12. MOLLUSCS AND OTHER MEGAFOSSILS

ROLF W. FEYLING-HANSSEN

Department of Micropalaeontology,
Geological Institute, University of Aarhus,
DK-8000 Aarhus C, Denmark

INTRODUCTION

Molluscs are an excellent tool in the stratigraphical evaluation of outcrops and cleared sections where they can be sampled in reasonable quantities, but not in thin cores where they, as other megafossils, are only casually and incompletely represented. Molluscs are so rare in the investigated cores that they should only be used with caution for biostratigraphical purposes in the present study.

The samples investigated represent half slices of the core. Most of them are 10 cm, some are 20 cm and some are less than 10 cm thick. The dry weight of the samples varies from 20 g to 90 g.

Out of 76 examined samples of the Solberga core, only 43 contained fragments or valves of molluscs. The valves are rare and the fragments are usually small. Of 45 examined samples of the Brastad core, 26 contained valves or fragments of molluscs. On the other hand, only 2 of the examined samples of the Moltemyr core were completely barren, but many mollusc fragments of this core were reworked.

It has been possible to group the occurring species into four zoogeographical units (Fig. 12:1), viz., *High-Arctic:* these are mainly limited to the present day High-Arctic region; *Arctic-Boreal:* Arctic species which may also occur in the Boreal region; *Boreal-Arctic:* Boreal species which may also occur in the Arctic region; *Boreal:* species which are limited to the Boreal region, or which are Boreal-Lusitanian in their distribution (for definition of these terms see Antevs 1928, p. 482, Hessland 1943, p. 273, Feyling-Hanssen 1955, p. 25). The most commonly occurring species of molluscs are the Arctic-Boreal *Nucula tenuis* (Montagu), *Nuculana minuta* (Müller), *Nuculana pernula* (Müller), *Yoldiella lenticula* (Møller), the Arctic *Yoldia hyperborea* (Lovén), and the High-Arctic *Portlandia arctica* (Gray). Arctic-Boreal in their main distribution are also *Macoma calcarea* (Gmelin), *Hiatella arctica* (Linné) and *Mya truncata* Linné, whereas *Mytilus edulis* Linné is Boreal-Arctic to Lusitanian. Its main habitat is the Boreal region, but it may occur in Low-Arctic waters. Boreal molluscs are *Nucula*

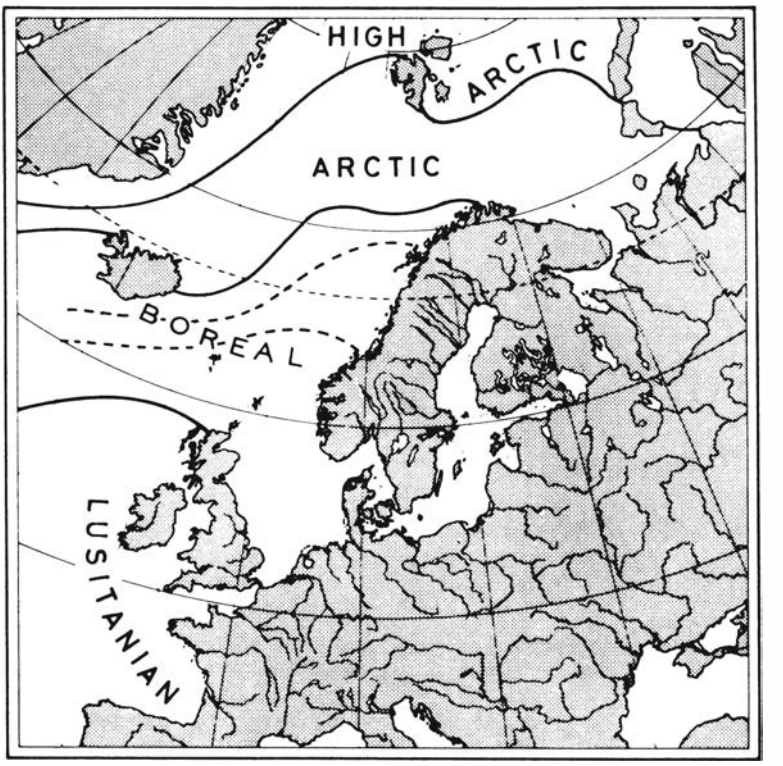


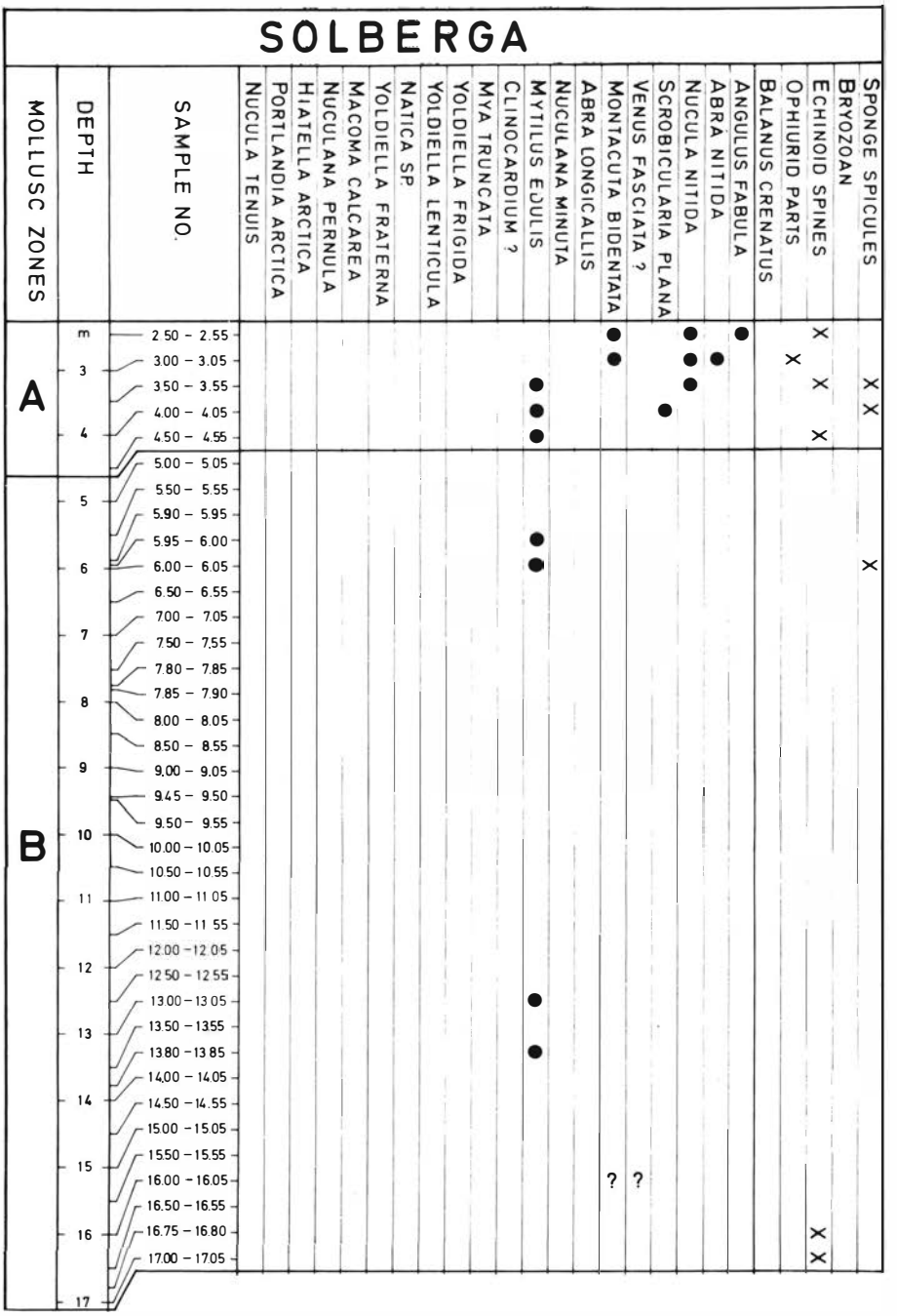
Fig. 12:1. Zoogeographical regions. Redrawn from Feyling-Hanssen 1955.

