bela nobilis* Møller, *B. conoidea* Sars, *B. harpularis* Couth.

Mytilus edulis Linné and the barnacle *Balanus crenatus* Bruguière were also recorded, but Bjørlykke (1908, p. 32) expressed some doubt about the two latter belonging to the clay. In the collections of the Paleontological Museum in Oslo I found some small boxes with shells and fragments of shells labelled: "Sandnes gamle teglværk" (The old brickworks of Sandnes). They were collected by P. A. Øyen in August 1899 and a few in July 1904. In addition to the species mentioned above this collection contained: *Yoldiella lenticula* (Fabricius), *Musculus discors substriatus* (Gray), *Musculus nigra* (Gray), *Macoma torelli* Jensen, and fragments of two or three other species which could not be identified. Most of the fossils, at least those mentioned in the literature, were found in stony and sandy clay, most probably our zone 1. As mentioned in the description of the borings, however, molluscan shell fragments occurred also in zone 3.

The mollusc species listed above are mostly arctic, but some of them live today in more southerly waters. The environmental indication of such an occurrence would be similar to that of the foraminiferal assemblages: water of boreo-arctic temperature and moderate depth.

Fossil foraminifera from Sandnes clay were mentioned by Feyling-Hanssen (1964 c, 1966).

With the above-mentioned shells, collected by Øyen in 1899, there also occurred a lump of clay, labelled "Sandnes gamle teglværk". It yielded a comparatively rich fauna of fossil foraminifera, almost 500 specimens in 35 g. The assemblage has most species in common with zone 1 of the Gann borings, but differs from zone 1 in having a high frequence of *Buccella frigida* and *Trifarina fluens* and by the occurrence of *Buccella tenerrima*. *Islandiella norcrossi* was not found but *Islandiella teretis* was present. Sandnes gamle teglværk was located some 250 m NNE of the Gann pit, but

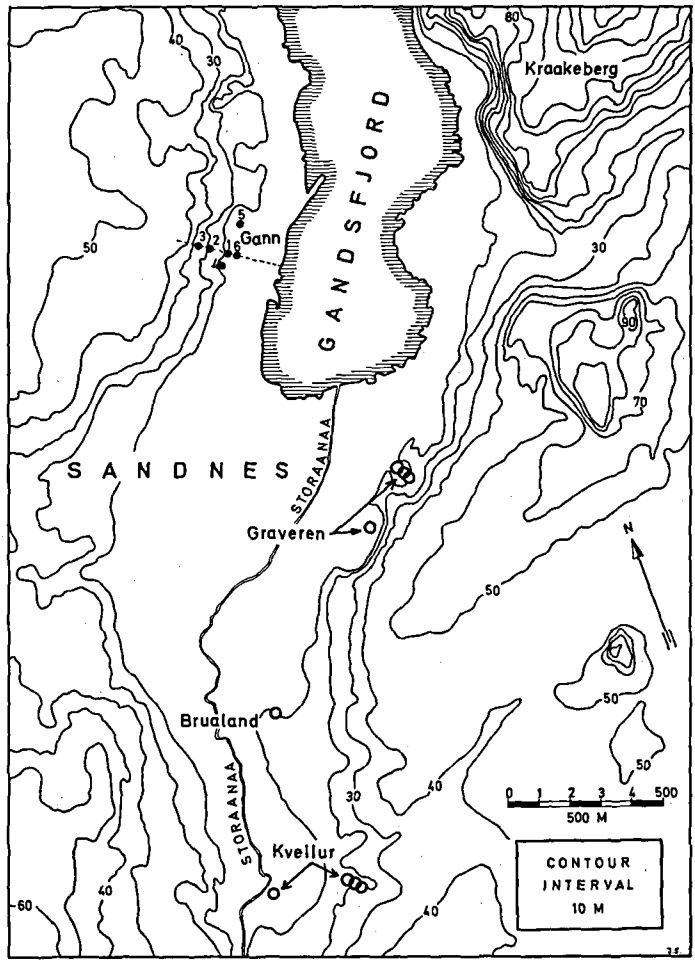

Fig. 9. Sandnes, at the head of the Gandsfjord. The six borings of the Gann area are indicated to the upper left, the pits of Graveren brickworks and the Kvellur pit on the east side of the Sandnes depression. At Brualand and at Kvellur sand samples from the valley bottom were taken, they were unfossiliferous.

