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Foraminifera

in Late Quaternary deposits from the Oslofjord area

By

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Abstract

Approximately 2500 core samples from 130 borings, 4 m to 40 m deep, in Late Quaternary (latest Allerød through Sub-Atlantic) clay deposits in the Oslofjord area in southeastern Norway were investigated micropaleontologically. In addition some samples from clay pits and excavations for foundation purposes were examined.

180 species, subspecies, and forms, of Foraminifera, belonging to 76 genera and 23 families of the superfamilies Astrorhizoidea, Lituoloidea, Milioloidea, Nodosarioidea, Buliminoidea, Spirillinoidea, and Rotalioidea occurred. Only one of the species was planktonic. Two of them, *Dentalina drammenensis* and *Dentalina trondheimensis*, were described as new. Additionally, 4 species of Thecamoebina were observed.

Statistical analysis revealed certain foraminiferal assemblages of considerable lateral extent in the deposits. These assemblages were assumed to reflect changes in the marine environment during the deposition of the sediments. A general amelioration from Arctic to Boreal conditions occurred, and a regional isostatic land rise caused a shallowing of the water in every locality in the investigated area. Species which dominated the fauna under glacial conditions became less frequent, did probably even disappear, following raised water temperature, expelled by new species which became dominant. Shallow-water species generally appeared in the upper parts of the cores, increasing in frequency towards the top levels. Nearly all, if not all, the Foraminifera species found in the core samples are represented in marine faunas of the present-day.

A subdivision of the deposits were undertaken, based upon foraminiferal zonation. For the purpose of brevity the units of this, entirely ecologically conditioned, zonation were called zones, and indicated by letters. 7 zones from A to G, and 10 subzones were recognized. The zones and subzones were ecologically and stratigraphically interpreted,

on the basis of comparison with Recent faunas from environments assumed to be similar to those of the fossil faunas, and by radiocarbon datings. They were correlated with substages of the recession of the land ice through the area and, as far as possible, with units of a previously established mollusc stratigraphy for the Oslofjord area. Subzone A_m (A_{middle}), with an abundance of *Elphidium incertum clavatum* and frequent occurrence of *Nonion labradoricum* was found to be of Younger Dryas age, deposited during the formation of the large glacial marginal ridge called the Ra. Subzone B_l (B_{lower}), with abundant *E. i. clavatum* and *Cassidulina crassa* and frequent occurrence of *Virgulina loeblichi* and *N. labradoricum* was assumed to be of Pre-Boreal age, deposited during the formation of the marginal ridges of the Ås–Ski substage. Zone C, of similar faunal composition as the above-mentioned subzone but with frequent occurrence of *Cassidulina laevigata carinata* instead of *Nonion labradoricum* was with some hesitation assumed to be of Pre-Boreal age, deposited during the formation of the marginal ridges of the Late Glacial Aker substage. Zone D, with poor assemblages, dominated by *E. i. clavatum* and with quite common occurrence of *Cassidulina crassa* and *Quinqueloculina stalkeri*, comprises sediments presumably deposited during the final rapid retreat of the ice margin, when large quantities of cold melt-water gushed into the comparatively shallow and narrow northern reaches of the ancient Oslofjord. Zone E, with frequent occurrence of *Elphidium i. incertum* and *E. i. clavatum*, and especially zone F, with abundant *Bulimina marginata*, forma *aculeata*, reflect Post Glacial Warm Interval conditions. Zone G, dominated by arenaceous shallow-water species e. g., *Eggerella scabra*, *Spiroplectammina biformis*, *Ammoscalaria runiana*, and *Miliammina fusca*, represents Holocene shallow-water deposits, in most instances contemporaneous with the zone F deposits.

Introduction

Scope of the study

The present study deals with Foraminifera from marine clay deposits of Late Quaternary age from the Oslofjord area in southeastern Norway from the outer parts of the fjord northwards to the southern end of the lake Mjøsa. The scope of the treatise concerned firstly with the registration and notice of the different species, subspecies, and forms found in the deposits; secondly with an attempt at establishing a zonational subdivision of the deposits based upon their content of fossil Foraminifera; thirdly an attempt at interpretation of the zonation and its possible correlation with previous classifications used in the area.

To gain the first end, approximately 2500 core samples from different localities within the area were examined and all species of Foraminifera found were recorded. The majority of the samples were quantitatively and statistically analyzed. For the purpose of establishing a subdivision of the deposits, certain foraminiferal assemblages were described and characterized and presented as analyses and in range charts from a selected number of borings, but were recognized in many others. No type section was chosen because this subdivision is not strictly stratigraphical. Ecological factors, not necessarily time-dependent, may have affected the faunal composition of the zones. To gain the third object, the attempt at interpretation of the zones, the assemblages recognized in the borings were compared with Recent foraminiferal assemblages developed under climatic conditions which may correspond to those which succeeded each other during the deposition of the marine clay sediments of the area. In addition to a description of Recent agglutinated Foraminifera from the Drøbaksund of the Oslofjord (Christiansen, 1958), an investigation of Recent foraminiferal faunas of the Oslofjord, now being undertaken by Risdal, may largely clarify any interpretation of the assemblages met with in the Late Quaternary clays of the area.

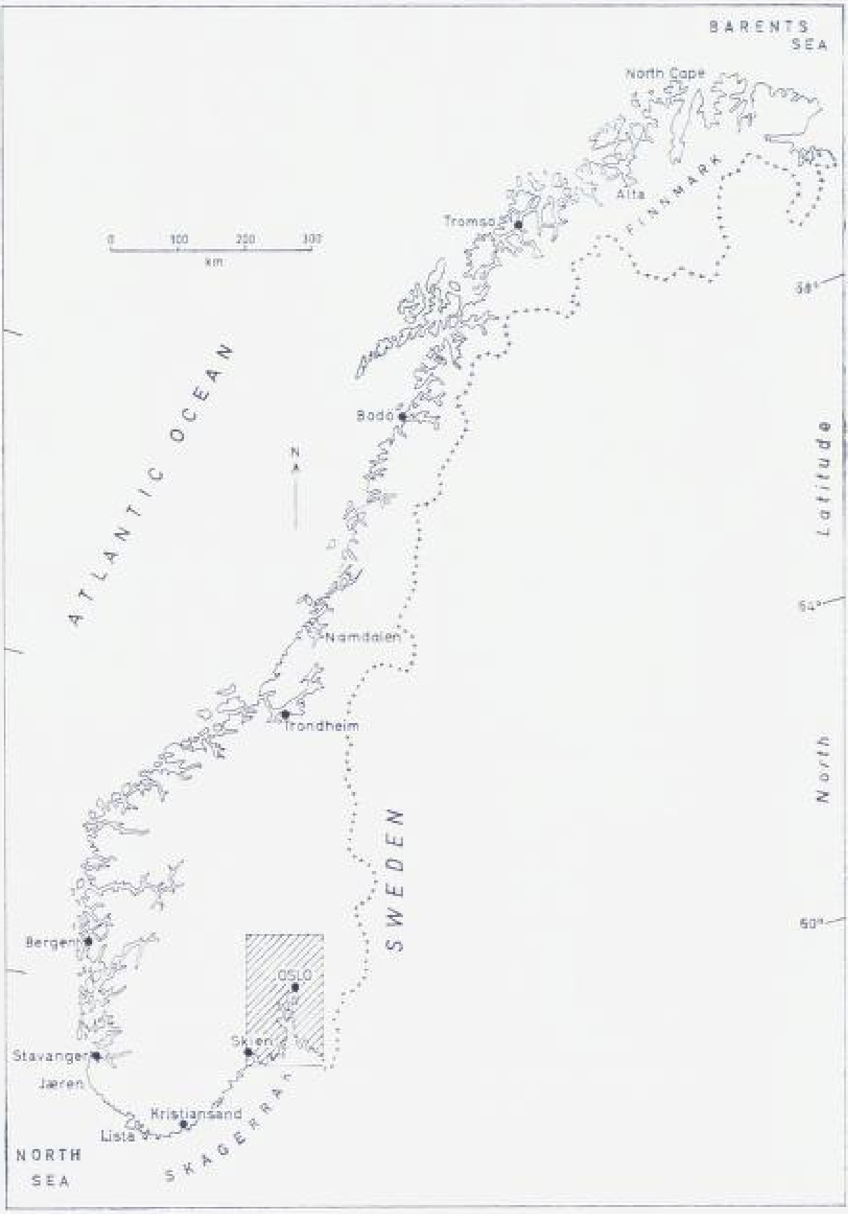

Fig. 1. Location map.

In order to correlate the Late Quaternary foraminiferal zonation with previous subdivisions of the deposits, especially with the mollusc stratigraphy elaborated by Brøgger (1900–1901), a number of well-defined classical clay samples from Brøgger's own collection in the Paleontological Museum of the University of Oslo, have been foraminiferologically examined (Feyling-Hanssen, 1954 a). More comparisons of this kind were undertaken for the present study and revealed in many instances in a direct way the composition of the fossil foraminiferal fauna, and thereby the unit in the foraminiferal zonation, corresponding to a certain unit in the mollusc stratigraphy. In order to support the correlation, radiocarbon datings of some micropaleontologically investigated samples have been presented.

Ackowledgements

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Faunistical remarks

The following groups of microfossils were observed during the present investigation: diatoms, spores, charophyte oogons, sponge spicules, thecamoebines, foraminifers, radiolarians, ostracodes and echinoid plates and spines. The selection, as well as the frequency within the different groups, is, at least partly, dependent on the sampling method and certainly on the technique used in treating the samples. To mention one factor only, if sieves with a smaller mesh diameter had been used in the washing process, some pollen grains should have been saved for the microscope stage, as well as more diatoms. The types of microfossils obtained are further dependent on physical and chemical conditions with the sediment, e. g. grain size, pore volume, degree of consolidation, chemical properties of the pore water. Presence of acidic pore water will certainly decrease the number of delicate calcareous tests. It is also possible that unfortunate combinations can occur between chemical compounds in the sediment and the chemical part of the laboratory technique applied to the sample, combinations which may result in reduction or complete effacing of certain groups of microfossils.

With the methods applied in the present study (Cp. p. 41), Foraminifera formed the bulk of the microfossil content in nearly all samples which were microscopically investigated. Foraminifera were far more frequent than any other group, both from the point of view of species as well as number of specimens. 30 000 individuals in a clay sample of 100 g dry weight was not extraordinary. However, the samples varied greatly in the total number of foraminiferal specimens. Some of these variations appeared to be connected with the stratigraphy, certain zones yielded, as a rule, richer faunas than others. Intrazonal variations, on the other hand, were common.

Among the many environmental factors influencing the frequency of Foraminifera attention should, in this introductory note, be called to sedimentation rate, median grain size of the sediment, concentrations of nutrients and trace elements, and water type. Lankford (1959) found that the degree of variability of sediment and water types was the most important ecological factor at the Mississippi delta margin. No single variable appeared to be the controlling factor, and besides the foraminiferal production was not constant in all environments. Boltovskoy (1956) supposed that the distribution of Foraminifera was subject to periodicity, while Shifflett (1961) found that living Foraminifera, in the Gulf of Mexico, were not uniformly distributed on the sea floor but appeared to live in colonies.

Larger Foraminifera were not observed in Late Quaternary clay samples of the Oslofjord area. All the species found belonged to the group of smaller Foraminifera. The size of the tests generally ranged from 0.1 mm to 1.0 mm, some specimens of the genus *Dentalina* being more than 2.0 mm long. Tests smaller than 0.1 mm were rare in samples treated with the present technique. By using sieves with smaller mesh diameter in the washing process the number of smaller tests would have been somewhat increased (Cp. p. 44). It is also possible that some of the slender forms, e. g., *Lagena distoma*, which may be more than 1.0 mm long but less than 0.1 mm broad, might have escaped through the sieve during washing, such forms in this way being underrepresented in the final analysis.

Specimens with calcareous tests formed the bulk of the microfossils in most samples. Agglutinated arenaceous tests with calcareous or siliceous cement were in general much rarer. Again, one reason for this may be sought in the laboratory technique. Loosely cemented arenaceous tests may well be disintegrated by the quite strong spray of water applied in the washing of the samples. It is, for example, suspicious that not a single specimen of the long-cylindrical or long-cylindrical-arbitrary forms of the genus *Rhabdammina* was observed in the many samples investigated, especially as this genus is commonly represented in the Recent fauna of the Oslofjord (Kiær, 1900; Christiansen, 1958). Maybe tests of this type are not easily preserved after death. On the other hand, some of the youngest samples, or samples presumably deposited in shallow water with relatively low salinity, contained microfaunas predominated by forms with arenaceous tests.

Tectinous tests occurred primarily in samples from sediments presumably deposited under ecologically unfavourable conditions. Species which are normally provided with arenaceous tests or species with calcareous tests occur in some samples with only the tectinous base of the wall developed or with very reduced amount of agglutinated or calcareous material. In a few instances mechanical erosion may be suggested as a reason for this. Reworked specimens would probably appear with projecting or inflated parts of their tests worn down until the tectinous base is exposed. In other instances secondary decalcination may have taken place by seepage of acidic ground water through the sediment. In many cases, however, the property is due to original low precipitation of calcium carbonate in the water where these forms lived. The composition of the fauna as well as the appearance and location of these sediments seem to prove this. This environment has much in common with marshes. Acid conditions resulting from decaying vegetation may also dissolve dead tests of calcareous species even if the species were able to live there (Cp. Lankford, 1959, p. 2077).

As seen from the chart on page 379, 180 species or subspecies, and forms of Foraminifera were identified in the Late Quaternary of the Oslofjord area, 23 families and 76 genera being represented. Additionally 4 species of Thecamoebina were recorded. Future investigation of other samples from the area will certainly augment these numbers. About 70 of the foraminiferal species were extremely rare; approximately 90 of them were moderately frequent, 10–100 specimens per sample. Only a limited number of species, about 20, occurred in abundance. It is on the whole characteristic of these faunas that a few populations, usually one or two, outshade the others.