nitida Sowerby, *Abra nitida* Müller, *Montacuta bidentata* Montagu, and *Hydrobia stagnalis* Baster. Of the most common cirripedes *Balanus crenatus* Bruguiere and *Balanus balanus* (Linné) occur today in Arctic and Boreal regions, whereas *Balanus balanoides* (Linné) is Boreal-Arctic (Brøgger 1901, Odhner 1915, Jensen 1905, Soot-Ryen 1932, Jensen and Spärck 1934, Thorson 1934, Feyling-Hanssen 1955, Ziegelmeier 1957, Ockelmann 1958, Petrov 1966, Simonarson 1977).

SOLBERGA

Zonation – This core is divided into three parts (Fig. 12:2), an upper part, zone A, down to 4.70 m below surface, with Boreal-Lusitanian shallow-water molluscs, a middle part, zone B, from 4.70 m to 17.15 m, practically without molluscs and a lower part consisting of zones C, D and E, from 17.15 m to the end of the core, with Boreal-Arctic to High-Arctic mollusc species.

Zone C, from 17.15 m to 19.30 m, is characterized by *Abra longicallis* Scacchi, *Nuculana minuta* and *Macoma calcarea;* zone D, from 19.30 m to


SOLBERGA
MOLLUSC ZONES
DEPTH
SAMPLE NO.
NUCULA TENUIS
PORTLANDIA ARCTICA
HIATELLA ARCTICA
NUCULANA PERNULA
MACOMA CALCAREA
YOLDIELLA FRATERNA
NATICA SP.
YOLDIELLA LENTICULA
YOLDIELLA FRIGIDA
MYA TRUNCATA
CLINOCARDIUM ?
MYTILUS EDULIS
NUCULANA MINUTA
ABRA LONGICALLIS
MONTACUTA BIDENTATA
VENUS FASCIATA ?
SCROBICULARIA PLANA
NUCULA NITIDA
ABRA NITIDA
ANGULUS FABULA
BALANUS CRENATUS
OPHIURID PARTS
ECHINOID SPINES
BRYOZOAN
SPONGE SPICULES
A
B
E
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
2.50 – 2.55
3.00 – 3.05
3.50 – 3.55
4.00 – 4.05
4.50 – 4.55
5.00 – 5.05
5.50 – 5.55
5.90 – 5.95
5.95 – 6.00
6.00 – 6.05
6.50 – 6.55
7.00 – 7.05
7.50 – 7.55
7.80 – 7.85
7.85 – 7.90
8.00 – 8.05
8.50 – 8.55
9.00 – 9.05
9.45 – 9.50
9.50 – 9.55
10.00 – 10.05
10.50 – 10.55
11.00 – 11.05
11.50 – 11.55
12.00 – 12.05
12.50 – 12.55
13.00 – 13.05
13.50 – 13.55
13.80 – 13.85
14.00 – 14.05
14.50 – 14.55
15.00 – 15.05
15.50 – 15.55
16.00 – 16.05
16.50 – 16.55
16.75 – 16.80
17.00 – 17.05

