# Eemian and Weichselian Deposits at Bø on Karmøy, SW Norway: A Preliminary Report

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Lithological and biostratigraphical studies, including studies of pollen, foraminifera and molluscs, together with amino acid analysis, radiocarbon datings and Uranium–Thorium datings of the deposits in a 21 m section with marine beds and tills at Bø on Karmøy gave the following main stratigraphical results: *Haugesund Stadial:* 6 m unit of clayey till and 5 m of tectonized marine beds (Late Weichselian and possibly late Middle Weichselian). *Bø Interstadial:* 5 m unit of marine sand and gravel with a cool climate fauna and flora (early Middle Weichselian or late Early Weichselian). *Karmøy Stadial:* 1.5 m sandy, gravelly till with large striated boulders and 1 m tectonized marine beds. *Torvastad Interstadial:* 0.5 m brown organical sand with a cool-climate flora and fauna (Early Weichselian). *Avaldsnes Interglacial:* 3 m yellow marine sand with a warm climate fauna and flora (Eemian).

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## Introduction

The presented results are based on studies from two excavations made on the floor of the old Bø clay pit at Karmøy (Fig. 1). The first excavation was dug in 1979 during extremely bad weather conditions. Interglacial deposits supposed to be of Eemian age were reached at a depth of 6 m – 10 m, 1 m to 7 m below sea level. In the following year a new excavation was made only 10 m from the former site. However, this time the very bouldery till which overlies the deposits of supposed Early Weichselian and Eemian age could not be penetrated, and only the beds above the till were studied.

## Review of previous studies

### BØ, KARMØY

Øyen (1905), Ringen (1964) and Andersen et al. (1981) observed the 6 m to 8 m thick bed of clayey till with shell fragments which overlies the marine beds at Bø. Øyen considered the till to be of pre-Weichselian age, but Ringen suggested that it is of Weichselian age and deposited by a glacier which moved in westerly direction. The investigations carried out by Andersen et al. (1981) supported Ringens observations. Below the till they observed *Mya* beds, and they correlated the beds with the Nygaard Interstadial somewhere between 40000 and 50000 years B.P. old. On the basis of amino-acid analysis Miller et al. (in press) arrived at the conclusion that the *Mya* beds are most likely of late Early Weichselian age.