nothing is known about the position of the sampled layer. In the museum the sample was placed in an open box which may have been moved from one case to another many times after its collection and any inference from this sample should be considered with care.

In the year of 1952, just before brick production was abandoned in the Gann pit, I collected a sample of clay below till in that pit; it yielded the following zone 1 fauna:

Gann clay pit. Clay below till, (1008). Coll. Feyling-Hanssen, 1952.

Species	Frequency	Percentage
Elphidium clavatum	280	67
Cassidulina crassa	60	14
Islandiella norcrossi	16	4
Nonion labradoricum	15	4
Buccella frigida	7	2
Cibicides lobatulus	7	2
Islandiella teretis	3	1
Hyalinea baltica	3	1
Elphidium bartletti	3	1
Trifarina fluens	2	<1
Cryptoelphidiella itriaensis	2	<1
Quinqueloculina seminulum	1	<1
Guttulina lactea	1	<1
Globulina gibba	1	<1
Fissurina sidebottomi	1	<1
Parafissurina tectulostoma	1	<1
Bulimina marginata	1	<1
Virgulina loeblichi	1	<1
Uvigerina peregrina	1	<1
Planulina ariminensis	1	<1
Cibicides pseudoungerianus	1	<1
Nonion barleeanum	1	<1
Astrononion gallowayi	1	<1
Elphidium incertum	1	<1
Elphidium subarcticum	1	<1
Protelphidium orbiculare	1	<1
Total	413	

In addition 1 *Heterohelix striata* from the Maastrichtian, and 4 valves of Quaternary ostracoda were found. Among the 26 species of Quaternary foraminifera a few specimens seem to have been reworked, e.g. the *Planulina ariminensis*, 1 *Hyalinea baltica* and 2 large *Cibicides lobatulus*. The faunal diversity is 8. The assemblage is representative in all respects of the *labradoricum-norcrossi* assemblage of the borings in the Gann area.

On the other side of the Gandsfjord-Ganddal valley, 1 km S and SSE of the Gann pit, there are the large pits of Graveren brickworks. The clay walls of the excavations are approximately 40 m high. The sections were described by Bjørlykke (1908), Grimnes (1910), Milthers (1913), and later reviewed by Isachsen (1943) and Jørstad (1964). At the top there is a sandy till, 2–3 m thick, with large blocks. Below this there is a grey-blue clay, which contains a few small stones, the content of stones decreasing downwards. The conditions compare with those at the Gann pit, but the valley side is

steeper. From the northernmost and low excavation Bjørlykke recorded sand and even beach deposits which he considered to be Lateglacial or Postglacial, i.e. deposits considerably younger than those dealt with in the present paper. At Sandnes the Lateglacial marine limit is supposed to be situated at an altitude of approximately 20 m above present-day sea level.

In 1952 I collected some samples from the clay pits of Graveren brickwork:

An unfossiliferous silt sample (1004) was taken 2.5 m below the top of the section, 38 m above sea level. The sample was taken close to the superincumbent till.

A sample of sandy clay (1000) from 36 m above sea level and approximately 5 m below the top of the section contained 20 specimens of *Elphidium clavatum,* 10 *Cassidulina crassa,* 4 *Nonion labradoricum,* 2 *Elphidium albiumbilicatum,* 1 *Virgulina loeblichi,* 1 *Bolivina pseudoplicata,* 1 *Cibicides lobatulus* and 1 *Elphidium incertum.*

Further down in the section a sample of sandy clay was taken just above a bed with quite many small stones; 100 g of the sample was washed and ⅔ of the foraminiferal content counted:

Graveren clay pit, Sandnes (1009). Coll. Feyling-Hanssen, 1952.