All the recorded Foraminifera, except three specimens of *Globigerina bulloides*, are benthonic forms. The three planktonic specimens must have drifted into the area accidentally from remote waters. There are no Recent records of this species from the Oslofjord, but some from the south coast of Norway (Lange, 1956). Assuming that the fossil faunas from the investigated area have remained in situ, the environmental indications which can be deduced from them, should always concern conditions at the bottom at that time.

In current work on identification of the Late Quaternary Foraminifera from the Oslofjord area, papers dealing with Recent foraminiferal faunas of some waters were more useful than others because they contained descriptions and illustrations of forms identical with or similar to the forms of the present study. These waters are the archipelago of the British Isles, the North Sea, Arctic and Subarctic waters (Iceland, Spitsbergen, Greenland, Alaska, Siberia), the northern east coast of North America, and also the waters around Japan, the Patagonian shelf and Subantarctic and Antarctic waters.

This would suggest a very wide Recent distribution of many species of Foraminifera present in Late Quaternary deposits of the Oslofjord area. Migration of benthos is certainly possible, primarily through current action during the zoosporic stage of every new generation. And given sufficient time, such migration may reach considerable distances. On the other hand the wide distribution may be only apparent. Closer examination, introducing other specific elements than those in common use, would probably reveal that there were cases of mistaken identity and that, really, homeomorphy occurred.

Many of the species from Post Glacial deposits in the Oslofjord area are found in Tertiary beds in localities outside Norway. *Pullenia subcarinata* and *Pullenia bulloides* are found even in the Eocene, *Höglundina elegans* back in Oligocene, *Cassidulina laevigata laevigata* in the Miocene, to mention a few examples only. A lot of the Post Glacial species are known from the Pliocene. With the species from Late Glacial deposits in the area, however, this seems to be less the case. The Late Glacial species which can be traced back into the Tertiary, seem to be those which occur also in Post Glacial deposits of the area.

Stratigraphical remarks

In accordance with the terminology of many students of Quaternary deposits the term *Quaternary* is in the present treatise given system rank. The *Quaternary system* comprises sediments deposited within the time interval called the *Quaternary period*. The Quaternary system is divided into three series, the Quaternary period into three epochs: *Eopleistocene*, *Pleistocene*, and *Holocene* (Cp. i. a., Gromov, Krasnov, Nikiferova and Schanzer, 1960). Eopleistocene is the epoch leading up to the great ice age, comprising the old units from Butley (Amstelian) to Mindel (Kansan) glacial. Pleistocene comprises the units from Mindel/Riss (Yarmouth) interglacial through Würm (Wisconsin) glacial. Holocene is the epoch in which the Fennoscandian land ice receded from the Fennoscandian marginal moraines (Ra, Central Swedish, and Salpausselkä) and disappeared. It started with Pre-Boreal time, in Blytt-Sernander's terminology. The term *Late Glacial* is used for sediments deposited under Arctic or Subarctic marine-climatic conditions, or the corresponding time interval, which started with the first sign of a climatic amelioration after the latest glacial optimum. Late Glacial marine-climatic conditions prevailed during subsequent ages with regional retreat of the ice margin. As long as ice, in considerable quantities, melted in contact with sea water, the temperature of this sea water remained low. And in this cold water an Arctic fauna could live and breed, following the ice front until this retreated ashore. Late Glacial marine-climatic conditions in this manner seem to have lasted in the Oslofjord through Pre-Boral time, and locally even into Boreal. The term *Post Glacial* indicates sediments deposited during times with improved marine-climatic conditions, or these times themselves. The Post Glacial age, as defined, seems to have started in the Oslofjord mainly with Boreal time, in Blytt-Sernander's terminology. The term *Recent*, when written with initial capital, is in the present study applied to deposits, or times, younger than approximately 2400 years. It starts with the Post Glacial climatic deterioration and is thus synonymous with Sub-Atlantic time (Cp. Brøgger, 1905; Feyling-Hanssen, 1963). Late Quaternary comprises Late Glacial and Post Glacial.

The marine deposits dealt with in this study belong to the Holocene and the latest part of the Pleistocene series. The oldest sample treated is hardly more than 12 000 years old. A biostratigraphy based on phylogenetic development cannot be applied for these young sediments because phylogenetic changes can hardly be traced within so small a time intervall. Nearly all, if not all, the Foraminifera species found in these sediments appear to be represented also in marine faunas of the present-day. Probably none of them have become extinct within this comparatively short span of time. Only one of the species here described as new, seems not to have been recorded from any Recent fauna as yet. It is in some cases difficult to judge whether any of the species from these Late Quaternary deposits make their first appearance in these strata because the knowledge of Quaternary Foraminifera is on the whole limited. The majority of the species are recorded from earlier parts of the Quaternary and many of them, as mentioned above, also from Tertiary beds. A biostratigraphy with units based on extinction (highest stratigraphical occurrence) or first appearance (lowest stratigraphical occurrence) of species would fail in the present case.

The foraminiferal zonation demonstrated with the cores of the present investigation was created by changes in the marine environment during deposition of the sediments penetrated by the present borings. A general amelioration of the marine-climatic conditions from Arctic to Sub-Boreal occurred, and a regional isostatic land rise caused a shallowing of the water in every locality of the investigated area. Again, this brought about, at least locally, changes of salinity and nutrient concentration of the water, to mention but a few factors.

These changes in the environment are reflected by the composition of the fossil fauna of Foraminifera. Species which dominate the fauna under glacial conditions become less frequent, may even disappear, with higher water temperature, expelled by new species which become dominant. Shallow-water species generally appear in the upper part of the cores and increase in frequency towards the top levels, having kept time with the decrease of depth in the locality. Such faunal changes occur because different species of Foraminifera have different habitats, and have different requirements as to their environment. Hence a subdivision of the deposits in accordance with, and based upon, the foraminiferal zonation of investigated cores will represent an *eco-stratigraphy* in Schindewolf's (1950, p. 35; 1954, p. 29; 1960, p. 31) meaning of the term. It is a stratigraphic interpretation of faunal communities, or assemblages, which are entirely ecologically conditioned. Such a stratigraphy will necessarily have only a limited regional applicability. Its units are small assemblage-zones or assemblage-zonules (Cp. International Subcommission on Stratigraphic Terminology, 1961, p. 11, 22). They are characterized for the Oslofjord area by certain natural assemblages of fossil Foraminifera, and may be given names derived from prominent constituents of the associations, e. g., *Bulimina marginata* Assemblage-zone or the Assemblage-zone with *Virgulina loeblichi* and *Nonion labradoricum*. As the present units are much smaller than the usual biostratigraphic zones, assemblage-zonules should probably be an appropriate term for them. However, in the concept of most stratigraphers even this term has a much greater range. In order to emphasize the eco-stratigraphic character of the present subdivision of Late Quaternary deposits, its units could be termed eco-zones. But in the mind of the zoologists this term would create the impression of ecological zones *as they are to-day*, i. e., simultaneously occurring biotopes. With our foraminiferal zonation the time factor is also involved. Animal communities as presented by Petersen (1913; cp. Thorson, 1957) comprise several different animal groups, not only one, as in the units of the present zonation.

For the purpose of brevity, and because it seems difficult to find a completely adequate term, the units of the Foraminifera zonation of the present cores are simply called *zones*. These zones are eco-stratigraphic units in the meaning of Schindewolf (l. c.).

The differences between the present zones are illustrated by differences in composition of the Foraminifera faunas. Differences which could be recognized, and recognized in the same succession, in a number of different borings, i. e., faunal differences which appeared to be laterally persistent to a reasonable degree within the investigated area, form the basis for the eco-stratigraphy established here. Again for the purpose of brevity, the zones are indicated by letters: Zone A, zone F. Subdivisions of zones are termed *sub-zones*, e. g., sub-zone F_1 (F_{lower}).

An important problem is to what extent, if any, does the series of eco-stratigraphic zones reflect regional Late Quaternary climatic changes, and to what extent do they represent biofacies which occurred extemporanous in different localities?

A study of Recent Foraminifera biotopes of the Oslofjord should contribute greatly to the solution of this problem. Such a study is now in progress, and problems of the Quaternary will be taken up in connection with it. The result of an investigation of Recent arenaceous Foraminifera in a limited area of the fjord, undertaken by Christiansen, appeared in 1958.

For the present discussion it would seem a great advantage that the Foraminifera species dealt with have representatives also in Recent faunas. It is, at least theoretically, possible to know something about their living conditions.

There has in late years been an increased demand for ecological information, and from different parts of the world students of Recent Foraminifera contribute to a steadily growing knowledge of the ecology of the group. The geographical distribution of a considerable number of species has become better known by the study of foraminiferal samples taken by many expeditions, old and new, and by workers at marine-biological stations in many countries. Faunas from certain biotopes demonstrate similarities in composition even in widely separated localities.

Unfortunately, however, many a valuable item of information about Recent distribution, which would i. a., form information of temperature limits for the habitat of certain species, is lost or obliterated because the recorder had a too broad consept of the species unit. In fact, different species are recorded under one and the same specific name, and this unit will then, in most cases, seem to have a much wider geographical distribution than a narrower species concept would allow. Good examples are *Polystomella striatopunctata* Parker and Jones, and *Dentalina communis* d'Orbigny. The latter is an example of subsequent broadening in the concept of an originally well defined species, inhomogenic forms having repeatedly been referred to that specific name.

A too broad concept of the species unit renders the Foraminifera less valuable in all stratigraphical work. Particularly is this true of the micropaleontologist trying to subdivide young, Late Quaternary, deposits on the basis of their foraminiferal content. He will soon detect that a careful handling of systematic problems, with a sharp and reasonably narrow concept of the species unit increases the stratigraphical value of his material. It is, therefore, natural that the micropaleontologist dealing with Late Quaternary deposits, in taxonomic questions will adhere to foraminiferologists exercising a tendency of splitting the old broad units. On the other hand he should be aware of the possibility of using taxonomic units of lower rank than species to separate his forms, subspecies, variety and especially forma (Hiltermann, 1954, p. 385, 1956 a; Boltovskoy, 1954 b, 1958, 1959, p. 32).

A serious complication of the present stratigraphical study is the possibility of sediments having been redeposited (Cp. Jones, 1958). It is difficult to determine to what extent the microfossils represent species which lived on the spot and belonged to the biotope of the corresponding time, or to what extent some of them, or all, have been brought there from a foreign environment by some transporting agency (Cp. Munthe, 1897, p. 35). Living Foraminifera as well as empty tests may be transported, along with the minerogenic fraction of a sediment, and deposited particle by particle in a foreign environment. By this the tendency is for the specimens to be carried into deeper water rather than the reverse. Rivers and brooks eroding raised marine deposits will carry away foraminiferal tests along with clay and mineral grains and deposit them into the fjord anew. By this means the tendency is for specimens belonging to older strata to be transferred to younger. Thus reworked shallow-water species should be expected in deep-water sediments, reworked Late Glacial species in Post Glacial sediments. In apparently undisturbed strata fossils may be considered to have remained in situ if the size and weight of the biogenic particles, size of fossil specimens or fragments thereof, are of an order of magnitude different from that of the particles of the minerogenic matrix. This is certainly the case with finer clay sediments of the area, with median grain size between 0.0015 mm and 0.0042 mm and quartiles 0.0005–0.0010 mm and 0.0035–0.0100 mm. Foraminiferal tests ranging in size between 0.1000 mm and 1.0000 mm represent particles of immense size compared with these minerogenic particles. And even if they are empty and hollow, it is hardly thinkable that the water movements which transported and deposited such small minerogenic particles, were also able to carry and deposit these giants. It seems more reasonable that the foraminiferal tests in such strata represent individuals which once lived and grew on this bottom. With coarser clay sediments with a less good degree of sorting, it can, on the other hand, easily be imagined that one and the same agency brought together minerogenic and biogenic particles. This may have happened particularly with some of the Late Glacial clays with median grain size of approximately 0.0070 mm and quartiles 0.0015 mm and 0.0500 mm.

Such considerations are not applicable to secondary sediment transportation which occurred more or less en block, e. g., redeposition by glacier advance or solifluction or land slide. The latter factor is probably the most serious, as the marine clay sediments of the Oslofjord area are slide-prone to a considerable degree. A large number of slides have occurred in historic time, and prehistoric slides have been traced in many localities within the area (Cp. G. Holmsen, 1929, 1934, 1955; G. Holmsen and P. Holmsen, 1946). Some of these slides confused the original stratification only in comparatively small, limited localities. But by some of the quick clay slides material, with megafossils and microfossils, run off over considerable distances. When such slide material run into a river, the possibilities of having confused indications from the fossils are seriously increased, because in addition to the chance of a still longer transportation, there is also a secondary sorting of the displaced material. Another serious possibility exist in redeposition by turbidity currents. Submarine slides, to a greater or lesser degree transformed into suspension currents, may have created false foraminiferal zonation, e. g., by carrying shallow-water assemblages into deeper environment and probably also by sorting the specimens according to size or buoyancy.

Historical

Retreat of glaciation

The Oslofjord area is a classical region of geological research. Its different formations, old and young, have been studied over more than a century. Numerous investigators have contributed to the understanding of its geology and geological history. An exhaustive summary of this is given in O. Holtedahl: "Geology of Norway" (1960), a short review of the marine Quaternary is found in Feyling-Hanssen: "Micropaleontology applied to soil mechanics in Norway" (1957), and a review in Norwegian was given by G. Holmsen: "Norske jordarter og geotekniske problemer knyttet til dem" (1955). Correlation of a selected number of Late Quaternary subdivisions of deposits and events in some parts of Norway, particularly in the Oslofjord area, was recently undertaken by the present writer (Feyling-Hanssen, 1963).