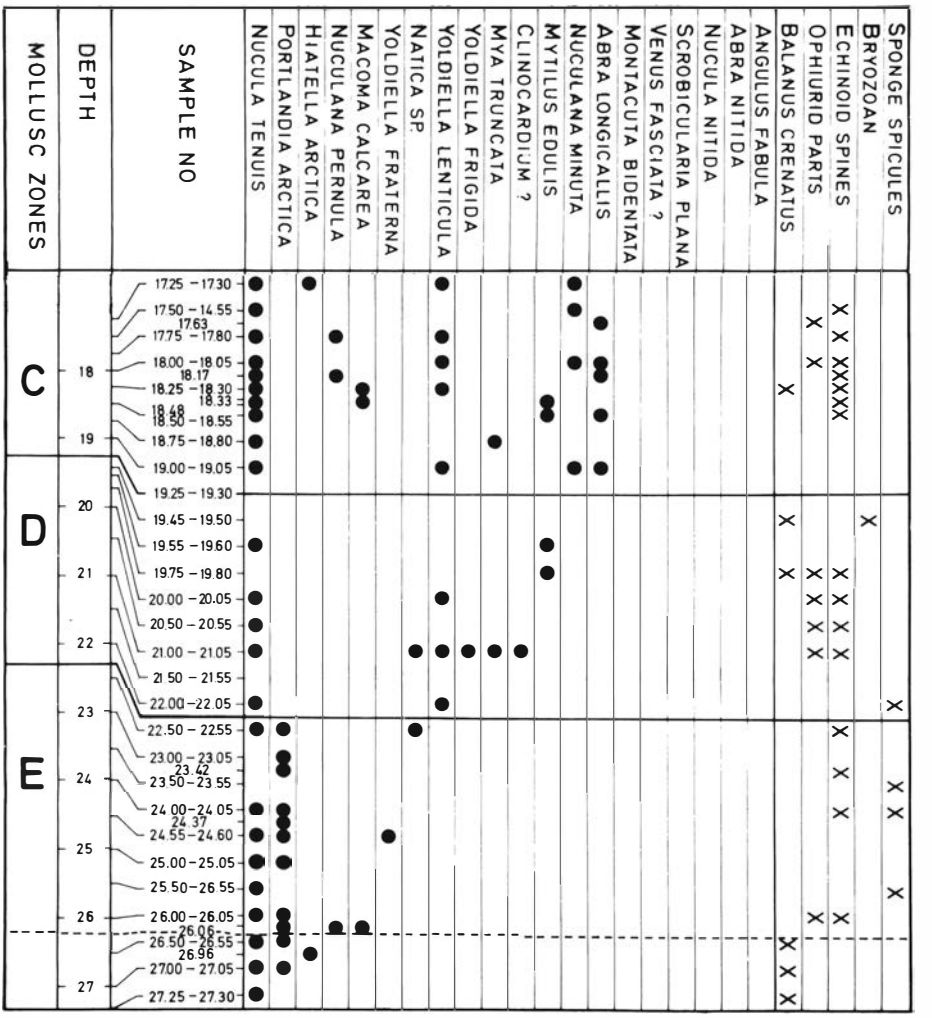


Fig. 12:2. Distribution of megafossils in the Solberga core. Zonation to the left.

22.30 m, is characterized by the appearance of *Yoldiella frigida* (Torell), *Mya truncata* and *Clinocardium ciliatum* (Fabricius); and zone E, from 22.30 m down, is characterized by *Portlandia arctica.*

In the lowest part of zone E, *Portlandia arctica* is quite frequent. There were six umbonal fragments and many others in sample 26.50–26.55 m and nine umbonal fragments and many others in sample 26.24 m. The barnacle *Balanus crenatus* is also present in the lowest quarter of zone E. Thus the lowest part of zone E could equally well have been distinguished as a separate zone.

Palaeoecology – Favourable marine-ecological conditions are mirrored by the species of zone A. In present day waters the zone A species are distributed in coast-near areas from western Norway to the Mediterranean. They live on or in muddy or sandy sea floors, mostly in shallow water. In the Solberga core they represent a Postglacial, Holocene, part of the sediment sequence. Most of these species are recorded from other Postglacial deposits on the Swedish West Coast (Antevs 1928, Asklund 1936, Hessland 1943).

Conditions have been unsuitable for molluscs during sedimentation of zone B.

Zone C reflects Arctic, but ameliorated, conditions. Most of the species of this zone occur in even High-Arctic waters of the present day, but they extend their habitat into the Boreal and some of them even into the Lusitanian zoogeographical region. *Nuculana minuta* does not occur in the High-Arctic region of the present day and *Abra longicallis* is registered as a Boreal species by Brøgger (1901) and as Boreal-Lusitanian by Antevs (1928). In the Quaternary deposits of the Oslofjord area its first appearance is in the Younger Arca Clay which was deposited during retreat of the inland ice front to the moraines in the northern part of the city of Oslo, the Aker substage. Antevs (1928) reports this species only from the Postglacial "Last uplift" at Heestrand, north of Lysekil.

Zone D is populated only by species which today extend their habitat into the High-Arctic region. *Abra longicallis* and *Nuculana minuta* are absent. A few fragments of *Mytilus edulis* are present in the upper part of the zone.

Zone E is characterized by the High-Arctic *Portlandia arctica.* At present *Portlandia arctica* prefers loose mud-bottom of shallow (10–50 m), sediment-loaded water. A retreating ice front and turbid water may have provided favourable conditions for this species. The foraminifers indicates that there was a high sedimentation rate in the upper three quarters of zone E (~ zone 5 of the Foraminifera zonation).

During sedimentation of the lowest part of zone E, where *Portlandia arctica* is frequent, an ice front might have been fairly close to the Solberga core site.

BRASTAD

Zonation – This core has been divided into seven zones (Fig. 12:3). An upper zone Q1, extending from the surface to 2.31 m contains no molluscs. A dubious fiber, which might have belonged to *Mytilus edulis* occurred at 2 m. Zone Q2, from 2.31 m to 4.75 m, has scattered *Mytilus edulis*. Zone Q3,

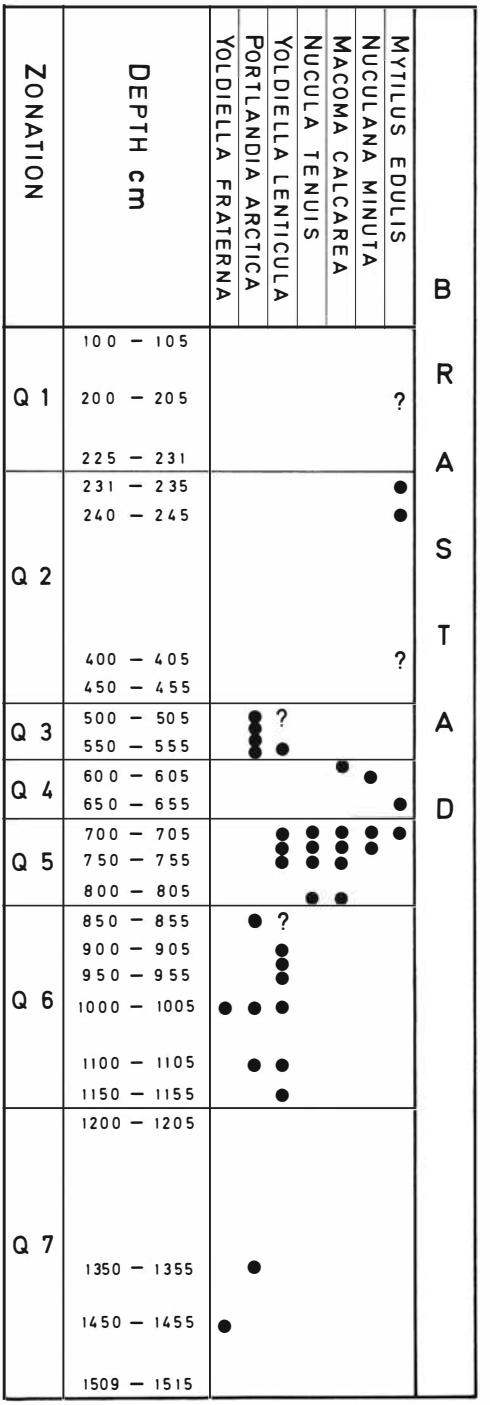


Fig. 12:3. Mollusc distribution in the Brastad core. Zonation to the left.

from 4.75 m to 5.70 m, carries *Portlandia arctica* and scattered *Yoldiella lenticula.* Zone Q4, from 5.70 m to 6.70 m, has scattered *Nuculana minuta, Mytilus edulis* and *Macoma calcarea.* Zone Q5, from 6.70 m to 8.30 m, shows a firm representation of *Nucula tenuis, Yoldiella lenticula, Nuculana minuta,* and *Macoma calcarea. Mytilus edulis* occurred in the lower part of Q4 and in the upper part of Q5. Zone Q6, from 8.30 m to 11.80 m, is characterized by *Yoldiella lenticula* and by the presence of *Portlandia arctica.* Zone Q7, from 11.80 m down, is almost barren of molluscs. Three umbonal fragments and other fragments of *Portlandia arctica* occurred at 13.50 m, and two valves of *Yoldiella fraterna* (Verrill and Bush) at 14.50 m.