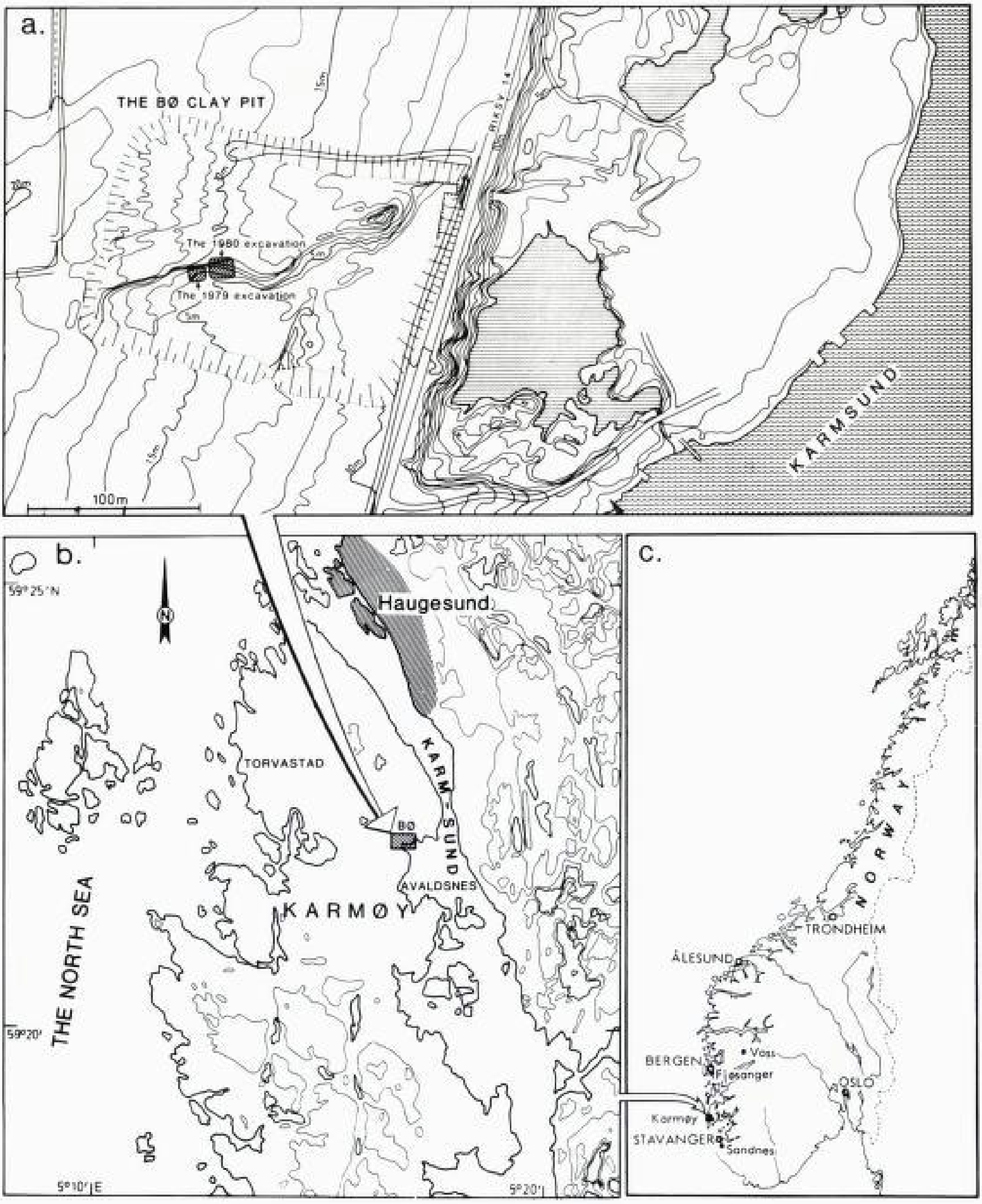



*Fig. 1.* Key map
a) Location of Bø clay pit and of the two excavations.
b) Location of Bø.

NYGAARD, KARMØY

In a clay pit at Nygaard, which lies only 4 km from Bø, Øyen (1905) recorded *Mya* beds which rest on a very bouldery till and are overlain by glacially tectonized *Portlandia arctica* beds. Andersen et al. (1981) suggested that the *Mya* beds represent an interstadial, the Nygaard Interstadial, and radiocarbon-dated *Mya* shells indicated an age approximately 40000–45000 years B.P. for the beds. The bouldery till below the *Mya* beds were supposed to represent an Early Weichselian stadial, a Karmøy Stadial.

## Lithostratigraphy

The lithostratigraphy exposed in the two excavations at Bø is shown in Figs. 2 and 3. Altogether 5 formations were distinguished: Haugesund Diamicton, Bø Sand, Karmøy Diamicton, Torvastad Sand and Avaldsnes Sand. Fig. 4 shows the results of grain-size analysis and of $CaCO_3$ determinations of samples from both excavations.

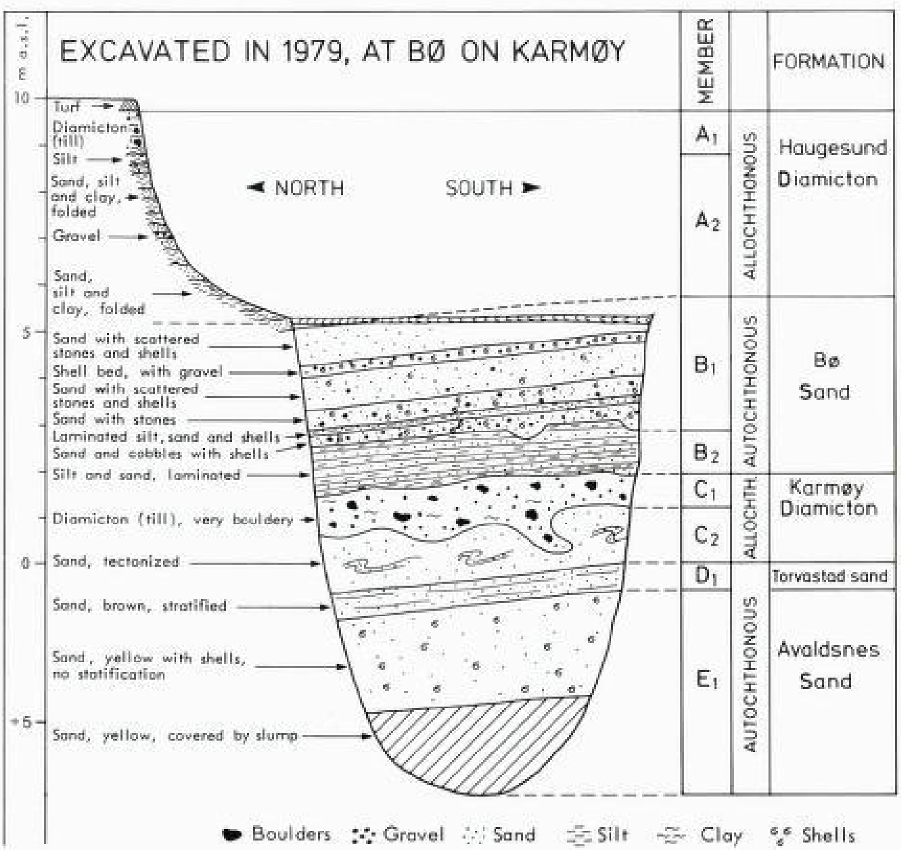



*Fig. 2.* Section exposed in 1979.