Species	Frequency	Percentage
Elphidium clavatum	436	69
Cassidulina crassa	104	17
Nonion labradoricum	30	5
Islandiella norcrossi	22	4
Elphidium bartletti	12	2
Buccella frigida	6	1
Virgulina loeblichi	2	<1
Islandiella teretis	2	<1
Pyrgo williamsoni	1	<1
Pateoris hauerinoides	1	<1
Guttulina austriaca	1	<1
Guttulina lactea	1	<1
Bulimina marginata	1	<1
Uvigerina peregrina	1	<1
Trifarina fluens	1	<1
Hyalinea baltica	1	<1
Cibicides lobatulus	1	<1
Nonion barleeanum	1	<1
Astrononion gallowayi	1	<1
Elphidium albiumbilicatum	1	<1
Elphidium asklundi	1	<1
Elphidium gerthi	1	<1
Elphidium incertum	1	<1
Total	629	

1 echinoid spine and 1 ostracod occurred with the foraminifera. There were 23 species of Quaternary foraminifera, the faunal diversity of the assemblage is 4. It is again a typical zone 1 assemblage.

A sample from below the bed with small stones contained the following assemblage in 100 g of sediment:

Graveren clay pit, Sandnes (1002). Coll. Feyling-Hanssen, 1952.

Species	Frequency	Percentage
Elphidium clavatum	200	67
Cassidulina crassa	64	21
Islandiella norcrossi	9	3
Nonion labradoricum	7	2
Elphidium albiumbilicatum	4	1
Virgulina loeblichi	3	1
Elphidium gerthi	3	1
Trifarina fluens	2	1
Buccella frigida	2	1
Astrononion gallowayi	2	1
Silicosigmoilina groenlandica	1	<1
Cibicides lobatulus	1	<1
Nonion barleeanum	1	<1
Elphidium bartletti	1	<1
Elphidium subarcticum	1	<1
Protelphidium orbiculare	1	<1
Total	302	

Two ostracod valves occurred with the foraminifera. The faunal diversity is 6.

Further down in the section, a sample (1007) which was collected at 8 m above sea level, contained a similar fauna, i.e. a zone 1 fauna, whereas a sample (1003) from near the base of the section, some 2 or 3 m above sea level contained only 4 specimens of *Elphidium clavatum,* 3 *Cassidulina crassa,* 3 *Islandiella norcrossi,* 2 *Nonion labradoricum* and 1 *Elphidium subarcticum.* This sample probably represents the base of zone 1 in the section of Graveren brickworks. The thickness of this zone would then be approximately 30 m which is about the same as the total thickness of zone 1 at Gann clay pit.

These conclusions are confirmed by the foraminiferal content of samples from a short boring which Dr. B. G. Andersen made in the bottom of Graveren clay pit in 1965. The samples, which were kindly placed at my disposal, revealed the following subsurface distribution of foraminifera: Sample no. 1, from 2 m below the surface, contained only a few scattered

and small specimens of *Elphidium clavatum* and *Cassidulina crassa*. Sample no. 2, from 4 m below the surface, in addition to a few specimens of the two species mentioned above contained 1 little test of *Nonion labradoricum*. Sample no. 3, from 6 m below the surface, contained 7 *Elphidium clavatum* and 4 *Cassidulina crassa* in 200 g sediment.

These three samples represent zone 2, the upper zone with scattered specimens, in the Gann area. The thickness of zone 2 at Graveren brickworks is not less than 4 m and most probably not more than 7.5 m, as the next sample will show. In boring no. V of the Gann area zone 2 had a thickness of approximately 6 m.

Sample no. 4, from 7.5 m below the surface, contained the following assemblage:

Graveren brickworks, 7.5 m below surface. Coll. B. G. Andersen, 1965.