Palaeoecology – No firm conclusions can be made about the environmental conditions during deposition of the zone Q1 sediments. Scattered fragments of *Mytilus edulis* in zone Q2 may indicate ameliorated conditions. The firm representation of *Portlandia arctica* in zone Q3 reflects High-Arctic conditions.

Zones Q4 and Q5 appear to have been deposited during somewhat ameliorated conditions as inferred by *Mytilus edulis* and *Nuculana minuta* and partly also by *Macoma calcarea* which is present in a small form not usually found in present day High-Arctic regions.

Zone Q6 indicates High-Arctic conditions. This may also apply to zone Q7, but there are too few molluscs for palaeoecological conclusions.

MOLTEMYR

Zonation and *palaeoecology* – Five units are distinguished in the 6.50 m long Moltemyr core (Fig. 12:4).

Zone V, comprising the uppermost sample, 222–230 cm below surface, contains plant remains, a few tiny fragments of *Mytilus edulis* and a small gastropod fragment. Very little can be deduced from these remains, the water was probably very shallow and the salinity very low.

Zone W, comprising the samples between 232 cm and 277 cm below surface, is characterized by some shells and fragments of the small gastropod *Hydrobia stagnalis,* by quite abundant fragments of *Mytilus edulis* and compartments and operculae of the cirripede *Balanus balanoides* in all samples except 250–258 cm, which is barren.

These remains indicate that sedimentation occurred in shallow water of low salinity, and that temperature conditions were close to those of the present day. *Balanus balanoides,* when attached to rocks, stones or other types of substratum, is linked to the tide-water zone, usually between low-water mark and mid-tide level. In the present sediment the species occurs as

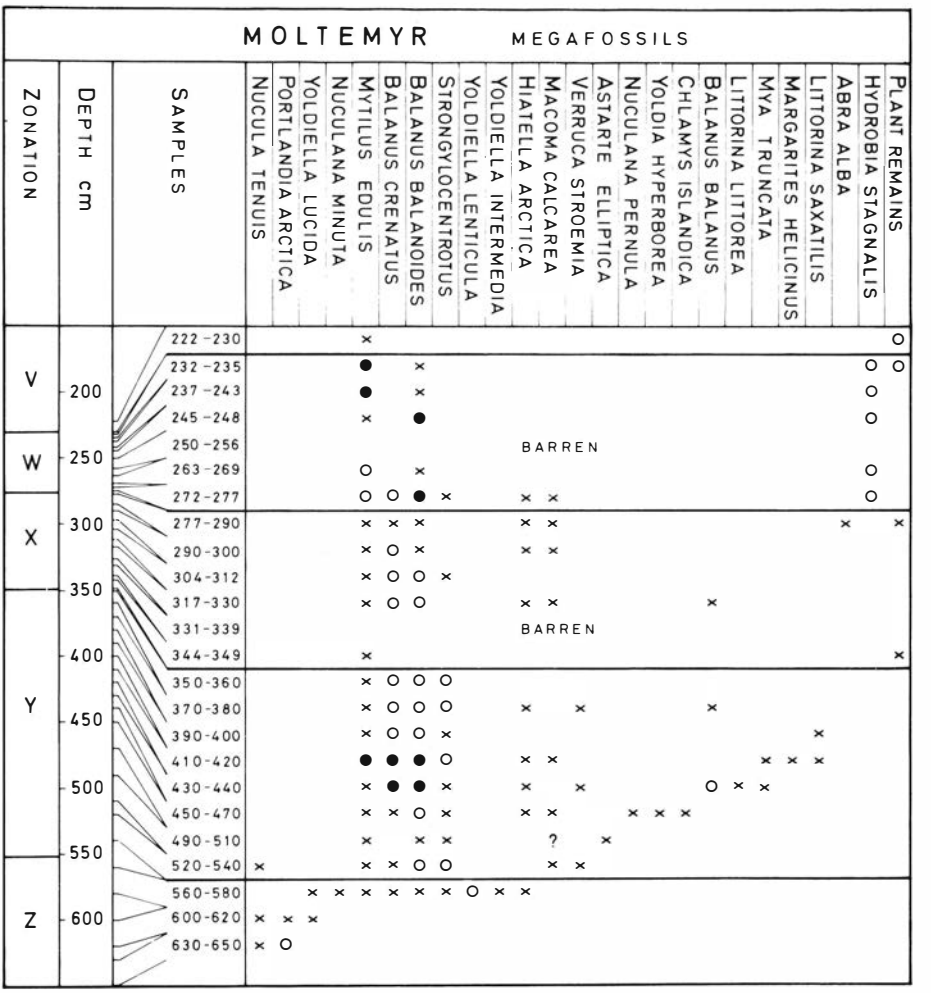


Fig. 12:4. Distribution of megafossils in the Moltemyr core. Zonation to the left.

loose compartments and other fragments, implying that the animals were washed off their substratum after death and their mural compartments carried out to greater depths than the tide-water zone. *Hydrobia stagnalis* indicates low salinity. It is able to live in salinities as low as 6 o/oo, dominating at salinity 12–15 o/oo, and has been found living in Denmark in waters of up to 20 o/oo salinity (Muus 1967).

Zone X, comprising the samples between 277 cm and 349 cm below surface, is characterized by *Balanus crenatus, Hiatella arctica* and *Macoma calcarea* in addition to the species which occur in the overlying unit.

Hydrobia stagnalis is absent. The fragments are few and many of them worn. *Mytilus edulis* is only represented by tiny fragments. One sample (331–339) contains no fossils, and the lowest sample (344–349) is almost barren. Many of the shell fragments in this unit may have been redeposited.