*The Avaldsnes Sand* is the oldest formation. About 4 m of this sand was exposed from 1 to 6 m below sea leavel, but only the upper 3 m could be sampled. It is a yellow fine sand with no clear stratification. Marine shells, including some bivalves in living position were seen throughout the formation. A high $CaCO_3$ content (20%) and a low loss of ignition (1.2–1.4%) could indicate relatively favourable current conditions. This together with the interpretation of the molluscan fauna (p. 197) suggest that there could have been a connection with the open sea across the island, and the sea level was most likely more tan 15 m–20 m higher than at present.

*The Torvastad Sand* is a c. 0.4 m thick formation of brown, partly stratified sand with much organic material of plant remains. Marine molluscs were present in the sand, but not as common as in the Avaldsnes Sand. The grain-size distribution was similar to the distribution in the Avaldsnes Sand (Fig. 4). A sheltered brackish-water environment, possibly a lagoon environment, seems most likely for this sand. The amino-acid chronology (Miller et al. in press) suggests a considerable hiatus between Torvastad Sand and the Avaldsnes Sand, but this hiatus was not observed in the excavated profile.

*The Karmøy Diamicton* was divided into two members $C_1$ and $C_2$. Member $C_1$ is a very bouldery till and $C_2$ is composed of strongly tectonized and folded sand beds with till lenses. All sand beds within $C_2$ seem to have been derived from the Torvastad and Avaldsnes Sands. Some of the erratics within $C_1$ are very large, 1 m to 3 m in diameter, and many of them are nicely striated. Both

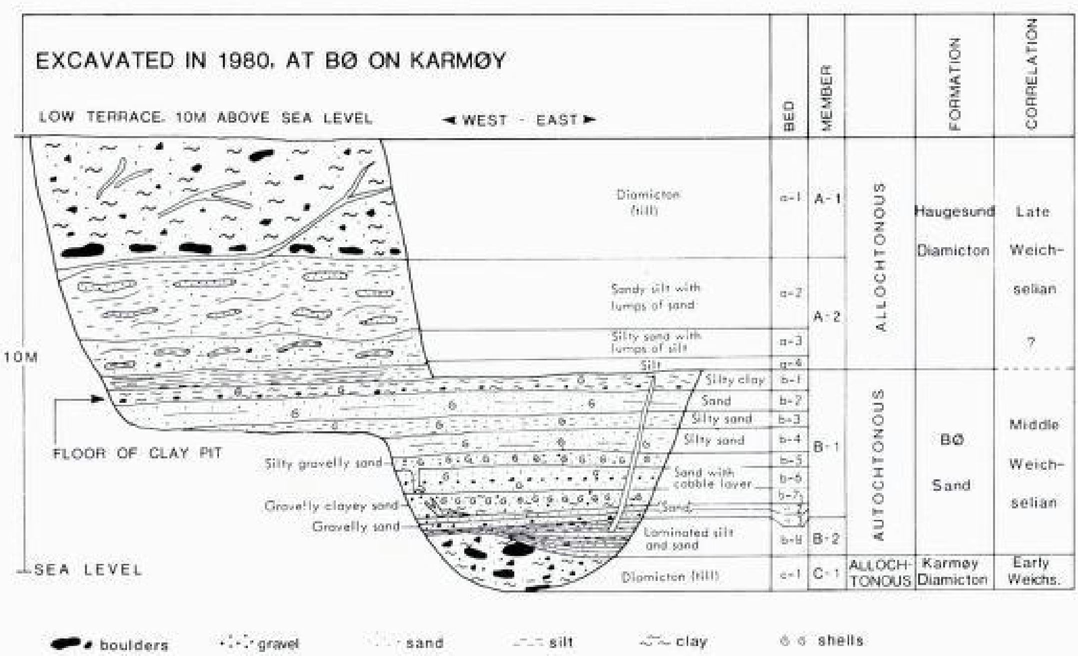



*Fig. 3.* Section exposed in 1980.

pebble counts, fabric analysis and the striation show that the Karmøy till was deposited by glaciers which moved in southwesterly, westerly and northerly directions at various phases. The Karmøy Diamicton represents a stadial older than 50000 years B.P. (see the following discussions).

*The Bø Sand* consists of 8 beds with a combined thickness of about 5 m (See Figs. 2 and 3). There is a hiatus between beds $b_8$ and $b_7$, and this hiatus separates member $B_1$ from $B_2$.

*Member $B_2$ (bed $b_8$)* is a laminated silt and fine sand which lies comformably on the surface of the Karmøy Diamicton. The thickness of $b_8$ varies from 1.5 m in the depressions to about 0.2 m on the higher parts of the till surface. A few scattered stones within the member are most likely dropstones. This suggests that the silt was deposited near an ice front. The lack of fosssils and organic carbon in $b_8$ together with the lamination could indicate that the bed was deposited in fresh or brackish water. Bed $b_8$ therefore most likely represents a phase during the glacial retreat immediately after the deposition of Karmøy till.