During the Quaternary period Fennoscandia was at least three times overridden by immence glaciations. Each time the advancing fronts of the growing ice sheets carried away most of the unconsolidated deposits, and even parts of the bedrock, which they met on their way. The unconsolidated sediments of Norway to-day are therefore, in general, those which were deposited at the retreating front of the latest, Würm–Wisconsin, glaciation. There exists in the Oslofjord area a great hiatus between the youngest rock formation, which is of Permian age, and the unconsolidated deposits of Late Quaternary age.

The retreat of the ice of the latest glaciation in the Oslofjord area has been traced by the study of marginal deposits (i. a., Keilhau, 1838;

Kjerulf, 1871; Hansen, 1910; Brøgger, 1900–1901; Holtedahl, 1924, 1960; G. Holmsen, 1951). From one time to another the retreat was interrupted by stagnations or oscillations of the ice front, stagnations which are now marked by marginal deposits, which were in most places deposited in the sea. The most prominent of these marginal formations is the *Ra* which in the Oslofjord area can be traced from Halden, at the Swedish border, through Sarpsborg to Moss, and on the west side of the fjord from Horten to Larvik–Helgeroa. The Ra marks the *Fenno-scandian stage* (Ra – central Swedish – Salpausselkä moraines) of the ice margin positions. It is supposed to be of younger Dryas age. (The position of the marginal formations is indicated in figure 2 on page 37.) The stratification of the Ra ridge material in many localities as well as its content of marine fossils indicate that the Ra in the Oslofjord area is a submarine formation. Two older moraine substages are known to the south of the Ra ridge. They are marked by discontinuous and rather inconspicuous marginal formations which have been difficult to refer to marked ice fronts (Cp. Størmer, 1935, p. 106–108). The outermost is called the *Tjøme–Hvaler substage*, whereas the marginal formations between this and the Ra ridge is called the *Tjølling–Slagen–Onsøy–Borge substage*. To the north of the Ra prominent morainic and glacifluvial marginal deposits are found at Mysen, Ås, Ski, Storsand, Svelvik, Sande. These formations are referred to the so-called *Ås–Ski substage*. The next indication of a stagnation or oscillation of the receding ice front is found in moraines in the northern outskirts of the city of Oslo, at Linnerud, Grefsen, Sognsvann, Bogstadvann and, farther west, at Egge in Lierdalen (Lier valley) north of the city of Drammen. They are referred to as the *Aker substage*. In the region of Romerike, northeast of the city of Oslo, Holtedahl (1924) described marginal glacifluvial formations at Berger, *Berger substage*, at Jessheim, *Jessheim substage*, at Hauerseter, *Hauerseter substage*, at Dal, *Dal substage*, and, finally, at Minnesund, *Minnesund substage* on the southern end of the lake of Mjøsa.

The inland ice seems to have been, on the whole, already inactive from the time it deposited the moraines of the Aker substage.

Shoreline displacement

A. M. Hansen (1890) connected the problem of shoreline displacement in Norway with the ice-pressure theory of Jamieson (1865), and it is now generally assumed that the accumulation of snow and ice in Fennoscandia caused a depression of the land mass so that its coasts became more deeply submerged into the sea than they were before the glaciation. During the subsequent climatic amelioration when the ice melted and the weight of its masses lessened, an isostatic elevation of the previously glaciated region took place. A great part of the marine sediments were raised above sea level. Due to the inertia of the earth's crust this elevation of the land mass continued, at a retarding rate, after the ice had melted away, and is still continued to-day. At Oslo the present shoreline displacement seems to be 0.36 m/century (Holtedahl, 1960, p. 386). The marine limit, the highest raised shoreline, is found at 221 m above the present shoreline. Two *Mytilus* samples which were C^{14} dated at 9450±250 years b. p. and 9250±250 years b. p. (Holtedahl, 1960, p. 377) were from this raised beach. The height of the marine limit sinks northward, at Jessheim it is 208 m, at Hauerseter 205 m and at Minnesund 192 m above present-day sea level (Holtedahl, 1924), proving that a land elevation took place during the deglaciation. Also in the sourthern part of the Oslofjord area the highest shoreline is found at somewhat lower levels than in Oslo, about 200 m at Halden (Holmsen, 1951; cp. also Undås, 1950).

Øyen (i. a., 1903, 1915) established a system of Holocene *shoreline stages* based upon occurrence of certain littoral molluscs in shore deposits at certain heights above present sea level. He found the highest level, 221 m, to be characterized by *Mytilus edulis*.

In the area around Oslo the Holocene shoreline displacements have been investigated by pollen analysis (Hafsten, 1956, 1959, 1960). He found that the shoreline shifted from 221 m above present sea level to its present position without any positive oscillation. The isostatic component outrivalled the eustatic one during the whole epoch. But the displacement was much more rapid in the oldest part of the Holocene than in the younger. It decreased from 11 m/century in Pre-Boreal time to 0.37 m/century in Sub-Atlantic. Two thirds of the Holocene shoreline displacement had taken place before the beginning of Atlantic time.

Mollusc stratigraphy

Sars and Kjerulf (1861) and Sars (1865) studied the fossils of Late Quaternary marine clays and shell beds at several localities in the Oslofjord area. On the basis of their fossil content Sars divided the deposits into *Glacial* and *Postglacial* formations. The Glacial formation comprised the *Glacial shell beds* and the so-called *Mergellere* (Marl clay), the Postglacial formation consisted of the *Postglacial shell beds* and the *Muslinglere* (Mussel clay).

In the year of 1900–1901 Brøgger published a comprehensive paper dealing with the stratigraphy and paleoclimatic indicators of the Late Quaternary deposits in the Oslofjord area. Littoral deposits were divided into 6 shell beds and the clay sediments into 12 zones, on the basis of their content of fossil pelecypods (bivalves). A review of the shell bed system was given by the present author in 1963. Of greater interest for the present study is Brøgger's stratigraphical subdivision of the clay deposits: The oldest unit is the *Yoldia clay*, according to Brøgger deposited outside, i. e., to the south of, the Ra ridge. Its characteristic fossil is the thermophobeous species *Portlandia arctica* (=*Yoldia arctica*). This clay was subdivided into an *Older Yoldia clay* and a *Younger Yoldia clay*. The *Arca clay*, characteristic fossil *Bathyarca glacialis* (=*Arca glacialis*), was deposited as the ice front retreated from the Ra to the Ås–Ski moraines. This was subdivided into an *Older Arca clay* and a *Middle Arca- and Older Portlandia clay*. During continued retreat of the ice margin to the moraines of the Aker substage the *Younger Arca- and Portlandia clay* was deposited. During further retreat of the ice margin to the great lakes of Southeast Norway the *Youngest Arca- and Portlandia clay* was deposited, mainly in the Romerike district. The small pelecypode *Yoldiella lenticula* (=*Portlandia lenticula*) characterizes the two last-mentioned units. During improving climatic conditions the following units were deposited: The *Mytilus- and Cyprina clay*, characteristic fossils *Mytilus edulis* and *Arctica islandica* (=*Cyprina islandica*), the *Older Cardium clay*, the *Younger Cardium clay*, characteristic fossil *Cerastoderma edule* (=*Cardium edule*), the *Isocardia clay*, characteristic fossil *Glossus humanus* (=*Isocardia cor*). The Isocardia clay, deposited at Oslo during shift of the shoreline from 69 to 19 m above present-day sea level, was considered to represent the Post Glacial climatic optimum. In the 1900–1901-paper an *Upper Ostrea clay* was distinguished between the Younger Cardium clay and the Isocardia clay. In his later paper Brøgger (1905, p. 111, 124) discarded this term and replaced it with the older part of the subsequent Isocardia clay. The next unit, the *Scrobicularia clay*, characteristic fossil *Scrobicularia plana*, was thought to have been deposited during the shift of the shoreline from 19 m to 9 (8–10) m above present sea level at Oslo, thus representing the latest part of the Post Glacial Warm Interval (Brøgger, 1905, p. 98, 124). According to recent radiocarbon datings the climatic deteroration ending the warm interval, started 2400 years ago, and no part of the Scrobicularia clay should be younger than that. However, two shell samples from the Scrobicularia clay were recently dated at 2050±150 and 980±100 years before present. The final unit in this mollusc stratigraphy is the *Mya clay*, which is of Recent origin. Its characteristic fossil is *Mya arenaria*.

Previous mention of Foraminifera

The first record of Foraminifera in Late Quaternary sediments from the Oslofjord area was made by M. Sars in the year of 1865. Like many of his contemporary zoologists and paleontologists Sars had a broad and tolerant concept of the species unit. His names of the Foraminifera are therefore seldom in agreement with modern taxonomy. It would have been of interest to restudy his specimens in order to associate corresponding modern names to his old names. Unfortunately the writer has not been able to find Sars's collection of Late Quaternary Foraminifera in the museums of natural history in Oslo. However, from a restudy of Sars's collection of Recent Foraminifera from the coast of Norway, the author is able to suggest modern taxonomic equivalents to the old names for Sars's Late Quaternary specimens also. In the following lists the suggested names have been placed in parentheses behind the old name. Where no suggestion could be offered, a question-mark is put in brackets.

In the so-called Glacial formation, comprising Glacial shell beds and Marl clay, Sars found the following species: *Miliolina seminulum* Linné (=*Quinqueloculina seminulum* (Linné)), *Biloculina ringens* Lamarck (= *Pyrgo williamsoni* (Silvestri)), *Cristellaria rotulata* Lamarck (=*Lenticulina* (*Robulus*) *rotulata* (Lamarck)), *Truncatulina lobatula* d'Orbigny (= *Cibicides lobatulus* (Walker and Jacob)), *Discorbina turbo* d'Orbigny (?), *Polystomella crispa* var. *striatopunctata* Fichtel and Moll (=*Elphidium incertum clavatum* Cushman).

In the Postglacial formation, comprising Postglacial shell beds and Mussel clay, he found: *Spiroloculina limbata* d'Orbigny (=*Spiroloculina norvegica* (Cushman and Todd)), *Miliolina seminulum* (Linné) (=*Quinqueloculina seminulum* (Linné)), *Biloculina ringens* Lamarck (=*Pyrgo williamsoni* (Silvestri)), *Cristellaria rotulata* Lamarck (=*Lenticulina* (*Robulus*) *rotulata* (Lamarck), forma *cultrata* Montfort), *Polymorphina lactea* Walker and Jacob (=*Guttlina lactea* (Walker and Jacob)), *Bulimina presli* Reuss (= *Bulimina marginata* d'Orbigny), *Cassidulina laevigata* d'Orbigny (=

Cassidulina laevigata d'Orbigny), *Cassidulina laevigata*, var. *crassa* d'Orbigny (=*Cassidulina crassa* d'Orbigny), *Discorbina turbo* d'Orbigny (?), *Truncatulina lobatula* d'Orbigny (=*Cibicides lobatulus* d'Orbigny), *Planorbulina farcta*, var. *mediterranensis* d'Orbigny (=*Planorbulina mediterranensis* d'Orbigny), *Rotalia beccarii* Linné (=*Ammonia batavus* (Hofker)), *Polystomella crispa* Linné (*Elphidum macellum* (Fichtel and Moll)), *Polystomella crispa*, var. *striato-punctata* Fichtel and Moll (=*Elphidium incertum incertum* Williamson) or *E. i. clavatum* Cushman or both), *Nonionina depressula* Walker and Jacob (=*Nonion depressula* (Walker and Jacob) or *Elphidium subarcticum* Cushman or both), *Nonionina umbilicatula* Montagu (=*Nonion barleeanum* (Williamson)), *Nonion communis* d'Orbigny (=*Nonion labradoricum* (Dawson)).

Crosskey and Robertson collected marine soil samples from 9 localities in the inner part of the Oslofjord and in the vicinity of the city of Skien, in the western neighbourhood of the southern part of the Oslofjord area. The Foraminifera of these samples were identified by H. B. Brady, and the species not already listed by Sars (1865) were recorded in Crosskey and Robertson: "Notes on the Post-tertiary Geology of Norway" (1868). Like Sars's specimens these Foraminifera were not figured, and the writer has not studied the collection. The findings of Crosskey and Robertson are therefore given here with the old names only, quoted verbatim except for the succession; the species have been rearranged in accordance with Pokorný's system, which is followed in the present study:

Lituola scorpiurus Montfort, *Lituola canariensis* d'Orbigny, *Cornuspira foliacea* (?) Philippi, *Quinqueloculina agglutinans* (?) d'Orbigny, *Quinqueloculina bicornis* Walker and Jacob, *Quinqueloculina secans* d'Orbigny, *Quinqueloculina subrotunda* Montagu, *Triloculina oblonga* d'Orbigny, *Triloculina trigonula* Lamarck, *Biloculina depressa* d'Orbigny, *Biloculina elongata* d'Orbigny, *Nodosaria boueana* d'Orbigny (?), *Nodosaria pyrula* d'Orbigny, *Dentalina brevis* d'Orbigny, *Dentalina communis* d'Orbigny, *Dentalina consobrina* d'Orbigny, *Dentalina obliquestriata*, *Dentalina pauperata* Parker and Jones, *Vaginulina legumen* Linné, *Glandulina laevigata* d'Orbigny, *Lagena apiculata* Reuss, *Lagena distoma* Parker and Jones, *Lagena globosa* Montagu, *Lagena gracillima* Seguenza, *Lagena gracilis* Williamson, *Lagena laevis* Montagu, *Lagena melo* d'Orbigny (?), *Lagena striata* Montagu, *Polymorphina compressa* d'Orbigny, *Polymorphina horrida* Reuss, *Bulimina elegantissima* Williamson, *Bulimina marginata* d'Orbigny, *Bulimina aculeata* d'Orbigny, *Bulimina ovata* d'Orbigny, *Bulimina* *pupoides* d'Orbigny, *Virgulina schreibersii* Czjzek, *Uvigerina angulosa* Williamson, *Uvigerina pygmaea* d'Orbigny, *Cassidulina oblonga* Reuss, *Nonionina asterizans* Fichtel and Moll, *Nonionina scapha* Fichtel and Moll, *Nonionina turgida* Williamson, *Pulvinulina elegans* d'Orbigny, *Pulvinulina repanda* Fichtel and Moll, *Truncatulina refulgens* Montfort, *Planorbulina haidingerii* d'Orbigny, *Planorbulina ungeriana* d'Orbigny, *Rotalia orbicularis* d'Orbigny.