The sediment of this zone was probably deposited in slightly deeper and somewhat more saline water than that of the overlying zone. The poor representation of *Mytilus edulis* may be explained by a somewhat greater depth; or such species may have been worn away during transport.

Zone Y, comprising the samples from 350 cm to 540 cm below the surface, is the most fossiliferous part of the core. The zone is characterized by consistent occurrence of echinoid spines and plates, most probably of *Strongylocentrotus droebachiensis* (Müller).

The comparatively high diversity – there is a total of 17 species within the zone – may indicate higher salinity than in the overlying zones. The occurrence, particularly in the lower part of the zone (below 450 cm), of some Arctic and Arctic-Boreal species, viz., *Nucula tenuis, Astarte elliptica* (Brown), *Nuculana pernula, Yoldia hyperborea,* and *Chlamys islandica* (Müller), indicates lower water temperature than in the overlying zones. It seems, however, that a temporary shift towards higher temperature occurred in the middle part of the zone where the Arctic and Arctic-Boreal species mentioned above are absent and *Balanus balanoides* and *Mytilus edulis* become frequent (sample 410–420 cm). *Littorina littorea* (Linné) occurs in sample 430–440 cm. The upper samples of the zone are again poorer in megafossils. The depth seems to have been slightly greater than in zone X, but many of the fragments are worn and may have been reworked.

Zone Z, comprising the samples from 560 cm to 650 cm, is characterized by *Portlandia arctica* and *Nucula tenuis,* and by the absence of many of the species of the overlying zone. Sample 560–580 cm forms a transition between High-Arctic conditions below to Arctic-Boreal conditions above. The water-depth during deposition of zone Z was greater than during any of the other zones, probably more than 20 m.

CORRELATION

The occurrence and distribution of mollusc shells and fragments in samples from the three cores treated suggest that the conspicuous boundary between zones Z and Y of Moltemyr correlates with the boundary between zones E and D of the mollusc zonation of the Solberga core (22.30 m below surface) and probably with the 4.75 m level below surface of the Brastad core. The other units of the cores are not easily correlated on the basis of their

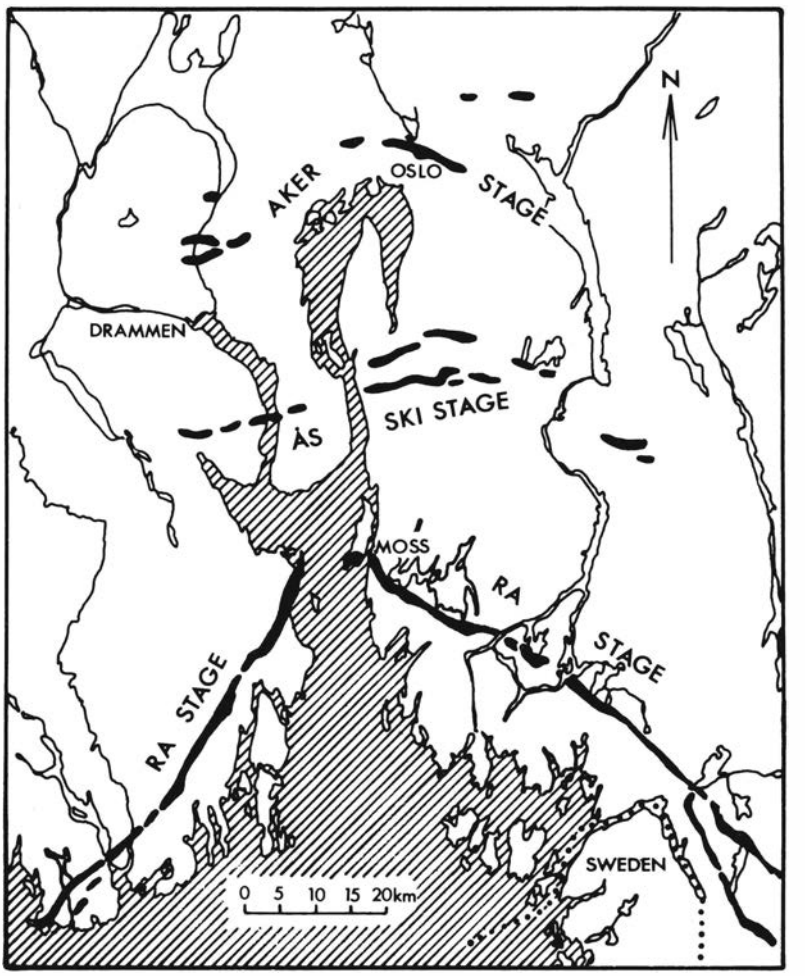


Fig. 12:5. Ice marginal formations in the Oslofjord area of Norway.

megafossil content, except that zone A of Solberga and zone V and W of Moltemyr represent Holocene deposits.

THE PLEISTOCENE/HOLOCENE BOUNDARY

The Scandinavian inland ice retreated from the area of investigation about 12 700 years before present (Berglund 1979). The marine deposits of our cores are, therefore, probably younger than this. The sedimentation may have continued in any one locality as long as the sea covered that site. The

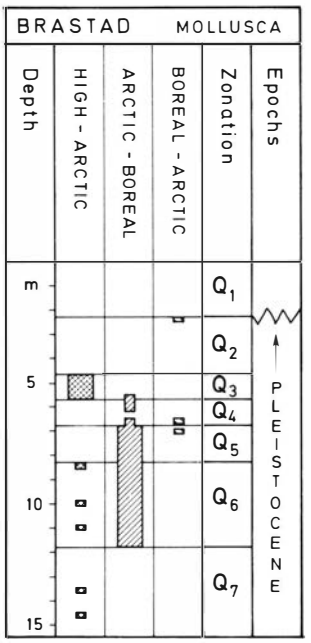


Fig. 12:6. Palaeoecology of the Brastad core.

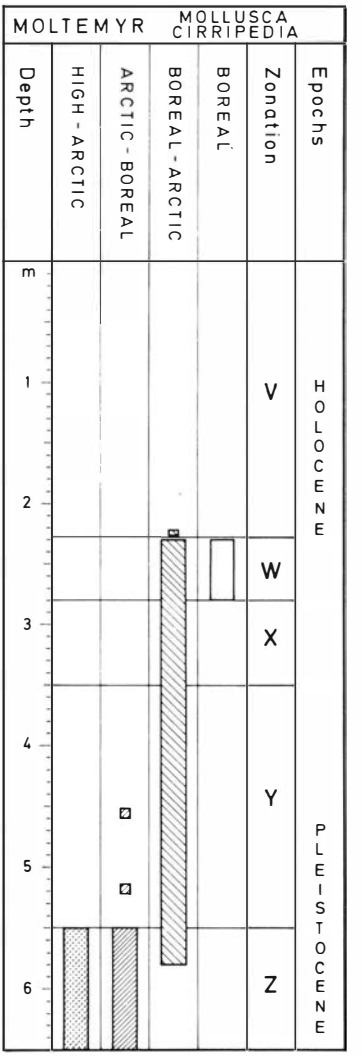


Fig. 12:7. Palaeoecology of the Moltemyr core.

lowest-lying core sites should thus contain the youngest marine deposits in their upper parts.