Species	Frequency	Percentage
Elphidium clavatum	250	81
Elphidium asklundi	14	5
Protelphidium orbiculare	12	4
Cassidulina crassa	8	3
Elphidium bartletti	6	2
Elphidium subarcticum	4	1
Guttulina austriaca	4	1
Elphidium albiumbilicatum	3	1
Parafissurina lateralis	2	1
Guttulina lactea	1	<1
Buccella frigida	1	<1
Elphidium umbilicatulum	1	<1
Elphidiella arctica	1	<1
Cryptoelphidiella itriaensis	1	<1
Total	308	

The dry weight of the sample was 100 g and all foraminifera in it were counted. Fourteen different species of foraminifera were present together with 4 ostracod valves, the faunal dominance is 81, the diversity 6. The composition of the assemblage is that of zone 3, the *asklundi-bartletti* assemblage of the borings in the Gann area. More precisely, this sample represents the upper part of zone 3, the subzone 3 upper, with a fairly good representation of the Polymorphinidae and few *Bucella frigida*.

Sample no. 5, from 8.8 m below the surface, again contained a fauna of zone 3 upper type, see p. 111.

The dry weight of this sample was also 100 g, but only $^2/_5$ of its foraminiferal content was counted. Four ostracod valves occurred with the

Graveren brickworks, 8.8 m below surface. Coll. B. G. Andersen, 1965.

Species	Frequency	Percentage
Elphidium clavatum	255	93
Elphidium asklundi	4	1
Elphidium bartletti	4	1
Fissurina marginata	3	1
Elphidium subarcticum	3	1
Protelphidium orbiculare	2	1
Guttulina austriaca	1	<1
Guttulina lactea	1	<1
Pseudopolymorphina novangliae	1	<1
Cassidulina crassa	1	<1
Elphidium albiumbilicatum	1	<1
Total	276	

foraminifera. The faunal dominance of 93 is very pronounced, the faunal diversity is only 3.

Sample no. 6, from 10 m below the surface, contained only some specimens of *Elphidium clavatum* and a few of *Silicosigmoilina groenlandica,* most likely representing the middle part of zone 3. This subzone was also poor in fossils in the Gann area.

The boundaries between zone 1 and zone 2, between zones 2 and 3 and between the two upper subzones of zone 3 are situated a few metres higher, in relation to present-day sea level, at Graveren brickworks, on the east side of the Sandnes depression, than they are in the Gann area, on the west side of the fjord. The faunal development and zonation is remarkably uniform in the two localities.

Kvellur clay pit is situated a little more than 1 km SW of Graveren brickworks and on the same side of the valley. A few samples of clay were collected from this pit. Some of them contained foraminiferal assemblages of zone 1 composition, some were barren. The geological conditions seems to be a little complicated and a closer investigation was not undertaken. Sand and boulders seem to occur associated with the clay. An important item of information for future investigators is that clay from the gravel pit of Foss-Eigeland is being stored in the Kvellur pit.

Sand from a few places in the bottom of the Ganddalen valley, e.g. at Brualand and Kvellur, was examined, but no fossils were found.

Jæren

Jæren (fig. 10) is a low foreland of approximately 1000 km² between the cities of Stavanger and Egersund. It resembles Vendsyssel in northern Jut-