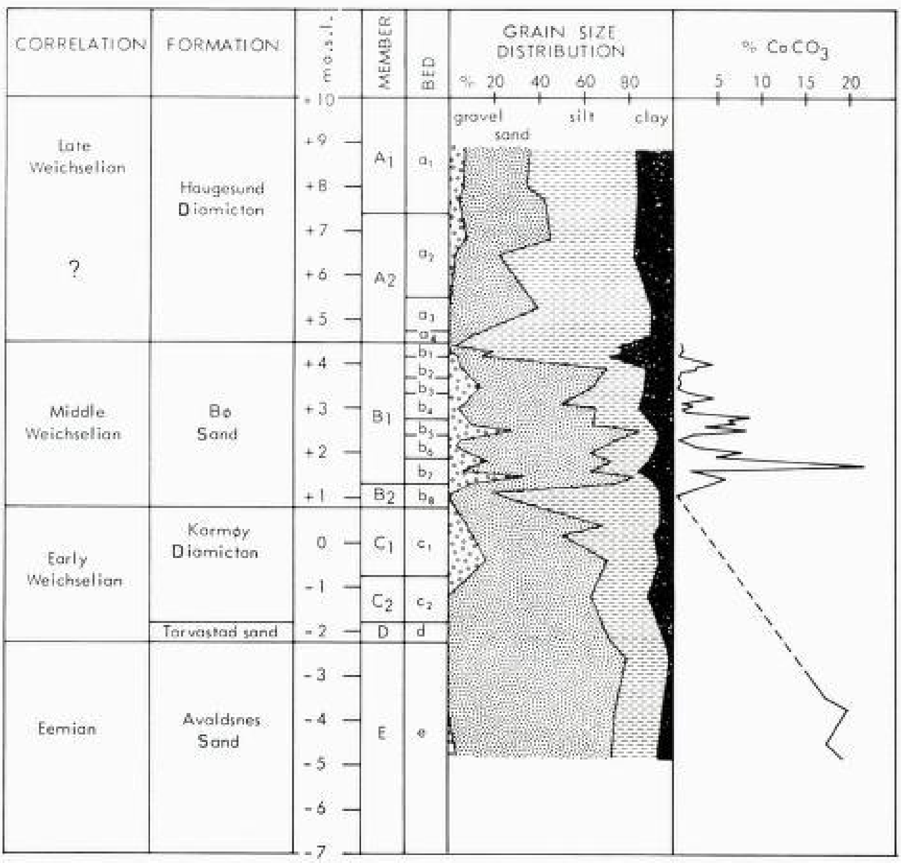



*Fig. 4.* Grain-size distribution and $CaCO_3$ content.

*Member $B_1$ (beds $b_7$–$b_2$)*

The upper laminae within bed $b_8$ are truncated by a bed of gravelly sand at the base of bed $b_7$. In addition about 0.2 m deep erosion channels were observed (Fig. 2). The erosion could have taken place below the sea level, but seen in connection with bed $b_8$ the erosion could as well occurred at or above sea level. Bed $b_7$ is very fossiliferous and it supposedly represents the most favourable part of an interstadial. Therefore, the hiatus below bed $b_7$ could represent a considerable part of an early phase of this interstadial.

Silty sand is the main constituent in all of the beds in $B_1$ (see Fig. 4). In addition some cobbles, gravel and clay occur, and stones with rounded or subrounded edges dominate in all beds. Some stones are striated which suggests a glacial origin. Paired bivalves were seen in all beds, and in some beds the shells are concentrated in zones which correspond with the peaks on the graph for the $CaCO_3$ content. Particularly bed $b_7$ is very fossiliferous.

*Bed $b_1$* is a stratified silty clay with many dropstones and a molluscan fauna with *Portlandia arctica*. This is clearly a glaciomarine near-ice deposit.

*The Haugesund Diamicton* was divided into two members, $A_1$ and $A_2$. *Member $A_1$* is a clayey till with shell fragments. Only the lower 2 m of the about 6 m thick till unit was exposed in the excavated sections. The till fabric (Ringen, 1964) together with the striation direction on bedrock show that it was deposited by a glacier which moved almost due west. Radiocarbon dates and Uranium–Thorium dates on thick *Mya truncata* shell fragments within the till suggest an age between 35 000 years B.P. and 50 000 years B.P. for the shells, and the till must be younger.

*Member $A_2$* consists of strongly tectonized beds of sand, silt and clay. The beds have obviously been moved in a westerly direction by the overriding glacier.

## Pollen stratigraphy

Samples from the Avaldsnes, Torvastad and Bø formations were analyzed. There were numerous pollen grains in the sand from the two first mentioned formations, and very few in the beds from the Bø Formation. In beds $b_8$, $b_6$, $b_4$ and $b_2$ there were too few grains for statistical treatment.

Most of the grains were corroded, and 5%–15% could not be identified. Calculations are based on a pollen sum (P) for aboreal pollen (AP) and non-arboreal pollen (NAP). Relatively few samples have been analyzed, and the presented diagram shows only the preliminary results.

### POLLEN ZONES WITHIN THE AVALDSNES–TORVASTAD SANDS

The two oldest zones are based on only two spectra and they are therefore questionable.