The lowest parts of the cores may contain sediments which are approximately 12 000 to 10 000 years old – those parts contain *Portlandia arctica.*

The High-Arctic mollusc species *Portlandia arctica* has previously been recorded from *glacial* clays of western Sweden (*i.a.,* Antevs 1928, Asklund 1936, Hessland 1943). In the Oslofjord area of Norway it characterizes the Yoldia Clay of the mollusc stratigraphy of Brøgger (1901). That clay was

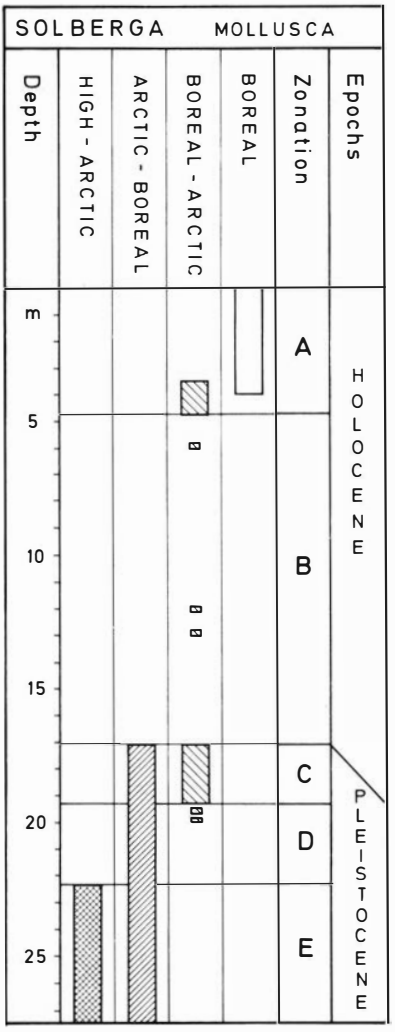


Fig. 12:8. Palaeoecology and the Pleistocene/Holocene boundary in the Solberga core.

deposited mainly outside (*i.e.*, south of) the conspicuous ice-marginal formation, the Ra ridge, of the Oslofjord area (Fig. 12:5). Deposits with *Portlandia arctica* in the Oslofjord area have radiocarbon ages between 11 200 and 9 950 years B.P., and the Ra ridge itself is considered to be a Younger Dryas formation (Holtedahl 1960, 1974, Feyling-Hanssen 1963, 1964). Andersen (1975) summarized occurrences and dates of the *Portlandia arctica* fauna in all Norwegian deposits and found that they are of Younger Dryas age or older. He writes (p. 54): "Evidently, P.a. lived near the ice fronts also during older glacial phases, but it seems to have disappeared from our coasts shortly after the Ra event, probably due to a warming of the sea".

In 1979 Sørensen reinterpreted radiocarbon dates of the Oslofjord area and found that the Ra ridge, or ridges, was formed in early Younger Dryas, and that it was still Younger Dryas when the inland ice margin halted at the marginal formations of Aas-Ski, midway between the Ra and the Aker stage of Oslo. This would imply that *Portlandia arctica* disappeared from the Oslofjord area before the end of Younger Dryas, that is, somewhat before 10 000 years B.P.

Portlandia arctica characterizes the molluscan zone E of the Solberga core, zone Z of the Moltemyr core and occurs up to 4.7 m below surface in the Brastad core (*i.e.,* up through Q3 at Brastad). The Pleistocene/Holocene boundary should be sought at the top of these occurrences or somewhat higher up in the cores.

The Brastad core contains very few mollusc fragments above zone Q3, and a boundary may be placed at or above 4.7 m (Fig. 12:6). The mollusc occurrences of this core cannot contribute further to the boundary location.

The Moltemyr core shows a quite distinct megafossil boundary between zones Z and Y at 5.5 m below surface (Fig. 12:7). The Pleistocene/Holocene boundary may be located there or higher up. No *clear* succession of climatic development is mirrored by the megafossils above zone Z. Arctic-Boreal

---

PLATE 12:1

Figs. 1, 2. *Portlandia arctica* (Gray). Left valve from 5.65 m depth, Brastad core. x 2.

Fig. 3. *Nuculana minuta* (Müller). Fragment of right valve from 7.00 m, Brastad core. x 3.

Figs. 4, 5. *Portlandia arctica* (Gray). Right valve from 24.37 m, Solberga core. x 2.

Figs. 6, 7. *Nuculana pernula* (Müller). Fragment of posterior end of a right valve from 18.17 m, Solberga core. x 4.