H. Kiær (1900, p. 52) published a list of six species from Sars's collection of fossil animal remains which were not listed by Sars. The present writer has not found this collection, but from examination of specimens in Sars's and Kiær's collections of Foraminifera from the coast of Norway, he suggests the following taxonomic equivalents to the old names:

Spiroloculina planulata (Lamarck) (= *Spiroloculina norvegica* Cushman and Todd), *Discorbina parisiensis* d'Orbigny (?), *Rotalia soldanii* d'Orbigny (= *Gyroidina neosoldani* Brotzen), *Pulvinulina karsteni* Reuss (= *Buccella tenerrima* Bandy ?), *Pulvinulina elegans* d'Orbigny (= *Höglundina elegans* (d'Orbigny)), *Gypsina vesicularis* Parker and Jones (= *Gypsina vesicularis* Parker and Jones).

Only two of these species are definitely found in the Oslofjord area, viz., *Pulvinulina elegans*, from Håøya (Hå Island) at Drøbak, and *Gypsina vesicularis*, from Kirkeøya (Church Island), Hvaler. The origin of the others is not indicated.

Kiær (l. c.) also inspected a collection of Foraminifera gathered by E. B. Münster in "post Tertiary" deposits chiefly in the neighbourhood of Skien, and published the following list:

Textularia williamsoni, Bulimina pyrula, B. elipsoides, B. marginata, Uvigerina angulosa, Lagena striata, L. marginata, L. williamsoni, L. sulcata, L. squamosa, L. hexagona, Discorbina globularis, D. obtusa, Rotalia beccarii, R. soldanii, Spiroloculina planulata, S. limbata, Biloculina elongata, Biloculina simplex, B. depressa, Nonionina umbilicatula, Polymorphina lactea, P. lactea, var. *fistulosa, P. compressa, Vaginulina linearis, Nodosaria communis, Gypsina vesicularis, Truncatulina lobatula, T. refulgens, T. coronata, T. akneriana, Polystomella striatopunctata, P. crispa, Pulvinulina puntulata, Nonionina scapha, N. depressa, Miliolina seminulum, M. oblonga, M. trigonula, M. bicornis, M. pulchella, Cristellaria rotulata.*

By *Textularia williamsoni* is probably meant *Textularia sagittula* Defrance; *Bulimina pyrula* is *Globobulimina turgida* (Bailey). Specimens labelled *Polymorphina compressa,* in Münster's material from the Tapes beds near Brevik (see later, p. 30) are all referable to *Sigmomorphina undu-*

losa (Terquem), this may also apply to the present record. It is interesting to see *Truncatulina coronata*=*Paromalina coronata* (Parker and Jones) recorded. I have not observed this large and beautiful species in any of my core samples. This is also the case with *Pulvinulina punctulata*=*Eponides punctulatus* (d'Orbigny). *Polystomella crispa* may probably be a misidentification of *Elphidium macellum*, and *Nonionina scapha* is probably *Nonion labradoricum*.

Furthermore Kiær (l. c., p. 53) examined the foraminiferal content of four clay samples collected by Brøgger. One of the samples was from Yoldia clay at Verlebukten, Moss. Kiær identified the following species in it (the writer has again not been able to see the specimens): *Virgulina squamosa* d'Orbigny, *Virgulina schreibersiana* Czjzek, *Cassidulina laevigata* d'Orbigny, *Cassidulina crassa* d'Orbigny, *Polymorphina rotundata* Bornemann, *Lagena sulcata* Walker and Jacob, *Lagena marginata* Walker and Boys, *Nonionina depressula* Walker and Jacob, *Nonionina scapha* Fichtel and Moll, *Polystomella striatopunctata* Parker and Jones var. *incerta* Williamson, *Miliolina seminulum* Linné, *Miliolina tricarinata* d'Orbigny, *Miliolina subrotunda* Montagu, *Biloculina simplex* d'Orbigny.

This list is published also by Brøgger (1900–1901, p. 33). The recorded *Virgulina schreibersiana* is probably identical with *V. loeblichi* Feyling-Hanssen, *Nonionina scapha* is *Nonion labradoricum* (Dawson), *Miliolina tricarinata* should most probably be referred to *Triloculina trihedra* Loeblich and Tappan and *Biloculina simplex* to *Pyrgo williamsoni* (Silvestri). Kiær reported *Polystomella striatopunctata* var. *incerta* to be frequent in the sample, I assume that this species should be referred to *Elphidium incertum clavatum* Cushman, even though Brøgger (l. c., p. 670) writes that Kiær informed him that some of the *P. striatopunctata* var. *incerta* of this sample should probably be referred to *Polystomella arctica* Parker and Jones.

Two of the samples were from the Younger Arca clay of Oslo, one collected at Svenengen, the other at Øvre Foss. The Foraminifera of the two samples, as identified by Kiær, are here listed together (Cp. Brøgger, 1900–1901, p. 161). The writer has not seen these specimens, but from examination of many core samples of corresponding age suggested modern taxonomic equivalents to some of the old names are given. The suggestions are entered parenthetically behind the old name:

Reophax nodulosus Brady, *Virgulina schreibersiana* Czjzek (*V. loeblichi* Feyling-Hanssen), *Virgulina squamosa* d'Orbigny (*V. schreibersiana* Czjzek ?), *Bulimina subteres* Brady (*Robertinoides* ?), *Bulimina ellipsoides*

Costa, *Cassidulina laevigata* d'Orbigny, *Cassidulina crassa* d'Orbigny, *Polymorphina* sp., *Cristellaria rotulata* Lamarck (*Lenticulina* (*Robulus*) *rotulata* Lamarck), *Lagena striata* d'Orbigny, *L. distoma* Parker and Jones, *L. gracillima* Seguenza, *L. marginata* Walker and Boys (*Fissurina*), *L. bicarinata* Terquem, *Nodosaria communis* d'Orbigny (*Dentalina inornata bradyensis* Dervieux), *Nodosaria calomorpha* Reuss (either *Dentalina ittai* Loeblich and Tappan or *D. drammenensis* Feyling-Hanssen), *Pullenia sphaeroides* d'Orbigny (*Pullenia osloensis* Feyling-Hanssen), *Nonionina scapha* Fichtel and Moll (*Nonion labradoricum* (Dawson)), *Nonionina umbilicatula* Montagu (a couple of specimens are recorded, may probably be *Nonion barleeanum* Williamson, which, however, does not normally occur in Late Glacial clays), *Polystomella striatapunctata* var. *incerta* Willamson (*Elphidium incertum clavatum* Cushman), *Miliolina oblonga* Montagu (*Triloculina oblonga* Montagu), *Miliolina seminulum* Linné (*Quinqueloculina seminulum* Linné), *Biloculina simplex* d'Orbigny (*Pyrgo williamsoni* (Silvestri) and probably also *Biloculinella inflata* (Wright)), *Biloculina elongata* d'Orbigny (*Pyrgo williamsoni* (Silvestri)). From Svenengen Kiær (1900, p. 53) also listed "*Cristellaria* sp., a young specimen", which may probably be identical with the form the present writer has called *Lenticulina* (*Robulus*) cf. *angulata* (Reuss).

The fourth sample was from the Post Glacial Isocardia clay, also collected at Svenengen. In this Kiær (l. c., p. 53) found: *Bulimina marginata* d'Orbigny, *Virgulina schreibersiana* Czjzek, *Virgulina squamosa* d'Orbigny, *Discorbina araucana* d'Orbigny, *Polystomella striatopunctata* Parker and Jones, and *Polystomella striatopunctata* var. *incerta* Williamson.

It is supposed that *Virgulina squamosa* in this sample represents *V. fusiformis* (Williamson) and that *Polystomella striatopunctata* var. *incerta* is the same as *Elphidium incertum incertum* (Williamson). Old samples from the coast of Norway show that neither Sars nor Kiær distinguished between the two subspecies of *E. incertum*, *incertum* and *clavatum*.

On page 436 in his comprehensive paper on the fossil mollusc fauna of Late Quaternary sediments in the Oslofjord area Brøgger (1900–1901) published a list of Foraminifera from a posthumous manuscript of E. B. Münster. Münster collected the specimens from *Upper Tapes beds* at four localities near Brevik, viz., Lunde, Rydningen, Jettegryten and Isdammen. These collections were stored in the Paleontological Museum of Oslo, and through the kindness of the director of the museum, Professor Dr. A. Heintz, I had the opportunity of studying and redetermining the specimens. In the following list my names are put in parentheses behind the original ones. The old succession is retained. Münster's collection from Upper Tapes beds near Brevik thus contained:

Nodosaria laevigata d'Orbigny (*Dentalina advena* (Cushman)), *Dentalina communis* d'Orbigny (*Lenticulina* (*Marginulinopsis*) *linearis* (Montagu)), *Polymorphina lactea* Walker and Jacob (*Globulina inaequalis* Reuss), *Polymorphina compressa* d'Orbigny (*Sigmomorphina undulosa* (Terquem)), *Polymorphina thoini* d'Orbigny (*Pseudopolymorphina suboblonga* Cushman and Ozawa), *Polymorphina horrida* Reuss (*Globulina inaequalis* Reuss, fistulose forms), *Nonionina foliacea* Philippi (*Cyclogyra foliacea* (Philippi)), *Nonionina asterizans* Fichtel and Moll (*Elphidium subarcticum* Cushman), *Polystomella striatopunctata* Fichtel and Moll (?), *Cristellaria calcar* Linné (*Lenticulina* (*Robulus*) *rotulata* (Lamarck), forma *cultrata* Montfort and *Lenticulina* (*Robulus*) *orbicularis* (d'Orbigny)), *Planorbulina nitida* d'Orbigny (*Rosalina vilardeboana* d'Orbigny), *Truncatulina lobatula* Walker and Jacob (*Cibicides lobatulus* (Walker and Jacob)), *Truncatulina refulgens* Montfort (*Cibicides lobatulus* (Walker and Jacob)), *Rotalia beccarii* Linné (*Ammonia batavus* (Hofker)), *Cassidulina laevigata* d'Orbigny (?), *Spiroloculina planulata* Lamarck (*Spiroloculina norvegica* Cushman and Todd), *Triloculina oblonga* Montfort (*Quinqueloculina seminulum* (Linné)), *Quinqueloculina lyra* d'Orbigny (*Quinqueloculina pulchelle* d'Orbigny), *Quinqueloculina ferussacii* d'Orbigny (*Quinqueloculina pulchella* d'Orbigny), *Planorbulina* sp. (?).

There was no specimen marked *Polystomella striatopunctata* in this collection, but there was a tube marked *Polystomella crispa*, which contained *Elphidium macellum* (Fichtel and Moll). *Cassidulina laevigata* and *Planorbulina* sp. were not found.

On page 520 Brøgger (1900–1901) published another list of Foraminifera from the same posthumous manuscript by Münster. These Foraminifera were collected by Münster from *Lower Tapes beds* at Smedholmen and Trosvik near Brevik. I have examined and redetermined these specimens also:

Lagena striata Montagu (*Lagena striata* (d'Orbigny)), *Lagena sulcata* Walker and Jacob (*Oolina williamsoni* (Alcock)), *Dentalina communis* d'Orbigny (*Lenticulina* (*Marginulinopsis*) *linearis* (Montagu)), *Polymorphina lactea* Walker and Jacob (*Globulina inaequalis* Reuss), *Polymorphina compressa* d'Orbigny (*Sigmomorphina undulosa* (Terquem)), *Polymorphina horrida* Reuss (*Globulina inaequalis* Reuss, fistulose forms), *Nonionina foliacea* Philippi (*Cyclogyra foliacea* (Philippi)), *Nonion asterizans* Fichtel and Moll (*Elphidium subarcticum* Cushman and *Cibicides pseudo-*

ungerianus (Cushman)), *Polystomella striatopunctata* Fichtel and Moll(?), *Cristellaria calcar* Linné (*Höglundina elegans* (d'Orbigny)), *Truncatulina lobatula* Walker and Jacob (*Cibicides lobatulus* (Walker and Jacob)), *Rotalia beccarii* Linné (*Ammonia batavus* (Hofker)), *Bulimina preslii* Reuss (*Bulimina marginata* d'Orbigny), *Uvigerina pygmaea* d'Orbigny(?), *Textularia sagittula* Defrance (*Textularia bocki* Höglund), *Biloculina ringens* Lamarck (*Pyrgo williamsoni* (Silvestri) and *Triloculina trigonula* (Lamarck)), *Biloculina depressa* d'Orbigny (*Biloculinella depressa* (d'Orbigny)), *Spiroloculina planulata* Lamarck (*S. norvegica* Cushman and Todd), *Triloculina trigonula* Lamarck (*Triloculina trigonula* (Lamarck)), *Triloculina oblonga* Montagu (*Quinqueloculina seminulum* (Linné)), *Quinqueloculina lyra* d'Orbigny (*Quinqueloculina bicornis* (Walker and Jacob) and *Q. pulchella* d'Orbigny), *Quinqueloculina ferussacii* d'Orbigny (*Quinqueloculina pulchella* d'Orbigny), *Planorbulina* sp. (?).

Neither in this collection was there any specimen marked *Polystomella striatopunctata;* there was one tube marked *Polystomella crispa* which contained *Elphidium macellum* (Fichtel and Moll), as in the previous collection. Another tube contained some specimens of *Gypsina vesicularis* (Parker and Jones).