*The Q.M. – Corylus assemblage zone*

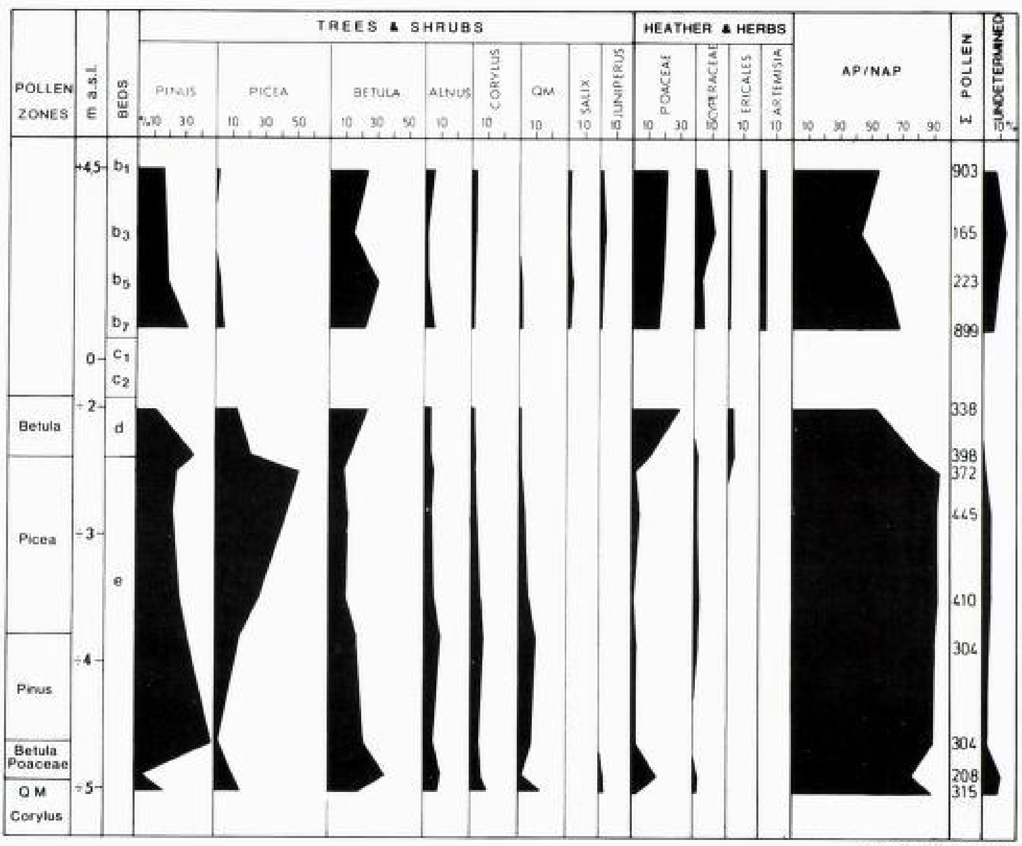
The zone is defined by an 8% NAP value, 12% Q.M. and 10% Corylus values. The Betula value is as low as 18%. If the presented analysis is representative this zone seems to represent the most favourable conditions.

*The Betula – Poaceae assemblage zone*

A 24% NAP value and a 34% Betula value define the zone. The Q.M. and Pinus values are respectively 2% and 5%. If the analysis is representative this zone represents a less favourable phase than the zones below and above. The high NAP value suggests that some deforestation had taken place.

*The Pinus assemblage zone*

*Pinus* values between 30% and 45%, Q.M. values at about 10% and NAP values less than 10% define this zones, which represents a favourable climate with a closed forest.




ANAL: Ø.KIRKHUS 1981

*Fig. 5.* Pollen diagram. The presented values for beds $b_1$, $b_3$, $b_5$ and $b_7$ are means of, respectively, 3, 2, 2 and 7 analysed samples.

### *The Picea assemblage zone*

The zone is defined by 2%–10% NAP values, and 20%–52% *Picea* values. In addition the *Pinus* and Q.M. values are relatively high, respectively 20%–35% and 4%–8%. The zone represents a boreal Picea–Pinus forest with some leave trees.

### *The Betula assemblage zone*

A rise in Betula and NAP values from respectively 12% to 25% and 20% to 53%, a drop in *Pinus* and *Picea* values to about 12% and the disappearance of Q.M. characterize this zone, which must represent a cool period, possibly with no trees during the latest phase. The amino-acid chronology (p. 199) suggests an Early Weichselian age for the *Betula* assemblage zone, and it suggests a considerable age difference between this zone and the *Picea* assemblage zone (p. 199).

## THE BØ SAND

Many of the pollen grains in the analyzed samples are most likely resedimented, and this in addition to the low number of grains in the samples makes the interpretation problematic. The presence of *Artemisia* (about 4%), *Salix* (about 2%), *Juniperus* (about 3%), *Betula* (20%–30%) and NAP values of (30%–55%) suggest an open, cold climate vegetation. Pollen of *Q.M., Corylus, Pinus* and *Picea* must be secondary resedimented pollen. This conclusion is supported by the fact that they were all, except for Q.M., found in bed $b_1$ which contains a high-artic *Portlandia arctic* molluscan fauna.