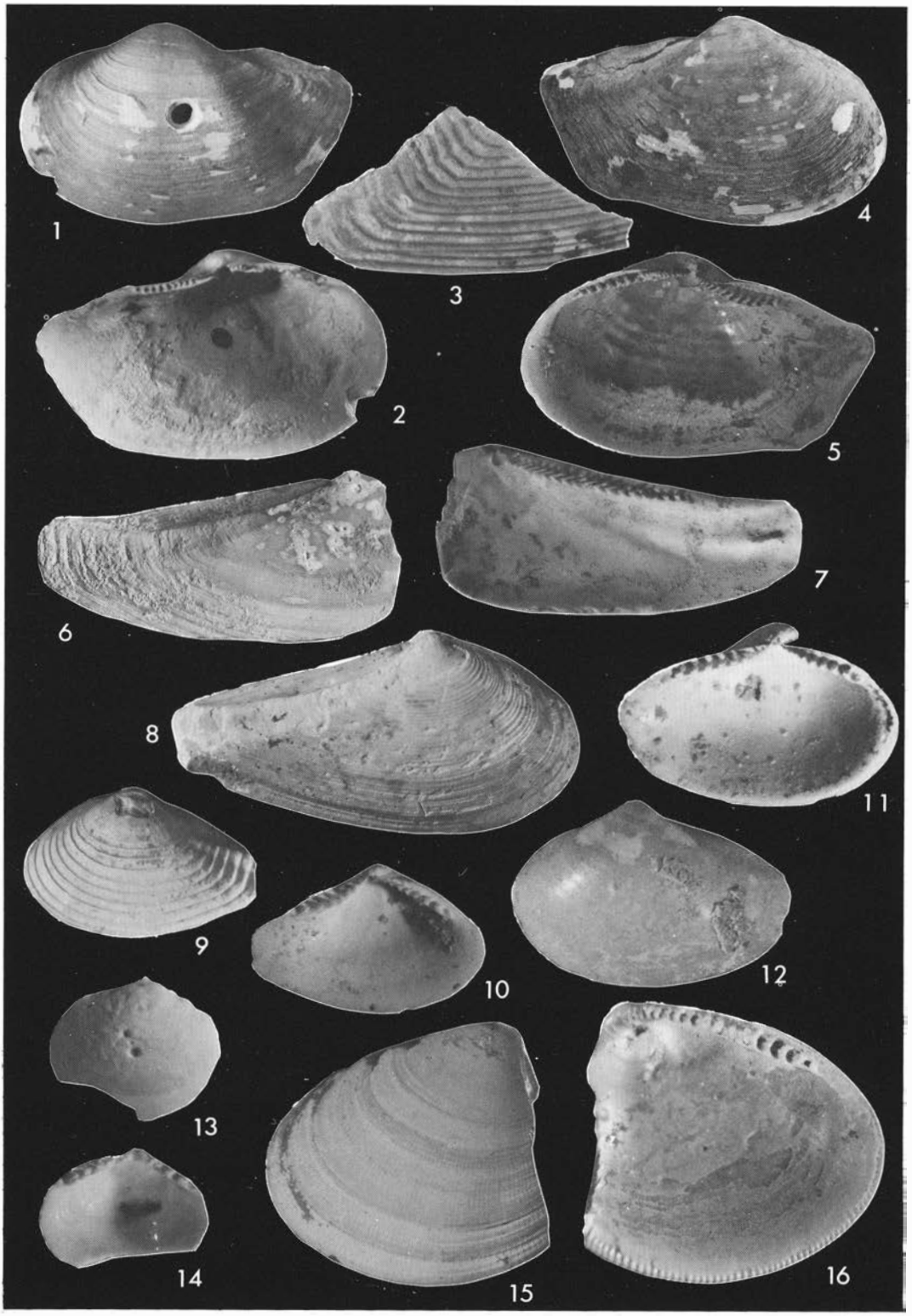
Fig. 8. *Nuculana pernula* (Müller). Right valve from 17.75 m, Solberga core. x 4.

Figs. 9, 10. *Nuculana minuta* (Müller). Left valve from 19.00 m, Solberga core. x 4.

Figs. 11, 12. *Yoldiella lenticula* (Møller). Left valve from 19.00 m, Solberga core. x 12.

Figs. 13, 14. *Yoldiella fraterna* (Verrill and Bush). Specimen from 14.50 m, Brastad core. x 21.

Figs. 15, 16. *Nucula nitida* Sowerby. Left valve from 3.00 m, Solberga core. x 4.


1
3
4
2
5
6
7
8
11
9
10
12
13
14
15
16

species continue, very sparsely, up to 4.5 m, but Boreal-Arctic species are also found in the upper part of zone Z, and there are indications of reworking.

The Solberga core displays an upward succession of increasingly ameliorated mollusc-stratigraphical units, from High-Arctic (zone E) to Arctic-Boreal (zone D), Arctic-Boreal and Boreal-Arctic (zone C) followed by a mollusc free section (zone B), to the pure Boreal zone A at the top (Fig. 12:8). Pure Arctic conditions end with zone E. The Pleistocene/Holocene boundary, reflecting the transition from the Younger Dryas to the Preboreal, may be found at the transition E/D or within zone D or close to, but hardly above, the transition D/C.

ACKNOWLEDGEMENTS

I wish to express my gratitude to Karen Luise Knudsen of the Micropalaeodepartment, Geological Institute, Aarhus University, who read the manuscript, and to J.R. Wilson, Geological Institute, Aarhus, who kindly revised the English of the text.

I extend my thanks to Jette Gissel Nielsen, who drew maps and diagrams, to Svend Meldgaard, who processed the samples and provided the photographs for the plates, and to Lissi Østerhaab Mogensen, who prepared the manuscript.

PLATE 12:2

Fig. 1. *Mytilus edulis* Linné. Fragments from 6.50 m. Brastad core. x 8.

Fig. 2. *Yoldiella lenticula* (Møller). Complete specimen from 19.25 m, Solberga core. x 12.

Figs. 3, 4. *Yoldiella frigida* (Torell). Right valve from 21.02 m, Solberga core. x 16.

Figs. 5, 6. *Abra longicallis* Scacchi. Fragment of right valve from 18.48 m, Solberga core. x 8.