In Münster's material, stored in the Paleontological Museum of Oslo, there are also two small collections of Foraminifera from Bislet in the city of Oslo, one marked "Bislet northerly", and one "Bislet southerly". The writer has reexamined the specimens, and as they have not previously been published, a list of the species which occurred is given. The two collections are treated together, and only my identifications are given:

Quinqueloculina seminulum (Linné), *Pyrgo comata* (Brady), *Pyrgo williamsoni* (Silvestri), *Lenticulina* (*Robulus*) *rotulata* (Lamarck), forma *cultrata* Montfort, *Lagena distoma* Parker and Jones, *Lagena mollis* Cushman, *Lagena laevis* (Montagu), *Globobulimina turgida* (Bailey), *Cassidulina crassa* d'Orbigny, *C. laevigata* d'Orbigny, *Nonion labradoricum* (Dawson), *Nonion barleeanum* (Williamson), *Cibicides pseudoungerianus* (Cushman), *Elphidium incertum incertum* (Williamson), *E. i. clavatum* Cushman.

Nothing is indicated as to the age of the deposits from which these specimens were collected. The fauna is Post Glacial.

From an ecostratigraphical point of view the present writer took up the study of Foraminifera in Late Quaternary marine clays of Norway in 1950, when a short article about Foraminifera and foraminiferal research appeared (Feyling-Hanssen, 1950). A subsequent quantitative study of the Foraminifera in a number of Late Quaternary clay samples mainly from Brøgger's classical collection from clay pits in the Oslofjord area, now in the Paleontological Museum of Oslo, revealed a primary result that sediments of Late Glacial age are readily distinguishable from Post Glacial sediments by a few dominant species among their fossil Foraminifera (Feyling-Hanssen, 1954 a). Late Glacial deposits, such as Yoldia clay and Arca clay, were found to be characterized by high frequency of *Elphidium incertum clavatum* together with *Cassidulina crassa,* whereas the Post Glacial Isocardia clay contains *Bulimina marginata* in abundance, usually together with *Elphidium incertum incertum.* This study represented an approach towards knowledge of the foraminiferal faunas corresponding to Brøgger's units Yoldia clay, Arca clay, and Isocardia clay. 65 species and subspecies of Foraminifera were recorded. A synopsis was published in the Inqua actes in 1955. In connection with a great quick clay slide which occurred at Bekkelaget, Oslo, in 1953, the foraminiferal content of two clay samples from the slide was analysed (Feyling-Hanssen, 1954 b). By this the clay samples were referred to corresponding units in Brøgger's mollusc stratigraphy on the basis of their foraminiferal content. Some diameter measurements of specimens of *Elphidium incertum clavatum* from the district of Romerike, northern part of the Oslofjord area, were also published in 1954 (Feyling-Hanssen, 1954 c).

The study of a selected number of core samples from the Oslofjord area made it possible, on the basis of Foraminifera, to subdivide Late Quaternary deposits into seven zones; the oldest one was called A, the youngest one G. These zones appeared to be of some importance for the solution of certain geotechnical problems, as a close correlation was detected between microstratigraphical units and geotechnical properties of corresponding parts of the cores. This was beautifully illustrated by the shear strength of the clays. In borings through homogenous sediments, which in spite of being homogenous showed discontinous variation of shear strength with depth, the breaks in the variation of shear strength occurred at the transitions between the stratigraphical zones. These observations were published in the paper "Micropaleontology applied to soil mechanics in Norway" (Feyling-Hanssen, 1957), in which the foraminiferal zones were presented and used, but only very briefly characterized. Vertical correlation charts for two borings in Oslo were also presented, and an approximate correlation of the micropaleontolocigal zones with Brøgger's molluscan zones attempted. That paper should have been preceded by the present one, which deals with the foraminiferal faunas characteristic of the foraminiferal zones. But from a geotechnical point of view it was thought desirable not to delay the publication of the micropaleontological–geotechnical results until this broader study of the Late Quaternary Foraminifera of the area was ready for presentation.

A synopsis of the 1957 paper appeared in 1958 (in Norwegian), and there the foraminiferal zones were again briefly recorded and some dominant and characteristic species mentioned and illustrated. In the paper "Mikropaleontologiens teknikk" (Technique of micropaleontology, Feyling-Hanssen, 1958 b) a simplified vertical distribution chart for the Late Quaternary of Oslo was presented. The microstratigraphical units C, D, E, F, and G were characterized by 14 common species of Foraminifera. In a shorter paper (Feyling-Hanssen, 1959 a) was recorded 8 species of Foraminifera from two borings at the outlet of the lake Storsjøen, 67 km northeast of Oslo centre. This is the northernmost certain finding of marine Late Quaternary fossils in the Oslofjord area. Holtedahl (1960, p. 387) mentioned the foraminiferal zones and recorded the most characteristic species.

Risdal (1962) studied core samples from the city of Drammen at the Dramsfjord, the western branch of the inner Oslofjord. He registered 68 different species of Foraminifera and recognized four of the abovementioned microstratigraphical zones there, viz., D, E, F, and G. He also confirmed the connection between shear strength variation and zone transitions, especially with the transition between zone E and D.

Material and methods

Samples

The procuring of subsurface samples for foraminiferal research is attended with great cost, and it is natural therefore that most investigations of this kind have been connected with practical purposes to which subsurface sampling by borings was a matter of necessity. The present study had no direct practical intention which could tempt any exploration company to finance the borings needed, and the present author was not in possession of grants for carrying out a boring programme.

However, by cooperation between the Norwegian Geotechnical Institute and the present writer, core samples from numerous borings, mostly through marine clay deposits, were placed at his disposal. An agreement came into exsistence by which the Geotechnical Institute currently provided the writer with core samples at 0.5 m interval of every boring they carried out. By this a considerable stock of core samples from many localities in Norway, and even some from foreign countries, were gathered without extra expence. Samples from a selected number of such borings in the Oslofjord area form the basis for the present study. Borings as well as samples are indicated in this treatise by the same initials and numbers which were given to them by the Norwegian Goetecnical Institute, so that it is always possible to trace a certain sample back to the archives of that institute if any additional information of its properties should be needed.

These core samples were procured with greatest care, all measures against contamination having been taken into account. But they were collected in connection with foundation and construction problems in clay, not for the purpose of a micropaleontological investigation of the marine sediments of the Oslofjord area. As a basis for the latter purpose the cores are heir to serious deficiencies:

(1) Some of the borings were carried out within the slide area of recently slid masses in order to investigate the cause of the slide. The stratigraphical value of such borings is limited because the original zonation of the sediment is usually disturbed.

(2) The location of the borings is on the whole not that which would have been desired from a micropaleontological point of view. They are concentrated within certain limited clay areas of industrial expansion or high building activity, such as the area near the issue of the river Glomma (Fredrikstad, Valle, Sarpsborg) and around the city of Oslo. A rich material is thus at hand from the outer, southern, part of the Oslofjord and from the inner part, around the head of the fjord. There is a third concentration in and around the city of Drammen, on the west side of the inner part of the Oslofjord. Within these regions the sampling is considered close enough to compensate for faunal variations which may be appreciable even within short lateral distances. There are good borings also at Sandefjord, on the west side of the outer part of the fjord, and at Moss and Halden on the east side. On the whole, a good and representative collection of core samples was at hand from the regions in front of the marginal moraines of the Ra substage and of the Aker substage. But the wide area between the Ra ridge and the moraines of

the Ås-Ski substage and the region north of the moraines of the Aker substage are poorly sampled by the Norwegian Geotechnical Institute.

(3) The sampling interval, i. e., the interval between the samples handed over to me, was with most of the borings 0.5 m, with some of them accidentally larger because all material in some parts of the cores were used for geotechnical experiments or measurements. 0.5 m sampling interval in many cases yield important stratigraphical information, and should be considered small enough, e. g., with thick zones without interzonal variation. But in other instances, specifically at the transition between different stratigraphical zones, a smaller interval would have been desirable. In fact, only continuous sampling should have given incontestable microstratigraphical results at the zone transitions. Unfortunately such sampling did not occur with the present material, except with boring no. 1 (F 226), Skøyen.

(4) The depth of some of the borings is not great enough from a microstratigraphical point of view. Most of them completely penetrated the unconsolidated Late Quaternary sediment and were not stopped until Cambro-Silurian or Archean bedrock was reached. They are fully satisfactory. But a few were stopped as they reached a subsoil with a shear strength sufficiently safe for foundation purposes. With these borings the earlier part of the Late Quaternary record, which would have been available in the locality, is lacking.

The samples for micropaleontological investigation were in most cases cut out of the cores as 3–4 cm thick transverse slices with a dry weight of approximately 100 g. They yielded usually 2 000–10 000 specimens of Foraminifera per sample. Statistical investigations by Schilder (Cp. Schindewolf, 1944) showed that 50 000 specimens were needed to obtain a certain record of all the species in a fauna with 60 species. Any further investigation of Late Quaternary marine sediments of the Oslofjord area will therefore augment the number of Foraminifera species here recorded. But the foraminiferal content of the present samples would seem sufficiently great to provide a practical and reliable picture of the corresponding fauna.

In order to compensate, to some extent, for the lack of material from the previously mentioned poorly sampled middle part of the investigation area, the writer turned to two other institutions, carrying out borings, with request for samples: The Veilaboratoriet (Road Laboratory) of the Norwegian Road administration in Oslo, through Civil engineer O. Flaate, provided me with core samples from Nesset (Nordby and Tohellinga), Årungen, Riser, Askim, Rakkestad (Klipper bridge), and Sande. The Norsk Teknisk Byggekontroll (Norwegian Technical Building Control), through its director, Civil engineer J. Friis, provided me with core material from Rakkestad (corn silo) and Holmestrand. From south of the Ra moraine the latter institute generously handed over to me a rich material from borings at Slagenstangen on the west side of the fjord, and from a third institution, the Geotechnical Laboratory of the Norwegian Railroads, I received core samples from borings at Onsøy on the east side of the fjord. Core material, stored in the Paleontological Museum of the University of Oslo (PM), from two older borings in the city of Oslo, one at the National Theater and one at Pilestredet, were placed at my disposal by Professor Dr. A. Heintz. Finally core samples from a boring at Lørenskog, northeast of the moraines of the Aker substage, carried out by Mr. J. Wilhelmsen of the Geological Survey of Norway (NGU), were investigated. With the borings from Rakkestad kornsilo, Holmestrand and Slagenstangen the sampling interval was 1.0 m.

The borings which have been micropaleontologically examined are listed below. The locality and its height above present sea level is given, furthermore the depth of the boring, its number and the number (and initials) of the project to which it belongs. The microstratigraphical zones recognized in the borings are also indicated, and if the deposit is known to have been disturbed, this is recorded under "remarks".

2500 core samples from 130 borings have been examined. In addition there are approximately 200 core samples from 9 borings in the city of Drammen, investigated by Risdal (1962), these borings are also on the list, but are marked with an asterisk. Most of the borings from the Oslofjord area are between 10 and 20 m deep. The deepest one, micropaleontologically investigated, reached 43.8 m (Sauøya, Halden), while another (Grønlandsleret, Oslo) reached 40 m. The southernmost borings are those at Sandefjord and Halden, the northernmost at Storsjøen in Odal. The borings are situated at different heights above present-day sea level, from 203 m above sea level at Jessheim, to 13.0 m below sea level at Slagenstangen south of Horten, and 21.9 m below at Herøya.

The location of the borings is indicated on the map (fig. 2) with filled rings. The accompanying numbers are the project numbers given to groups of borings by the institute who carried them out. Some places, e. g., in Oslo and Drammen, the borings are so numerous that not all of them could be plotted, because there was insufficient room on the scale used. They will appear in some large-scale detail sketches presented

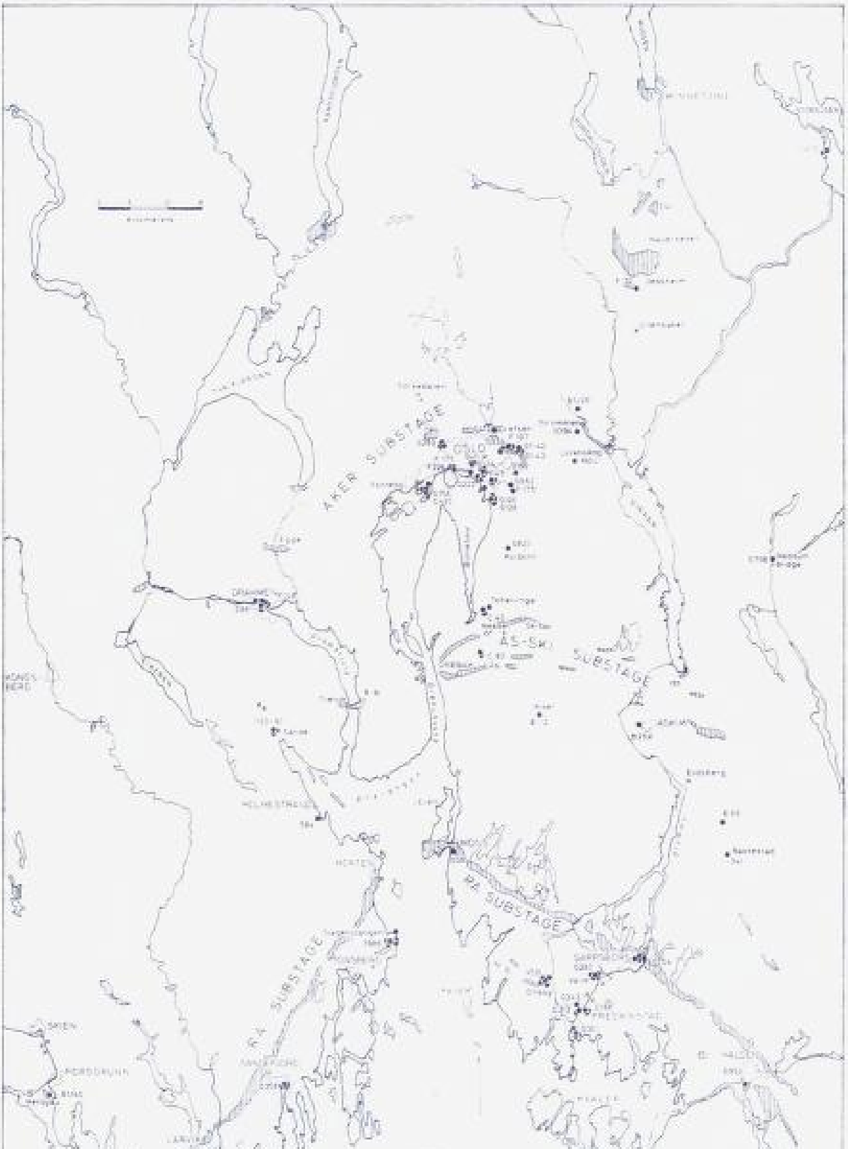


Fig. 2. The Oslofjord area. Borings are marked with filled rings, surface samples with crosses.

later in the paper. The map clearly illustrates that the core material at hand is insufficient for an exhaustive stratigraphical investigation of the whole Oslofjord area. Quite detailed understanding of the stratigraphy may be obtained for regions around Fredrikstad–Sarpsborg, Drammen and Oslo, where the sampling coverage is good. But the material for the rest of the Oslofjord area allows in most cases only a preliminary introduction to the problems, even though it may reveal important characteristics in the stratigraphical development of the whole area.