### *Correlation with the pollen flora at Fjøsanger*

Mangerud et al. (1981) recorded interglacial deposits between beds of glacial deposits at Fjøsanger near Bergen. The corresponding interglacial was called the Fjøsangerian Interglacial and it was correlated with the Eemian. The pollen diagram from the Fjøsangerian deposits shows a division into 5 zones. The youngest zone is a *Picea* zone with 20%–40% *Picea,* 5%–25% *Pinus,* less than 10% *Q.M.*, generally less than 15% *Corylus* and 5%–10% *Betula*. The *Picea* zone overlies a *Corylus–Quercus–Alnus* (C–Q–A) zone with very high *Corylus* values (max. 30%), Q.M. values (max. 25%), *Alnus* values (max. 15%) and *Pinus* values (max. 40%). The *Picea* values lie below 10% and the *Picea* curve starts in this zone.

The *Picea* zone at Karmøy resembles very much the *Picea* zone at Fjøsanger. In both zones the *Picea* and the *Pinus* values are very high and *Q.M., Alnus Corylus* and *Betula* values are relatively low (5%–15%). The *Pinus* zone and the older zones at Karmøy are most likely younger than the middle of the C–Q–A zone at Fjøsanger since they all contain *Picea* and in general low values of *Corylus*. The highest *Corylus* values (10%) and *Q.M.* values (15%) at Karmøy were found in the *Q.M. – Corylus* zone, which could correspond to the upper part of the C–Q–A zone at Fjøsanger. In addition, the very low values of both *Pinus* and *Picea* immediately above the two zones support this correlation. Thus, the pollen assemblages found in the *Avaldsnes Sand* may be correlated with parts of the *Corylus* – *Quercus* – *Alnus* and the *Picea* assemblage zones of the Fjøsangerian.

## Marine molluscs

Fig. 6 shows the distribution of seven selected bivalves and one gastropod in a composite diagram, which is based on material collected from both excavations. A more detailed description and discussion of the molluscs and foraminifera faunas will be given elsewhere (Sejrup et al. in prep.). In the diagram the present-day distribution of the presented species is shown by the zoogeographic division used by Feyling-Hanssen (1955). The use of the symbols rare to frequent is based on a subjective judgement of data from samples and observations in field. Marine molluscs were found in all the beds at Bø except from the laminated silt and sand in bed b-8. All the marine fossils found at Bø are of species that are living in the world's ocean today. This suggests that the deposits are not older than the Hoxnian in England, since many of the species in older faunas are now extinct (West 1968).

*The Avaldsnes Sand* contains a mollusc fauna rich in individuals and species. This together with the presence of the species *Ostrea edulis* (Linné) and the lack of cold water indicators, suggest that the temperature conditions during deposition probably were similar or warmer than today (Dons 1936, Feyling-Hanssen 1955, 1960).

Warm demanding faunas of this kind could not have existed in this area without the presence of warm Atlantic surface water in the Norwegian Sea. According to Kellogg et al. (1978) such conditions have only prevailed two times in the Norwegian Sea during the last 440.000 years, in oxygen-isotope stage 5 e and in the Holocene. On the basis of the marine fauna the Avaldsnes Interglacial is correlated with oxygen-isotope stage 5 e. A similar fauna found by Mangerud et al. (1979) at Fjøsanger near Bergen was correlated with stage 5 e and the Eemian, and they recorded a pollen flora which supported this correlation.

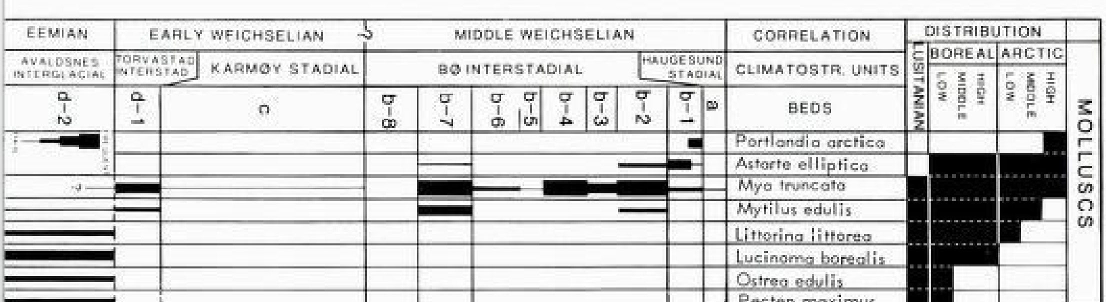



*Fig. 6.* The distribution of seven selected bivalves and one gastropod.