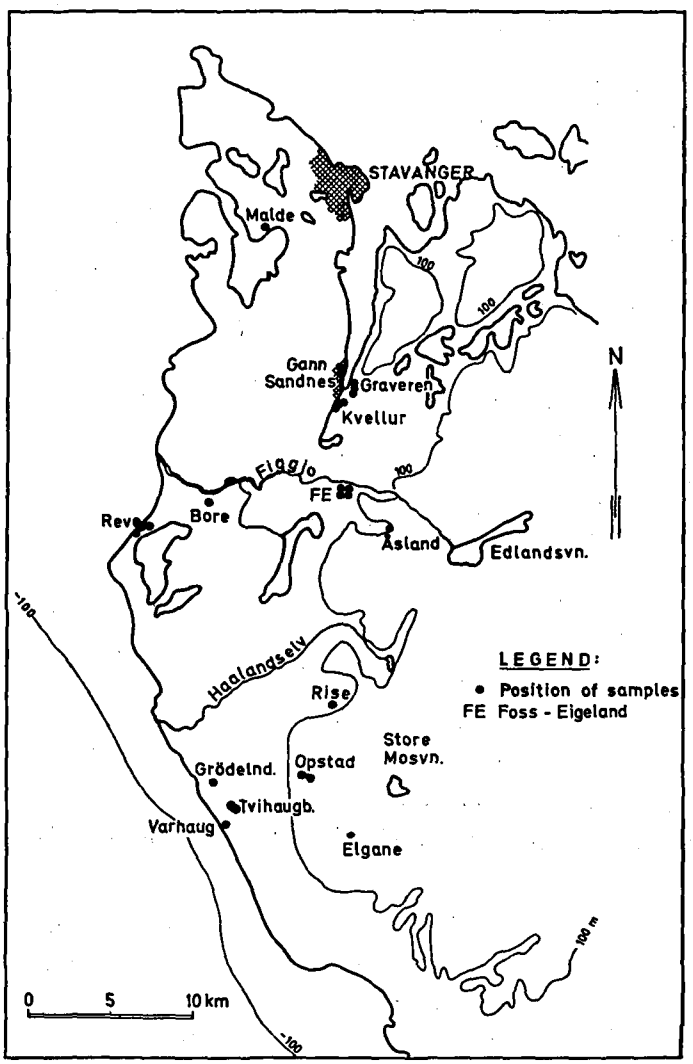

Fig. 10. Jæren with the sampled localities.

land, and constitutes a morphological contrast to the otherwise rocky and mountainous Norwegian coasts. Borings carried out in 1873 and 1874, soil surveys made by Grimnes (1909 and 1910) and Semb (1962) and many other investigations have revealed that Jæren is covered with Quaternary deposits of considerable thickness. A boring at Grødeland, in the south part of Jæren reached bedrock 92.5 m below the surface. Among these unconsolidated deposits is a so-called marl clay with a calcium carbonate content of 10–12 %. This clay crops out at a few localities, but mostly

it is covered by till. Foraminiferal faunas comparable to those described from Sandnes have been found in samples of the clay.

In the gravel pit of Foss-Eigeland, 6 km south of Sandnes, foraminiferal faunas of zone 1 type occurred in an up to 10 m thick clay, at approximately 70 m above present-day sea level (Feyling-Hanssen, 1966). The clay is overlain by till and rests upon till, gravel and sand deposits which are periglacially distorted in upper parts.

At Malde, 10 km NNW of Sandnes, similar faunas occurred only a few metres above sea level.

At Reve, close to the westernmost point of Jæren (see Bjørlykke, 1908, pp. 32–35) shallow-water faunas of subarctic environment have been found. The samples, which were collected by Bjørlykke in 1907 and by Øyen in 1922 at approximately 6 m above sea level, and kept in the Paleontological Museum, Oslo, contained quite many specimens of *Protelphidium orbiculare* and *Elphidium gerthi*. But otherwise these faunas show affinity to Sandnes Interstadial faunas.

A sample from the farm Rise, 75 m–80 m a.s.l. (see Grimnes, 1910, pp. 39–41) yielded a fauna which was nearly equal to that of zone 1 in the Sandnes borings.

At Elgane, 3 km southwest of the lake Store Mosevann (see Semb, 1962, soil survey Varhaug, Høgjæren) there are extensive occurrences of clay below till. A clay sample collected 1924 by Vistnes at this locality was kept in the Paleontological Museum, Oslo. It had been collected 2 m below the surface at a height of 198 m above sea level. One hundred gram of this sample was washed and yielded quite a rich fauna of fossil foraminifera. One half of the sample was counted, with the result listed on p. 114. In addition a specimen of *Praebulimina* from the Upper Cretaceous was found.