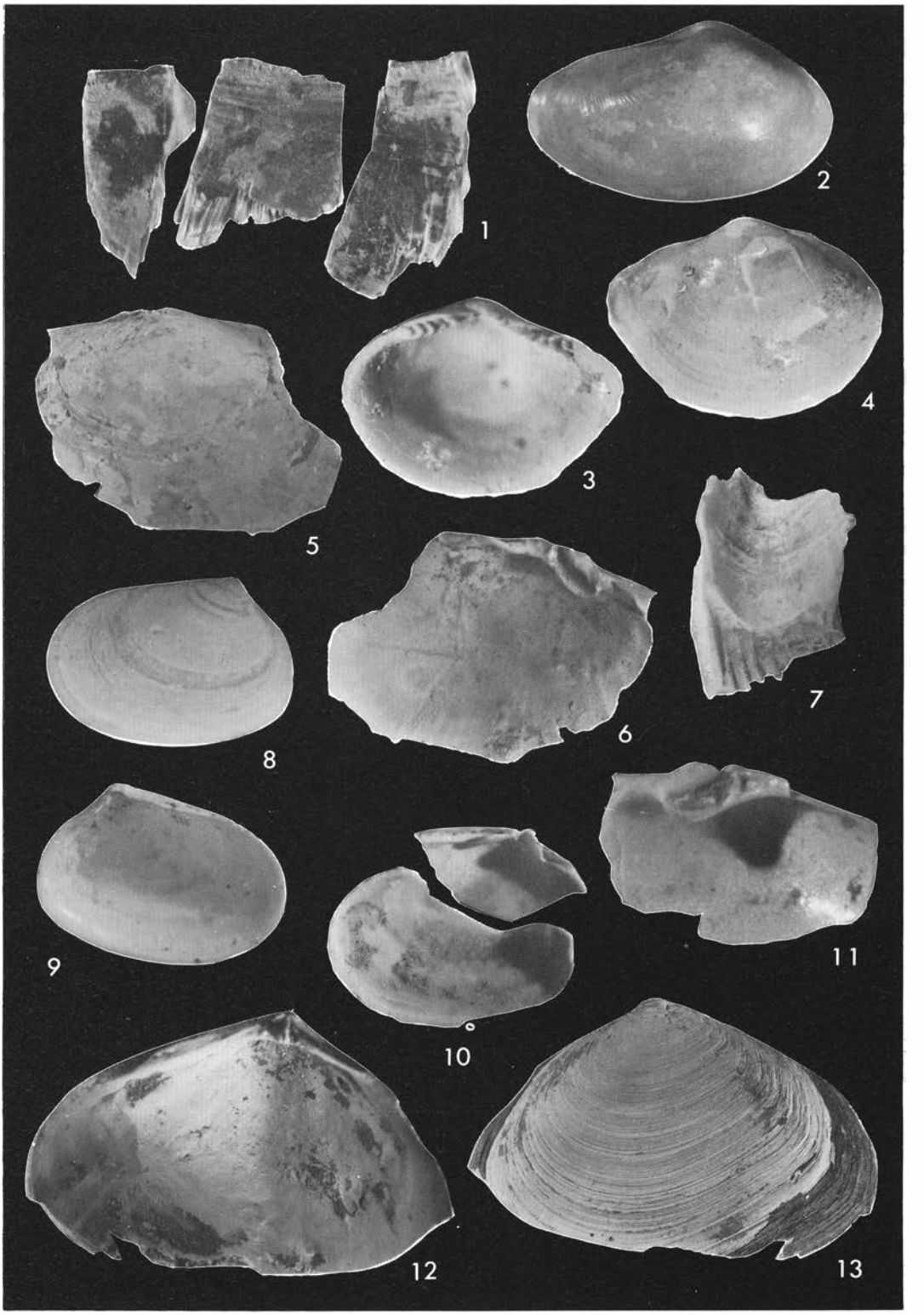
Fig. 7. *Balanus crenatus* Bruguiere. Compartment from 6.52 m, Brastad core. x 8.

Figs. 8, 9. *Montacuta bidentata* Montagu. Left valve from 2.52 m, Solberga core. x 14.

Fig. 10. *Montacuta bidentata* Montagu. Broken right valve from 2.52 m, Solberga core. x 14.

Fig. 11. *Abra nitida* Müller. Fragment of left valve from 3.02 m, Solberga core. x 30.

Figs. 12, 13. *Macoma calcarea* (Gmelin). Left valve from 7.32 m, Brastad core. x 2.


1
2
3
4
5
6
7
8
9
10
11
12
13

REFERENCES

ANDERSEN, B.G., 1975: Glacial geology of northern Nordland, North Norway. – Norges geol. unders. 320, 1–74.

ANTEVS, E., 1928: Shell beds on the Skagerack. – Geol. Fören. Stockh. Förh. 50 (4), 479–750.

ASKLUND, B., 1936: Den marina skalbärande faunan och de Senglaciala nivåförändringarna, med särskild hänsyn till den Gotiglaciala avsmältningszonen i Halland. – Sveriges geol. unders., C 393, 1–103.

BERGLUND, B., 1979: The deglaciation of southern Sweden 13,500–10,000 B.P. – Boreas 8, 89–118.

BRØGGER, W.C., 1901: Om de Senglaciale og Postglaciale Nivåforandringer i Kristianiafeltet (Molluskfaunaen). – Norges geol. unders. 31, 1–731. Oslo.

FEYLING-HANSSEN, R.W., 1953: The barnacle *Balanus balanoides* (Linné, 1766) in Spitsbergen. – Norsk Polarinst. Skr. 98, 1–64.

– 1955: Stratigraphy of the marine Late-Pleistocene of Billefjorden, Vestspitsbergen. – Norsk Polarinst. Skr. 107, 1–186.

– 1963: A Late Quaternary correlation chart for Norway. – Norges geol. unders. 223, 67–91.

– 1964: Foraminifera in Late Quaternary deposits from the Oslofjord area. – Norges geol. unders. 225, 1–383.

HESSLAND, I., 1943: Marine Schalenablagerungen Nord-Bohusläns. – Bull. Geol. Inst. of Upsala, 31, 1–348.

HOLTEDAHL, O., 1960: Geology of Norway. – Norges geol. unders. 208, 1–540.

– 1974: Noen glasifluviale israndavsetninger i den sydlige del av Glommavassdragets nåværende dreneringsområde. – Norges geol. unders. 306, 1–85.

JENSEN, AD.S., and SPÄRCK, R., 1934: Bløddyr II. Saltvandsmuslinger. – Danmarks Fauna, G.E.C. Gads Forlag, København, 208 pp.

MUUS, B.J., 1967: The fauna of Danish estuaries and Lagoons. – Meddr. Danmarks Fiskeri- og Havunders. N.S. 5, (1), 1–316.

ODHNER, N.H., 1915: Zoologische Ergebnisse der Schwedischen Expedition nach Spitzbergen 1908. Teil II. 1. Die Molluskenfauna des Eisfjordes. – Kungl. Svenska Vetensk. Akad. Handl. 54 (1), 1–274.

OCKELMANN, W.K., 1958: Zoology of East Greenland, marine Lamellibranchiata. – Meddr. Grønland 122, 257 pp.

PETROV, O.M., 1965: Stratigraphy and fauna of marine molluscs in the Quaternary deposits of the Chukotsk Peninsula. – Akad. Nauk SSSR, Geol. Inst. Transact. 155, 1–291.

SIMONARSON, L.A., 1977: Upper Pleistocene and Holocene marine deposits in the Umanak Fjord, West Greenland. – University of Copenhagen, unpubl. thesis, 1–204.

SOOT-RYEN, T., 1932: Pelecypoda, with a discussion of possible migrations of Arctic pelecypods in Tertiary times. – The Norwegian North Polar Exped. with the "Maud" 1918–1925, Scient. Res. 5 (12), 1–36. Bergen.

SØRENSEN, R., 1979: Late Weichselian deglaciation in the Oslofjord area, south Norway. – Boreas 8, 241–246.

THORSON, G., 1934: Contributions to the animal ecology of the Scoresby Sound fjord complex (East Greenland). – Meddr. Grønland 100:3, 69 pp.

ZIEGELMEIER, E., 1957: Die Muscheln (Bivalvia) der deutschen Meeresgebiete. – Helgoländer Wiss. Meeresunt. 6 (1), 1–56.