The presence of *Mytilus edulis* (Linné) and *Littornia littorea* (Linné) could indicate a deposition in the tidal zone or just below, but rather large frequencies of *Lucinoma borealis* (Linné), which is most common at depths between 20 and 50 m (Jensen & Spärck 1934), suggest that the extreme shallow-water species could have been redeposited. No safe statement can thus be made about the depth of deposition.

As mentioned before, the boundary between the Avaldsnes Sand and the superimposed *Torvastad Sand* (d-2) is probably erosional and represents a major hiatus. In the Torvastad Sand all the termophileous molluscs have been replaced by species wich tolerate rather cold water. However, the lithology shows no evidence of glaciomarine conditions, and this together with the presence of *Mytilus edulis* suggest that Torvastad Sand was deposited in a period when at least the costal areas of Western Norway were ice free. The marine conditions could have been similar to those found in the middle to low arctic region today.

Ockelman (1958) explains the northern limit of *Mytilus edulis* in arctic areas as a result of long seasons with sea-ice destroying the shallow-water faunas. In this period, which is called the Torvastad Interstadial, the sea level was most likely about 0–5 m above the present sea-level at Bø.

*The Karmøy Diamicton* (beds $c_1$ and $c_2$) represents a glacial advance, the Karmøy Stadial. Abraided fragments of marine molluscs found in these deposits show that the glacier, prior to the deposition of the till, picked up material from older deposits.

*The Bø Sand.* No marine macrofossils were found in the laminated sand-silt in bed b–8. A possibility is that this bed represents a very low-salinity depositional environment just in front of the retreating glacier. The beds $b_7$ to $b_2$ are rich in marine molluscs, and many molluscs lay in living position. The relative abundance between the different species is changing from bed to bed, but this might be a result of small local changes in the sedimentation environment. No thermophileos species were found, but the fauna suggests that the marine condition in this period might have been slightly more favorable than in the period when the Torvastad Sand was deposited. The presence of *Mytilus edulis* indicates shallow water during deposition of beds $b_7$ to $b_2$.

Both the lithology (Fig. 4) and the mollusc fauna of bed b–1 differ from those of bed $b_8$ to $b_2$. The fauna is poorer in species, and in the upper part the high-arctic species *Portlandia arctica* dominates. This species can live under the extreme conditions near calving glaciers (Ockelman 1958). Therefore both the sediments and the lithology in b–1 suggest that a glacier was close to to the Bø locality when this bed was deposited.

*The Haugesund Diamicton.* Only scattered shell fragments were found in the two members of this formation. Fragments of *Mya truncata* are most common. They were most likely picked up by the glacier from the Bø Sand.

## Dating and correlations

*Radiocarbon dates.* Shells of *Mya truncata* from the Bø Sand, beds $b_7$–$b_5$–$b_3$, and $b_1$, have been radiocarbon dated (Fig. 7). Their radiocarbon age is about the same, about 39 000–42 000 years B.P. The same age was obtained for *Mya* shell fragments from the Haugesund Diamicton ($a_1$, 3 samples) and from the *Mya* beds at Nygaard (3 samples), Andersen et al. (1981). For a shell from the Avaldsnes Sand an age of about 49 000 years B.P. was obtained, but this is considered to be a minimum age (cf. Fig. 7).

*U-Th dates* of samples from the different beds will be carried out. Three samples of *Mya truncata* fragments from the clayey Haugesund till ($a_1$) were U-Th dated (Andersen et al. 1981). Three fractions of each sample were dated, and the ages of the inner fractions range between 36 200 and 40 000 years B.P. The apparent radiocarbon age of the three samples range between 34 000 and 38 000 years B.P.: see Andersen et al. (1981). Since the shell fragments were most likely derived from the *Mya* beds in the Bø Sand, the dates support the conclusion about a Middle Weichselian age for this formation.

### AMINO-ACID GEOCHRONOLOGY

The results of the amino-acid analysis on the material from the two excavations at Bø have been published by Miller et al. (in press). The degree of isoleucine epimerization was measured in different species of marine molluscs and benthonic foraminifera. Fig. 7 shows the D-alloisoleucine/L-isoleucine ratios (aJle/Jle) in the total fraction of *Mya truncata* and *Cibicides lobatulus* from the marine beds at Bø. For comparison the ratios in the same species from Fjøsanger are also shown.

| STRATIGRAPHY GENERAL | STRATIGRAPHY BØ/FJØSANGER | AMINO ACID GEOCHRON. (aJle/Jle) BØ | | FJØSANGER | | RADIOCARBON BØ |
|---|---|---|---|---|---|---|
| | | Mya tr. | Cib. lob | Mya tr. | Cib. lob. | Years B.P. |
| late Late Weichselian | late Late Weichselian | 0.076$^{x}$ | 0.044$^{x}$ | 0.076$^{x}$ | 0.044$^{x}$ | |
| Middle Weichselian | Bø Interst. | 0.14 | 0.102 | | | $b_1$ 37.000 $^{+800}_{-700}$<br>$b_2$ 41.300 $^{+1200}_{-1000}$<br>$b_4$ 39.600 $^{+1100}_{-1000}$<br>$b_7$ 40.600 $^{+1200}_{-1000}$ |
| Early Weichselian | Torvastad Interst.<br>Fana Interst.<br>Gulstein Stadial | 0.21 | 0.123 | 0.27<br>0.28 | | |
| Eemian late<br>Eemian early | Avaldsnes/ Fjøsanger Intergl. | | 0.169 | 0.32<br>0.37 | 0.164<br>0.205 | 49.900 $^{+5500}_{-3300}$ xx |

*Fig. 7.* Radiocarbon dates and the D-alloisoleucine/L.-isoleucine ratios in *Mya truncata* and *Cibicides lobatulus*. Ratios for the same species in beds at Fjøsanger are plotted for comparison.