This is a rich fauna of zone 1 composition, when compared with the assemblages in Sandnes; 30 species from the Quaternary are present. Most of them live to-day in an arctic environment, but some of them indicate subarctic to boreal conditions, e.g. *Fissurina orbignyana, Bulimina marginata, Uvigerina peregrina, Globulina inaequalis, Bolivina pseudoplicata, Nonion barleeanum,* and *Ammonia batavus*. This is typical also of the interstadial faunas from the Sandnes Clay. The depth of deposition indicated by the present fauna is decidedly greater than that indicated by the Reve faunas. On the other hand, the occurrence of *Protelphidium orbiculare* and *Islandiella teretis* together with 6 % *Cibicides lobatulus* may suggest somewhat shallower water than indicated by most of the zone 1 faunas. However, the *Cibicides lobatulus* specimens occurring in the sample from Elgane are of regular, planoconvex shape with subcircular, entire, not lobate outline. They occupy a position between the comparatively high *Cibicides* forms from the Pliocene (e.g. *Cibicides lobatulus* var. *grossa* Ten Dam & Reinhold) and the

Elgane, Jæren, 198 m above sea level. Coll. Vistnes, 1924.

Species	Frequency	Percentage
Elphidium clavatum	154	39
Cassidulina crassa	102	26
Cibicides lobatulus	22	6
Islandiella norcrossi	17	4
Elphidium subarcticum	11	3
Islandiella teretis	10	2
Nonion labradoricum	9	2
Trifarina fluens	8	2
Astrononion gallowayi	7	2
Protelphidium orbiculare	7	2
Virgulina loeblichi	6	2
Elphidium asklundi	5	1
Elphidium bartletti	5	1
Buccella frigida	5	1
Elphidium incertum	4	1
Islandiella islandica	3	<1
Nonion barleeanum	3	<1
Fissurina laevigata	2	<1
Uvigerina peregrina	2	<1
Bulimina marginata	2	<1
Buccella tenerrima	2	<1
Elphidium groenlandicum	2	<1
Elphidium ustulatum	2	<1
Ammonia batavus	2	<1
Guttulina glacialis	1	<1
Globulina inaequalis	1	<1
Fissurina orbignyana	1	<1
Bolivina pseudoplicata	1	<1
Nonionella auricula	1	<1
Elphidium albiumbilicatum	1	<1
Total	398	

flat, flaring and lobate shallow-water forms from Holocene and Recent deposits. The depth indicated by the Høgjæren fauna is, therefore, considered approximately similar to that indicated by the *labradoricum-norcrossi* assemblage of the Sandnes Clay.

The old and now abandoned clay pit of Opstad brickworks (Opstad teglverk) is situated 175 m above sea level at the junction between the rivulet Tvihaugbekken and a tributary from the southeast debouching into Tvihaugbekken 250 m southeast of Årdal farm. From this pit Reusch collected fragments of the following mollusc species (see Brøgger, 1901, p. 110; Bjørlykke, 1908, p. 25): *Arctica islandica* (= *Cyprina islandica*), *Chlamys islandica* (= *Pecten islandicus*), *Hiatella arctica* (= *Saxicava arc-*

tica), *Macoma calcarea* and the barnacle *Balanus hameri*. To these species Bjørlykke (1908) added *Nuculana pernula* (= *Leda pernula*) and *Mya truncata*. Danielsen (1912, p. 361) found *Mytilus edulis* at this locality, and Milthers (1913, pp. 120–121) added *Astarte montagui* and *A. elliptica* to the list of fossil molluscs. Some of the fragments of *Arctica islandica* from this locality were extraordinarily thick. Milthers found the clay to be 10 m thick and observed some small stones in its upper part, but it became pure and sticky with depth.