In addition to the core samples some 200 surface samples were micropaleontologically investigated. Only a few of them are plotted on the map, with an "*". The major part was collected by the author in different clay pits of the area, some of them were taken from classical collections in the Paleontological Museum of Oslo. Shells of megafossils from a few of these samples were dated radiologically (Cp. p. 154–174).

List of examined borings, arranged from north to south

Locality	Project number	Boring number	Heigth above sea level m	Depht of boring m	Foraminiferal zones present	Remarks
Storsjøen, Odal	0410	1	133.5	18.0	D	
—»—	»	3	133.0	16.0	D	
Jessheim	F 32	3	203.0	10.0	D	
Strømmen	0394	1	129.6	18.0	D	
Lørenskog	NGU	1	180.0	15.0	D	
Myrer, Oslo	0412	22	174.0	24.0	D	
Veitvedt, Oslo	01–43	2	153.0	6.5	D	
Linderud, Oslo	01–42	1	137.1	4.1	D	
—»—	»	1B	137.1	10.5	D	
—»—	»	2	137.7	10.6	D	
Brobekkveien, Oslo	01–41	1	119.0	13.0	C ? D	
—»—	»	2	119.0	10.4	C D	
Ryen, Oslo	0962	2	129.3	21.8	B_u C D	
Manglerud, Oslo	F 175	1	130.0	14.6	B_u C D	
Ulven, Oslo	0329	7	99.0	4.0	D	
—»—	»	22	99.0	7.0	D	
Brobekkveien/Ulven, Oslo	01–40	1	92.6	20.3	D E	
Brobekkveien, Oslo	F 107	1	120.0	11.0	D	
—»—	»	2	120.0	12.0	D	
Bryn, Oslo	0199	18	80.0	19.7	D	
Majorstuen, Oslo	0283	4	48.7	20.3	D F G	
—»—	»	1	48.4	18.8	D F G	
—»—	»	5	47.2	22.3	C D E F G	

Locality	Project number	Boring number	Heigth above sea level m	Depth of boring m	Foraminiferal zones present	Remarks
Lodalen, Konows gt., Oslo	F 45	1	25.0	14.0	D E F G	Disturbed
—»—	»	7	19.6	10.0	F G	»
—»—	»	2	18.2	22.8	C D E F G	»
—»—	»	3	16.3	12.8	D E F G	»
—»—	»	4	14.9	11.0	D E F	»
—»—	»	6	10.0	10.0	D E F	»
Pilestredet 48B, Oslo	PM	5	29.0	13.4	D E F	
Pilestredet 24, Oslo	0411	2	15.9	5.3	F G	
—»—	»	7	15.6	12.8	C D F	
—»—	»	4	14.7	10.5	E F G	Disturbed
—»—	»	10	13.9	10.3	C D E F	
Skøyen, Oslo	F 175	2	2.0	23.2	D E F G	
—»—	»	1	2.0	11.9	F	
—»—	»	E	2.0	11.7	F	
—»—	F 226	1	2.0	27.0	C D E F G	Upper part disturbed
Nationaltheateret, Oslo	PM	20	7.0	13.0	F	
Akerselva, Oslo	01–33	31	3.2	19.2	C D E F G	
Gunnerus gate, Oslo	01–14	4	2.6	24.0	D E F G	Disturbed
—»—	01–36	55	2.6	20.8	D E F G	
Grønland, Oslo	01–20	3	2.5	24.0	D E F G	
—»—	»	4	2.4	24.0	D F G	Disturbed
Grønlandsleret, Oslo	01–33	48	2.4	40.0	D E F G	Disturbed
Bjørvika, Oslo	0223	1	−7.0	14.0	D F G	»
—»—	»	2	−3.5	25.5	D E F G	Disturbed ?
—»—	»	4	−6.1	25.5	D E F G	
—»—	»	5	−7.1	11.0	F G	
—»—	»	6	−4.4	19.8	D F G	Disturbed
Grønlia, Oslo	0269	13	2.0	11.0	F G	
—»—	»	14	2.0	15.0	E F G	
Bekkelaget, Oslo	0100	1	5.3	12.4	C D E F_1	
—»—	»	5	8.6	11.6	C D E F G	
—»—	»	6	6.8	8.5	C D E F	
—»—	»	7	8.4	6.6	C D E F	
—»—	»	8	11.4	6.5	C D E	Disturbed
—»—	0126	1	−1.0	14.8	C D E F_1 G	
—»—	»	8	−3.4	15.0	C D E F_1	
—»—	»	9	−6.0	7.5	C D E	
Storøysund, Fornebo, Oslo	0420	5	−9.6	17.2	B_u C D E F G	
Storøymyr, Fornebo, Oslo	0700	1	0.8	13.8	C D E F	
—»—	»	F1	0.7	20.5	B_u C D E F G	
—»—	»	2	1.0	19.3	C D E F	
—»—	»	3	0.7	19.7	C D E F G	
—»—	»	4	0.7	8.8	D E F	
—»—	»	5	2.6	17.1	C D E F	
Kolbotn, Oppegård	0823	1	96.8	14.0	B_u C D E	
Naddum bridge, Høland	0708	2	140.0	19.3	Late Glacial	
Tohellinga, Nesset	C 13	3	c. 7.0	10.7	E F G	
Nordby, Nesset	C 43	297	c. 2.0	9.7	C E F	

Locality	Project number	Boring number	Height above sea level m	Depht of boring m	Foraminiferal zones present	Remarks
Årungen, Ås	C 63	1	26.4	13.5	E F	
—»—	»	2	31.0	13.0	F G	
Drammen	088	15	2.6	25.0	D E	
»	»	25	3.1	21.5	D	
»	»	27	–5.2	22.2	D	
Drammen	F 144	1	–8.0	15.3	D	
»	»	3	3.0	16.6	D	
*Turnhallen, Drammen	F 31	3	2.0	22.0	D E F G	
*Skoger Bank, Drammen	0267	1	2.0	37.0	D E	Low part
*Folkets hus, Drammen	0383	2	c. 2.0	21.0	D E F G	
*Gl. Kirkeplass, Drammen	0373	4	c. 2.0	23.5	D	
*Park Auto, Drammen	088	20	c. 2.0	27.0	D	
* —»—	»	21	c. 2.0	24.5	D	
* —»—	»	22	c. 2.0	19.0	D	
*Rosenkrantz gt., Drammen	0568	1	c. 2.0	20.0	D E F (G)	
*Drammen Slip, Drammen	0419	1	–1.2	20.0	E F G	
Askim	B 20A	2	130.0	9.9	A_u B_l B_u	
Riser, Hobøl	B 12	1	55.0	11.8	G	
Søndre Sandeelv bridge	1191	1	?	7.3	G	
—»—	»	2	?	15.1	F_u G	
—»—	»	3	?	14.0	F_u G	
Holmestrand	564	1	?	12.6	A_u B	
Klipper bridge, Rakkestad	B 09	3	100.0	12.0	B_l B_u	
Rakkestad silo, Rakkestad	341	1	103.0	17.0	A_u B_l B_u	
Verlebukten, Moss	038–2	10	28.0	16.5	A_u	
Borregaard, Sarpsborg ..	0204	1	17.0	16.2	A_m	Ra ridge
—»— ..	»	2	27.8	20.2	A_m	—»—
—»— ..	»	3	38.2	17.3	A_m	—»—
—»— ..	»	5	23.5	5.4	A_m	—»—
—»—	»	13	24.8	11.3	A_l A_m	—»—
Slagenstangen	3986	83b	25.2	21.3	A_l?	Moraine
»	»	250	25.8	16.4	A_l?	»
»	»	XIV	19.7	9.5	A_l?	Few fossils
»	»	186	14.5	27.4	No fossils	Moraine
»	»	350	28.0	9.7	A_l A_m	»
»	»	527	–13.0	11.6	A_u G	
Onsøy, Østfoldbanen ..	NSB	A	5.5	10.5	F_m F_u	
—»— ..	»	B	5.5	10.5	F_m F_u	
—»— ..	»	C	5.5	10.5	F_m F_u	
—»— ..	»	17	5.0	14.0	E F	Disturbed
—»— ..	»	21	3.3	18.0	A_m A_u E F G	
Valle by Sarpsborg	0287	22	17.6	23.8	A_m A_u B_l E F G	
—»—	»	27	9.1	7.6	A	
—»—	»	31	5.4	12.8	A_m A_u B_l E F_l	
—»—	»	1	–4.2	3.6	A	
—»—	»	13	11.6	14.7	A_u F	

Locality	Project number	Boring number	Height above sea level m	Depth of boring m	Foraminiferal zones present	Remarks
Valle by Sarpsborg	0287	46	-4.0	2.8	A	
Fredrikstad, profile A ..	0168	28	8.0	25.3	F G	East of river
—»— ..	»	26	1.8	18.3	A_m F_l F_u G	»
—»— ..	»	25	0.9	8.8	F_u G	»
—»— ..	»	24	1.5	19.8	A_m A_u B_l F_l F_u G	»
Fredrikstad, profile B ..	0313	2	2.0	26.0	A_m F_u G	West of river
—»— ..	»	5	-4.1	12.0	F_u G	»
Glemmen church, Fredrikstad	0343	3	6.7	6.8	F_u G	
Fredrikstad, profile C ..	F 31	1	2.4	20.6	A_m A_u F_u G	
—»— ..	0301	2	2.5	17.5	F_u G	0.301–3
—»— ..	»	4	-6.6	20.4	G	
—»— ..	»	5	1.8	18.6	G	
«DeNoFa», Fredrikstad	»	1	-6.4	16.0	G	
—»—	»	3	2.4	14.7	G	
—»—	»	7	-7.2	18.0	G	
—»—	»	13	2.5	21.8	F_u G	0.301–2
Sauøya, Halden	0953	1	-6.1	43.8	A_m A_u	Lower part only
Sandefjord.............	0358	1	0.9	28.0	A_u B_l E F G	
»	»	3	0.9	10.0	F_m F_u G	
»	»	5	0.9	36.0	A_m A_u B_l E F G	
Herøya	61/40	2	-21.9	26.0	A_u B_l F	Disturbed ?

Collection and disintegration

The samples provided by the Norwegian Geotechnical Institute, the Road Laboratory, and the Norwegian Technical Buliding Control were collected with a thin-wall stationary piston sampler with entrance diameter 5.4 cm. Its construction and use is described by Vold (1956). The sample tubes in which the samples were brought to the surface, are made of seamless stainless steel, polished inside. Their length is 80 cm or 100 cm. With this sampler it is possible to obtain undisturbed samples from depths as great as 25 m to 35 m even in the most sensitive clays (Bjerrum, 1954). In less sensitive clays samples can be taken from greater depth. In the laboratory the samples are pressed out of the tubes by the aid of a special aparatus. With continuous sampling in a bore hole the content of the successive tubes forms a complete core when 100 cm tubes are used; when 80 cm tubes are used, there is an interval of 20 cm between the tubes.

For foraminiferal analyses 3 cm to 4 cm thick transverse slices were cut out of the core at intervals of 50 cm. When collected in 80 cm tubes, which was most common, this sample interval was easily obtained by cutting out the slices 15 cm from each end of the tube. If sandy lamina accidentally occurred at these levels, the micropalentological samples were taken in finer-grained, usually clay, layers nearest 15 cm from the end of the tube. Sandy strata were always less fossiliferous than the clay. The samples were dried and, duly labelled, kept in plastic boxes until they could be subjected to further treatment.

The average dry weight of a sample of this kind was 100 g. Investigating, microstratigraphically, the Santon (Mesozoicum) of Lengede-Broistedt, between Hildesheim and Braunschweig in Germany, Hiltermann and Koch (1956) used rock samples which weighed 2 kg (2000 g) each. As a normal micropaleontological sample size Hiltermann (oral communication) recommends 0.5 kg–1.0 kg. He adds, however, that even samples of 10 g weight may yield unobjectionable stratigraphical results. The coring tube used by Höglund (1947) for his well-known Gullmar Fjord investigation and by Christiansen (1958) in the Drøbaksund of the Oslofjord, provided samples with dry weight up to 20 g (bottom surface), and the average dry weight of the North Atlantic submarine core samples studies by Phleger, Parker, and Peirson (1953) was 3 g.

The core samples received from the Geotechnical Labroatory of the Norwegian Railroads and some of the samples from the Norwegian Technical Building Control, a small percentage of the total sample mass here treated, were collected with piston samplers with entrance diameter 4.0 cm. The core samples from the boring at Lorenskog, carried out by the Geological Survey of Norway, were also 4.0 cm in diameter. As far as possible for the present study it was attempted to get samples with dry weight 100 g, only very few samples weighed less.