The similar ratios in *Cibicides lobatulus* from the *Picea zone at Karmøy and at the top of the Eemian at Fjøsanger (also from the Picea* zone) strongly support the correlation of these two interglacial sequences.

Based on the assumption that the Avaldsnes and Fjøsangerian Interglacials represents the last interglacial, the Eemian, and that this ended about 120 000 years B.P., age-estimates were made for the two interstadials at Bø. The results indicate that the Torvastad Sand was deposited 78 000 ± 7 000 years B.P. and the Bø Sand 52 000 ± 12 000 years B.P. (Miller et al. in press.).

## Summary of main results

*Avaldsnes Interglacial:* The fauna and flora assemblages observed in the Avaldsnes Sand show that this sand represents a warm interglacial. On the basis of fauna, flora and amino-acid ratios the Avaldsnes Interglacial was correlated with the Fjøsangerian, oxygen-isotope stage 5e and the Eemian. The sea level was most likely more than 15 m–20 m higher than today at Bø.

*Torvastad Interglacial:* The flora and fauna assemblages in the Torvastad Sand together with the age estimate on the basis of the amino-acid ratio suggest that the sand represents a cool Early Weichselian interstadial. The sea level was about 0–5 m higher than today at Bø.

*Karmøy Stadial:* The Karmøy diamicton with large striated boulders represents a true till. This till was deposited by an ice sheet which covered southwestern Norway and moved in southwesterly and westerly to northerly directions at Bø. The age estimates suggest that this happened in Early Weichselian time.

*Bø Interstadial:* Both the fauna, flora and the lithology of the Bø Sand suggest a cool to cold climate. The ice front was located near Bø during the early and late phases of the Bø Interstadial, which is most likely of early Middle Weichselian or late Early Weichselian age. The sea level was not much higher than 5 m above the present.

*Haugesund Stadial:* The clayey Haugesund diamicton is a clayey till deposited after 40 000–60 000 years B.P., most likely by the Late Weichselian glacier which covered the entire southwest coast of Norway.

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REFERENCES

Andersen, B. G., Nydal, R., Wangen, O. P. & Østmo, S. R. 1981: Weichselian before 15.000 years BP at Jæren – Karmøy in southwestern Norway. *Boreas 10*, 297–314.

Dons, C. 1936: Norges strandfauna XIII. Muslinger 1. *Det Kgl. Norske Vid. Selsk. Forhandl. Bd. 9, nr. 42.*

Feyling-Hanssen, R. W. 1960: *In:* Holtedahl, O. (ed.) Geology of Norway. *Norges geol. Unders. 208*, 384.

Feyling-Hanssen, R. W. 1955: Stratigraphy of the marin Late-Pleistocene of Billefjorden, Vestspitsbergen. *Nor. Polarinst. Skr. 107*, 226 p.

Jensen, A. S. & Spärck, R. 1934: Bløddyr II. Saltvandsmuslinger. *Danm. Fauna, 40*, 208 p.

Kellogg, T. B., Duplessy, J. C. & Shacleton, N. J. 1978: Planktonic foraminiferal and oxygen isotopic stratigraphy of Norwegian deep-sea cores. *Boreas 7*, 61–73.

Mangerud, J., Sønstegaard, E., Sejrup, H.-P. & Haldorsen, S., 1981: A contineous Eemian–Early Weichselian sequence containing pollen and marine fossils at Fjøsanger, western Norway. *Boreas 10*, 137–208.

Ockelman, W. K. 1958: The zoology of East Greenland. Marine Lamellibranchiata. *Med. Grønnland 122*, 256 p.

Miller, G. H., Sejrup, H.-P., Mangerud, J. & Andersen, B. G. (in press): Amino acid ratiois in Quaternary molluscs and foraminifera from western Norway: Correlation. geochronology and paleotemperature estimates. *Boreas*.

Ringen, E. 1964: Om drumliner og Skagerakmorenene på Karmøy. *Nor. geogr. Tidsskr. 19*, 205–228.

West, R. G. 1968: Pleistocene Geology and Biology. 377 pp, Longmans, Green & Co. Ltd.

Øyen, P. A. 1905: Nygaardsprofilet på Karmoen. *Christiania Vidensk.-Selsk. Forhandl. 8*, 1–15.