In the collection of the Paleontological Museum, Oslo, there was a sample of sandy clay, collected in Opstad clay pit in 1900 by P. A. Øyen. It weighed only 40 g, and contained the following Quarternary foraminiera:

Opstad brickworks, 175 m above sea level. Coll. P. A. Øyen, 1900.

Species	Frequency	Percentage
Elphidium clavatum	77	53
Cassidulina crassa	34	23
Islandiella norcrossi	7	5
Cibicides lobatulus	7	5
Rosalina vilardeboana	3	2
Elphidium groenlandicum	3	2
Protelphidium orbiculare	3	2
Nonion labradoricum	2	1
Elphidium subarcticum	2	1
Trifarina fluens	1	1
Islandiella teretis	1	1
Epistominella exigua	1	1
Buccella frigida	1	1
Nonion aff. *auricula*	1	1
Nonion barleeanum	1	1
Astrononion gallowayi	1	1
Elphidium albiumbilicatum	1	1
Total	146	102

In addition there was 1 *Heterohelix*, 2 *Globigerinelloides* and 1 *Osangularia* from the Upper Cretaceous. Some of the specimens of *Cibicides lobatulus* and one of *Elphidium groenlandicum* are reworked.

The Quarternary assemblage of this sample has affinity to arctic or subarctic inner shelf and shallow fjord faunas of the present day. Again, it compares well with the assemblages from zone 1 of the Sandnes Clay.

A sample from Åsland, 110 m above sea level contained a poor assemblage of zone 1 type. A fauna from Lerbrekk at Tvihaugbekken was discussed on p. 97.

From many other places in the district of Jæren similar samples of this kind of clay could have been collected and examined.

The foraminiferal faunas from the marl clay share a difference from Recent faunas of the Gandsfjord and of the North Sea, and they differ also from Postglacial and Lateglacial faunas from Jæren. A Recent fauna from the innermost part of the Gandsfjord was crowded with *Elphidium umbilicatulum, E. selseyense, Protelphidium anglicum,* with many *Eggerella scabra,* some *Ammonia batavus* and some additional forms including agglutinated species. Recent samples from the North Sea west of Stavanger are characterised by the frequent occurrence of *Cassidulina laevigata, Hyalinea baltica, Uvigerina peregrina, Bulimina marginata* and some agglutinated forms. A Postglacial sample, collected by P. A. Øyen at the rivulet Boreelven, was dominated by *Ammonia batavus* and *Elphidium umbilicatulum,* whereas *Protelphidium anglicum* was frequent. A Lateglacial sample from an old canal digging at Bø – Vistevik in the northernmost part of Jæren, collected 4 m above sea level and 250 m from the sea shore, was crowded with *Elphidium subarcticum* and *E. incertum* together with *E. clavatum, E. frigida,* and *Elphidiella arctica.*

Finally, the faunas from the so-called marl clay of Jæren also have the fact in common that they compare with the faunas of the Sandnes Clay. They may differ somewhat in age, and they reflect different facies, but they probably all lived, and their tests were deposited, during the longlasting Sandnes Interstadial.

A sample of sandy clay from the 1874 boring at Grødeland in the south part of Jæren was found in the collection of the Paleontological Museum, Oslo. It was taken at 265–285 feet below the surface. It weighed only 11.9 g and contained 9 specimens of *Elphidium clavatum,* 5 *Cibicides refulgens,* 4 *Cassidulina crassa,* 3 *Cibicides lobatulus,* 1 *Textularia,* 1 *Dorothia,* 1 *Trifarina angulosa,* 1 *Pseudonodosaria,* 1 *Islandiella norcrossi,* 1 *I. teretis,* 1 *Gyroidina neosoldani,* and 1 *Eponides pygmaeus.* The sample was small, the fauna poor and many of the specimens most probably reworked. The majority of the specimens belongs to the Quarternary, but a closer dating does not seem possible. The assemblage, if the term assemblage can be used for such a small collection of specimens, does not compare with any of those from the Sandnes Clay; it is most probably older.