The dry clay or silty clay samples were treated as rock samples with the common micropaleontological laboratory technique which is now employed in approximately the same manner all over the world (Cp. i. a., Hecht, 1933; Schenck and Bradford, 1943; Wick, 1947; Bartenstein, 1954; Hiltermann, 1956 b; Feyling-Hanssen, 1958 a). They were crushed between the jaws of a hydraulic vice until no fragment was larger than 1 cm^3. It is experienced by a large number of micropaleontologists that this apparently rough treatment does in general not destroy the microfossils. Pressure breaks the sample along fissures and also mainly around the enclosed fossils, leaving the majority of them, even the most delicate forms, unbroken. It is possible, though not directly observed with the present study, that extremely long and loosely cemented arenaceous forms may suffer from the treatment.

For the purpose of further disintegration the sample was placed in a 2% to 5% solution of hydrogen peroxide (H_2O_2) for 10 to 15 minutes. The solution causes an energetic effervescence during which the sample fully disintegrates. The use of hydrogen peroxide for the purpose of disintegration was introduced, and exhaustively described, by Wick (1947); for rock samples he recommends a 10% to 15% solution. There is a possibility that delicate arenaceous forms are disintegrated during the H_2O_2-treatment.

Naturally, clay samples would disintegrate satisfactorily by simply being placed in water, and left there for a day or two, if the samples were undried. However, by crushing the dried sample and then treating it with hydrogen peroxide, it was completely disintegrated within a quarter of an hour, the fossils then being clean and freed from the matrix because the hydrogen peroxide also partly oxidized organic material.

Washing and separation

The fossils were separated from the clay and silt fraction of the disintegrated sediment sample by washing on two sieves, the screen of the upper one having openings of 1.00 mm, the lower one openings of 0.10 mm (approximately 150 meshes pro inch). The construction of the sieves allows the screens to be detached from the frames for cleaning (Bartenstein, 1954). The splitting into these two fractions seems to be sufficient (Bartenstein, l. c.). The upper sieve occasionally retains granules and shells, or shell fragments, of megafossils, e. g., pelecypods, whereas the lower sieve retains sand grains and microfossils in the fraction 1.00–0.10 mm. The fraction finer than 0.10 mm was discarded in the present study.

The possibility that certain Foraminifera are broken by the quite strong spray of water applied in the washing process was mentioned in the introduction (p. 14). In general the Foraminifera can bear the effect of the water jet.

On an early phase of this investigation the samples were split into three fractions by being washed on three sieves with mesh diameter

1.000 mm, 0.125 mm, and 0.060 mm (the latter with approximately 250 meshes pro inch). It soon became clear, however, that the bulk of the Foraminifera was retained on the 0.125 mm sieve. The small fraction, 0.125–0.060 mm, generally contained juvenile individuals and dwarf forms, and little was gained statistically and stratigraphically by also investigating this fraction. The result of the faunal analyses was, as a rule, only insignificantly altered by taking into account the smallest fraction. Two examples are presented here:

A Late Glacial clay sample from a clay pit at Korshavn, Hvaler, south of Fredrikstad, contained:

Species	Specimens on the 0.125 mm sieve	Percentage distribution on the 0.125 mm sieve	Specimens on the 0.06 mm sieve	Total percentage distribution
Nonion labradoricum	161	65.2	4	64.0
Elphidium incertum clavatum	49	20.1	5	20.9
Cassidulina crassa	26	10.6	1	10.4
Islandiella norcrossi	2	0.8	2	1.5
Cibicides lobatulus	4	1.6		1.5
Astrononion gallowayi	2	0.8		0.8
Angulogerina fluens	1	0.4		0.4

5.4% of the washed Foraminifera of this sample was retained on the 0.060 mm sieve.

A Late Glacial sample from Valle brickworks, near Sarpsborg, contained:

Species	Specimens on the 0.125 mm seive	Percentage distribution on the 0.125 mm sieve	Specimens on the 0.06 mm sieve	Total percentage distribution
Elphidium incertum clavatum	84	70.1	10	71.0
Nonion labradoricum	15	12.3	1	12.0
Cibicides lobatulus	6	5.0		4.5
Virgulina loeblichi	5	4.2	1	4.5
Cassidulina crassa	2	1.7	1	2.2
Islandiella norcrossi	2	1.7		1.5
Astrononion gallowayi	2	1.7		1.5
Elphidium incertum incertum	2	1.7		1.5
Pyrgo williamsoni	1	0.8		0.8
Bulimina marginata	1	0.8		0.8

9.8% of the washed Foraminifera was retained on the 0.060 mm sieve. In neither of these samples were there found in the small fraction any species which were not represented in the coarser.

Similar experience has been mentioned by several other foraminiferologists. Van Voorthuysen (1960, pt. 19) split his Dollart-Ems samples with Recent Foraminifera into four fractions:

1. 1.00 mm, with no Foraminifera.
2. 1.00–0.30 mm, with only few Foraminifera.
3. 0.30–0.15 mm, with Foraminifera in abundance.
4. 0.15–0.05 mm, with only juveniles and dwarf forms and additionally a good deal reworked Foraminifera from the Upper Cretaceous.

Walton (1955, p. 960) found by experiment that most of the Foraminifera (Recent Foraminifera of Baja California) were concentrated in the size fractions between 1.000 mm and 0.088 mm. The fractions above 1 mm contained Foraminifera attached to larger sediment particles, and those below 0.088 mm juvenile forms.

Phleger, Parker, and Peirson (1953) washed their North Atlantic submarine core samples on a sieve having openings of 0.074 mm (200-mesh sieve), but in their study only the fraction retained on a sieve with openings of 0.149 mm (100-mesh) was examined. Parker (1958) did the same with her eastern Mediterranean deep sea core samples, and Todd (1958) with her western Mediterranean samples. The fine sediment was washed from the samples through a sieve with 0.074 mm openings. Each sample was examined, but population counts (analyses) were made only from screened samples obtained by using a sieve with openings of 0.149 mm (Parker, 1958, p. 223. Cp. Glaessner, 1948, p. 39; King and Hida, 1957; Bradshaw, 1959). Madsen (1895 a) used for his study of Quaternary Foraminifera of Denmark a sieve with openings of 0.13 mm. Brotzen (1951) in his foraminiferal research of two Late Quaternary cores from Surte, near Göteborg in Sweden, discarded the fraction finer than 0.15 mm, and Buch (1955) discarded the fraction finer than 0.10 mm in his investigation of the 110 m deep boring through the Quaternary of Inder Bjergum, Denmark.

In accordance with these data, the finest sieve used in the washing process of the Late Quaternary samples treated here is one with openings of 0.10 mm, the fraction finer than 0.10 mm was discarded. With the comparatively large number of samples studied, it would have entailed a disproportionately large amount of time and resulted in unremunerative extra work to investigate a fraction finer than 0.10 mm.

Pokorný (1958, p. 14) recommended the use of sieves with openings of 0.08–0.06 mm, i. e., 0.02–0.04 mm finer than that used in the present study. With samples from a certain zone, viz., zone D in the northern part of the Oslofjord area, it would possibly have been of importance to examine a fraction finer than 0.10 mm, because a depauperate Foraminifera fauna seems to have developed on the fjord bottom at the corresponding time. In order to see if a comparatively larger amount of small forms are lost with zone D – samples, the core samples from the boring at Røiri, Lørenskog, were washed on three sieves with openings of 1.000 mm, 0.100 mm, and 0.074 mm, and all fractions counted. As with other samples the bulk of Foraminifera was retained on the sieve with openings of 0.100 mm, whereas a minor part occurred on the 0.074 mm sieve. This part was, however, quite large, e. g. 25% in the sample from core level 8 m, and in a very poor sample, core level 6 m, the fine fraction contained approximately 30% of the washed Foraminifera. By this latter sample there occurred also a considerable change in the result of the count when the content of the fine fraction was added, because there occurred two species in this fraction which were not represented in the coarse: The fraction 1.000–0.100 mm contained 53 specimens of *Elphidium incertum clavatum* and 2 of *Cassidulina crassa*, whereas the fraction 0.100–0.074 mm contained 25 specimens of *Elphidium incertum clavatum*, 1 of *Cassidulina crassa*, 1 of *Quinqueloculina stalkeri*, and 1 of *Nonionella turgida*.

This example shows that the result of a foraminiferal analysis may be to a considerable degree dependent on the fractions which have been counted. It is therefore emphazised as important in any study of Foraminifera faunas to give information of the kind of sieves used. Population counts of faunas obtained with sieves of different coarseness are not immediately comparable.

Many samples, after having been washed, contained so many mineral grains on the 0.10 mm sive that it would have been too time-consuming to separate the microfossils from the sand grains under the microscope. In such samples the microfossils were concentrated by the use of the heavy liquid carbon tetrachloride (CCl_4). The washed and dried sample was simply placed in a beaker and the liquid poured over it, whereafter the floating Foraminifera were decanted from the mineral grains and filtered through a funnel.

Some specimens of Foraminifera were filled with secondary pyrite. Many of these would, after separation with the heavy liquid, be found among the mineral grains and not among the fossils. In this way the separation may have an undesired effect on the statistical result of the subsequent analysis (Cp. Triebel, 1947). However, with the Late Quaternary material studied, the risk of having the analyses seriously disturbed is small, because only few of the Foraminifera, as observed in samples not subjected to heavy liquid separation, were filled with pyrite.

Examination and plotting

The fossils were studied under the binocular microscope on a so-called extraction tray, the black base of which is divided into squares by white lines. There are holes made through the tray at every intersection of the lines (Triebel, 1938; Bartenstein, 1954). A cardboard slide is placed under the stage of the microscope so that the open cell of the slide is situated under a corresponding hole in the stage. The washed and dried, in most cases also separated, residue was poured in a single layer on the extraction tray so that all objects were clearly outlined against the black background. A fossil is transferred from the tray to the slide simply by dropping it through any one hole in the bottom of the tray within the actual microscope field, it will then fall through the hole in the stage down into the cell. The fossils were picked up with a steel needle. During the analyses, all counted specimens were usually transferred to faunal slides which are kept as faunal references to the corresponding samples. Figured specimens are kept in separate slides. All reference material is stored in the Paleontological Museum of the University of Oslo.

In each sample which was examined in detail, 200–600 specimens were counted. Usually not less than 300 specimens were counted, while in a few samples more than 1000 were dealt with (Cp. Walton, 1955, p. 993). In poor samples the entire content of Foraminifera was counted, in rich ones only a part of it. Total populations, exclusive of the small forms not retained in the 0.10 mm sieve, were then estimated by extrapolation (Cp. Phleger, 1960, p. 33–35). Occurrences of species were usually listed as percentages of total counted populations. With samples which contained less than 100 specimens, however, occurrences of species were listed simply as the actual number of specimens of each. Specimens of Thecamoebina, which occurred occasionally, were counted with the Foraminifera, and the presence of Ostracoda and Mollusca and echinoid remains was recorded.

The statistical record of Foraminifera (and Thecamoebina) was transferred to *range charts*, one for each boring investigated. The range chart shows the vertical distribution and abundance of the different species throughout the boring, thus clearly illustrating the faunal changes which occur. Symbols, indicating percentage frequency of specimens of each species, were used for plotting the counts on the charts. Explanation of the symbols is given in some of the charts. Usually *percentage* symbols were used exclusively in the charts. From some borings, however, there occurred one or more samples with few Foraminifera, less than 100 specimens per sample. The *number* of specimens were plotted directly for these samples.

On the basis of the range charts the cores were subdivided into vertical units according to range and frequency of certain species. This zonation is indicated with capital letters and different hatching in the column to the left of the species record of the chart. To the left of that column there is a simple lithologic-granulumetric record of the core, mainly based upon observations by the staff of the Norwegian Geotechnical Institute.

The foraminiferal species found in the samples from a boring are arranged mainly according to their first appearance in the core. This was necessary to have the faunal changes at different depths visualized as clearly as possible. An arrangement, e. g., according to the last appearance in the core would be almost impossible and of little value because emigration of species with time is much less characteristic with the present material than immigration. Species with simultaneous first appearance were arranged systematically, but not without exceptions, however. It was attempted to maintain the same arrangement of species from chart to chart as far as possible.

To the right of the species record the *number* of different *species* per sample is plotted in the form of a diagram, and on the extreme right the *number* of *specimens* per sample (Cp. discussion by Walton, 1955, p. 992).

On the basis of the range charts established, two simplified visual charts were constructed, one for the northern part of the Oslofjord area, and one for the southern part. They illustrate zonation by the vertical distribution and frequency of a few important species which occurred in most of the investigated borings. These standard charts served as practical keys to the stratigraphy as, on a later phase of the present investigation, a number of cores were subject to a reconnaissance study, in order to have them subdivided into zones.

Aniseed oil was applied to the specimens in order to make internal structures of the Foraminifera visible. This simple and effective method was first described by Bock (Cp. Höglund, 1947, p. 18). The composition of the test wall was in some cases checked by the use of hydrochloric acid or examination under a polarizing microscope. The photographs for the plates were taken by the Faculty Photographer O. Brynildsrud, who used a lens with 28 mm focal length and two strong projection lamps.

Paleoenvironment

Position

The present Oslofjord, which is the greatest fjord of Southeast Norway, forms a wedgelike northward branch of the Skagerrak, 100 km long and about 25 km broad in the southern, outer, part. It extends from Latitude 59° 0′ N. to 59° 55′ N., and from Longitude 10° 15′ E. to 11° 10′ E. The entrance of the fjord is broad and open, but between 60 km and 70 km from the sea it narrows in the Drøbaksund which is only about 2 km broad. The city of Oslo lies at the hook-shaped northern end of the fjord, and the city of Drammen at the head of the narrow Dramsfjord, a western branch of the Oslofjord. A number of rivers issues into the fjord, the two largest ones being the Glomma, debouching at Fredrikstad in the southeastern part of the fjord, and the Drams River, draining into Dramsfjord. The total area of the present fjord is approximately 16 km^2.

The Late Quaternary maximum extension of the fjord according to observations of the upper marine limit (Cp. Holmsen, 1951, 1954; the present paper, p. 23), was considerably greater. Approximately 9500 years before present, at a rough estimate, it probably had an area of 100 km^2, i. e., 6 times that of the present fjord. Approximately 84 km^2 of this area is now raised above sea level. The marine sediments of Late Quaternary age, partly covering this previously drowned land, were mapped by several geologists over many years. A collective representation was compiled by Holmsen (1951 and 1954), on two sheets, in the scale 1:250 000, Oslo and Oppland. Maps of the outcropping bedrock of the area, Archean to Permian, were compiled by Brøgger and Schetelig in 1923 and by Holtedahl and Dons in 1952.

Brøgger (1886) found that the Oslofjord was originally formed along fault lines and later glacially sculptured. Størmer (1935) assumed that these faults were of Late Mesozoic or Tertiary age, at least in the southern part of the area.

Depth

The submarine topography of the present Oslofjord is well known, and has been discussed by a number of investigators, i. a., Brøgger (1886), Størmer (1935), Braarud and Ruud (1937), Sundene (1953), Christiansen (1958). The water depths over a greater part of the fjord are less than 100 m. Smaller areas with depths of approximately 150–160 m are found near the head of the fjord as well as in the middle part of the Dramsfjord. In the narrow Drøbaksund there are depths slightly exceeding 200 m. East of the city of Tønsberg the depth reaches 360 m, and southwest of the Hvaler islands the bottom slopes steeply to 400 m.

Sills separates the fjord into different basins. The entrance to the fjord is partly barred by the 120 m deep Ferder sill. The Jeløy sill, between Horten and Moss, is 110 m deep, whereas the Drøbak sill, separating the sound of Drøbaksund from the inner part of the Oslofjord, is only 19.5 m deep (Beyer, 1956). There is, finally, a 50 m deep sill dividing the inner, bent part of the fjord into a western part, the Vestfjord, and an eastern, the Bunnefjord.

The Late Quaternary marine limit at Oslo is, as already mentioned, 221 m above present sea level. The deepest core sample from Oslo is the lowest sample of boring no. 48 of Grønlandsleret, depth 40 m. The present surface at this boring is 2.4 m above sea level. Provided this sample was from a sediment in situ, the greatest depth at which the Foraminifera of that sample can possibly have lived is 258.6 m. The deepest sample of the boring belongs to the foraminiferal zone D. A rapid land uplift, or negative shift of the shoreline, seems to have taken place during deposition of sediments belonging to that zone. The earliest zone D-deposits may well correspond to the highest position of the shoreline. However, as the underlying zone was not reached by the boring mentioned, the sample discussed may well represent a later phase of zone D-time with a corresponding smaller water depth in the locality.

A boring at Sauøya, Halden, had its surface 6.1 m below present-day sea level and reached 43.8 m, i. e., 49.9 m below present sea level. Shore formations, probaly representing the upper marine limit, have been observed in the vicinity of Halden at different heights, from 175 m at Tistedal to 190 m at Enningdal (Holmsen, 1951). If the deepest Sauøya core sample, which belongs to the microstratigraphical subzone A_m, if not of a redeposited sediment, and if subzone A_m corresponds to the highest measured shoreline, the Foraminifera of the said subzone once lived at a depth of approximately 240 m in this locality.

In consequence, none of the foraminiferal populations recorded in the present paper inhabited greater depths than approximately 250 m.

On the other hand, some of the populations from zone G may, in living condition, have inhabited very shallow water, some of them probably in the inter-tidal zone.

Circulation

The surface water of the present Oslofjord moves comparatively freely in accordance with the prevailing winds (Braarud and Ruud, 1937; Braarud, 1945; Sundene, 1953). Northerly winds during wintertime push the surface layer outwards in the inner parts of the fjord so that water from deeper layers can move to the surface. This causes an inward running compensation current in deeper layers, so that renewal of the bottom water in the inner parts may take place, at least to some extent. During summertime predominant southerly winds force the surface layer inwards.

The bottom water of the fjord, on the other hand, is divided into more less isolated and stagnant masses by the already mentioned sills in the bottom topography. Especially is this true of the water masses in deeper parts of the basins north of the Drøbak sill. During the past decades the conditions there have been worsened by steadily increasing sewege pollution from the city of Oslo. The ventilation is at a minimum and the water is poisoned by the presence of hydrogen sulphide (Beyer and Føyn, 1951; Braarud, 1955; Christiansen, 1958; Føyn, 1958). The water in deeper parts of the outer basins of the fjord may probably communicate quite freely with the water of the Skagerrak. Comparatively strong currents must occur in the narrow Drøbak sound, the only connection between the inner and outher basins of the fjord. These currents may have been capable of moving empty tests of Foraminifera, and probably living faunas (Cp. Christiansen, 1958, p. 24).

At some time in the past, probably towards the end of Late Glacial time, as the shoreline at Oslo was situated 221 m higher than to-day, the fjord was broad and open, and greater areas were drowned under well areated water. During the subsequent lowering of the shoreline previously well ventilated parts of the fjord were in many places changed into more or less land-locked bays or inlets, badly ventilated, some of them finally turning into fresh-water lakes. The actual occurrence of lakes in the area to some extent illustrates these conditions. At certain stages during the period of land rise it is theoretically possible to have water masses in certain parts of the corresponding fjord basin more or less trapped. Such trapped water masses would probably, in the course of time, yield faunas which, compared with the normal marine-climatic development in the area, give delayed paleoclimatic indications.

During the rapid Pre-Boreal retreat of the front of the inland ice in the Oslofjord area, the fjord was supplied with large amounts of fresh melt-water originating both from icemelting in the fjord and from regional surface melting inland. Because of its lower specific weight this water normally kept to the surface on its outward flow, and created an outward directed surface current; since drag between the fresh-water and the fjord-water caused the surface layer of the fjord-water to move outwards as well. In addition, outwards directed katabatic winds, which frequently occur at the front of glaciers during the melting period, increased the force of the outfjord flow of surface water (Liestøl, personal communication). Again, this would cause an inwardly directed reaction current along the bottom, or at least in deeper layers. A vertical exchange may in this way have taken place, water from deeper parts having been brought to the surface in front of glaciers or by the issuing of melt-water streams into the fjord (Cp. Sandström, 1905; Hessland, 1943; Emery and Stevenson, 1957). An inward bottom current created in this way would cease towards the end of the summer because, ordinarliy no melting takes place in the winter (Ryder, 1895, Cp. Ussing in Thorson, 1934, p. 16).

On the other hand, it is possible that the enormous Pre-Boreal melt-water supply created extensive turbulence in the corresponding Oslofjord so that a vigorous intermixing of water strata occurred. Investigations on animal communities near river mouths in East Greenland, carried out by Thorson (1933, p. 63–65), showed that bottom dwelling animals were absent immediately off the river mouths, from the shore line down to at least 38 m depth. At 100 m distance from the river mouth, however, vast number of animals were found in the samples. Thorson ascribed the absence of animals on the fjord bottom immediately in front of the river moths to the effect of fresh water, even at depths of 40 m. The ice of the large rivers of East Greenland break up while the fjord is still covered by unbroken ice. The fresh-water which is emptied into the fjord is forced in under the ice at an enormous pressure, and may probably be pressed towards the bottom. The presence of fresh-water at the bottom, even for only 3–4 days annually, would be able to kill all animal life there. Thorson (l. c., p. 65) assumed that this effect would be traceable even at greater depths.

Another possibility of fresh melt-water being able to affect the bottom fauna of the fjord even at considerable depth is provided by the sediment load. De Geer (1912, p. 250) claimed that sediment-laden melt-water flowed along the bottom at least when entering glacial lakes. Kuenen (1951) discussed to what extent such underflow or turbidity current takes place in fresh, brackish, and salt water. The poorly populated zone D-sediments in the northern parts of the Oslofjord area may be at least partly explained by the effect of turbid melt-water.

Tidewater currents are of minor importance in the present-day Oslofjord because the ordinary difference between high and low tide is small. The role of tidewater currents in the Late Glacial Oslofjord is unknown.

Temperature

Great importance is generally attached to the water temperature as ecological factor. Thorson (1936, p. 144) concluded his extensive study of the larval development and metabolism of Arctic marine bottom invertebrates as follows: "there seems to be a great probability that the characteristic composition of the bottom faunas of the Arctic, the Antarctic, and the deep seas and the biological features common to them can be explained by the influence of a great number of different ecological conditions, all of which are either caused by or act through the same main factors, viz. the low temperature alone, or through this low temperature in connection with the poor food conditions". Phleger (1960, p. 108) summarized the result of the hitherto meagre experimetal data on temperature effects on Foraminifera as follows: "1. Temperature is effective in controlling the viability and repopulation of some Foraminifera. 2. Certain species of Foraminifera are able to withstand extreme temperature ranges, especially those forms which are adapted to environments where extremes are normal. 3. Different species have different temperature tolerances."

The annual variation of surface temperatures of the present Oslofjord is considerable. For the year 1933–1934 Braarud and Ruud (1937, p.12) found the temperature range at 1 m depth in the Bunnefjord, the innermost part of the Oslofjord, to be 21.63° C (22.16° to 0.53° C.) At the same level in the outer part of the fjord, at Rauer, the annual temperature range for the same period was 19.35° C (20.23° to 0.88° C). Eggvin (1944, p. 66) found the mean yearly temperature amplitude for the years 1935–1940 at 4 m depth to be 17.4° C in the inner Oslofjord and 18.4° C at Ferder, at the very mouth of the fjord. In 1941 the temperature range in the inner Oslofjord was 20.2° C and at Ferder 20.1° C (l. c., p. 64). Sundene (1953, p. 17 and fig. 7) calculated the monthly mean surface temperature for the period 1.6.1950 to 1.7 1951 at Ferder. The temperature range there for that year was 17.5° C, with a minimum in February, 0.7° C, and a maximum in August, 18.2° C. In sheltered parts of the fjord ice is formed in the winter and surface temperatures of more than 20° C reached in the summer. At 1 m depth the temperature is always above 0° C, at 25–30 m the minimum temperature is 4–5° C.

The surface layer, characterized by this great variation in temperature is approximately 40 m thick, in the summer it may be only 25 m thick or even less. The waters below this surface layer show very small changes in temperature. At depths of 40 m to 150 m in Bunnefjord the temperature range in the year 1933–1934 was 0.77° C (6.98° to 6.21° C). At a depth of 200 m at Rauer the temperature range that year was 1.17° C (6.90° to 5.73° C). There is a transition zone between the surface layer and the deeper waters, no sharp limit. Irregular changes also occur as the surface layers are moved by the winds.

In the deepest part of the Skagerrak the temperature is always between 5° and 6° C (Christiansen, 1958, p. 9).

Beyer (1956, p. 1050) presents a diagram of temperature measurements from surface to 140 m depth in the Bunnefjord, innermost part of the Oslofjord, during the period July 30th, 1946 to January 16th, 1947. The the surface temperature at the end of July was 19.6° C and the maximum effect of the previous winter's cooling was still found at only 25 m depth, where the temperature was 4.5° C. At depths of 70 m and deeper there was a temperature of 6.7° C. The very slow penetration of the cooling is explained by the rapid increase of salinity with depth. The surface water with its comparatively low salinity (p. 62) is never cooled sufficiently to raise convection streams. In this way the surface layer is effectively separated from the deeper water masses. –

During a greater part of Post Glacial time the temperature conditions of the Oslofjord were presumably not essentially different from those described above. The Post Glacial Warm Interval temperatures were certainly somewhat higher than the present, Brøgger (1900–1901, p. 650 a) compared the climate of the Oslofjord area during the deposition of the Isocardia clay and the Scrobicularia clay with that of North England and Scotland. But distribution and annual variations were probably approximately conformable with the Recent, only somewhat shifted towards higher temperatures. This must have been essential for the composition of the foraminiferal benthos communities. Stenotherme species, species which cannot bear great temperature variations, must be assumed to have inhabited deeper parts of the fjord bottom, up to depths of 40 m, probably 25 m, whereas eurytherme species would be able to live and breed also on the shallowest, in most cases coast-nearest, parts of the bottom. –

Recent temperature conditions exactly comparable with those which prevailed in the Late Glacial Oslofjord (Late Pleistocene and Early Holocene) are impossible to pick out because so many interacting factors are unknown, e. g., nothing is known about the main trend of the corresponding circulation in the Oslofjord, assumptions replace observation.

The 100 km long Isfjord in Spitsbergen, situated between Latitude 78° 3′ N and 78° 50′ N and between 13° 0′ E and 17° 20′ E, is in greater parts shallower than even the present Oslofjord, and is separed from the Arctic Ocean in the west by an almost 10 km broad shelf with depths approximately equal to the main depth of the fjord, no tresholds divide the fjord into separate basins there. In consequence the hydrological conditions in the fjord are strongly influenced by the Atlantic Spitsbergen current, which is a branch of the Gulf Stream, and the cold Spitsbergen Polar current, both running northwards along the west coast.

In figure 3 is given diagrams compiled from two series of temperature measurements at the mouth of the Isfjord, carried out by Nansen, in 1912, one series on July 21st (Station 10) and one on August 24th (Station 44, Nansen, 1915, p. 108, 114). The surface temperature on July 21st was 4.80° C. At 50 m depth the temperature was negative, —0.55° C, at 100 m it was —0.42° to —0.43° C, but at 200 m again positive, +0.37° C. At 300 m and 400 m it was slightly above +1° C. On August 24th a considerable cooling of the surface water had taken place, the temperature at 0 m depth being 0.80° C. In 5 m depth, however, the temperature was 1.02° C, and at 10 m 1.59° C. Negative temperatures were measured at 100 m, —0.16° C, and at 200 m, —0.12° C.

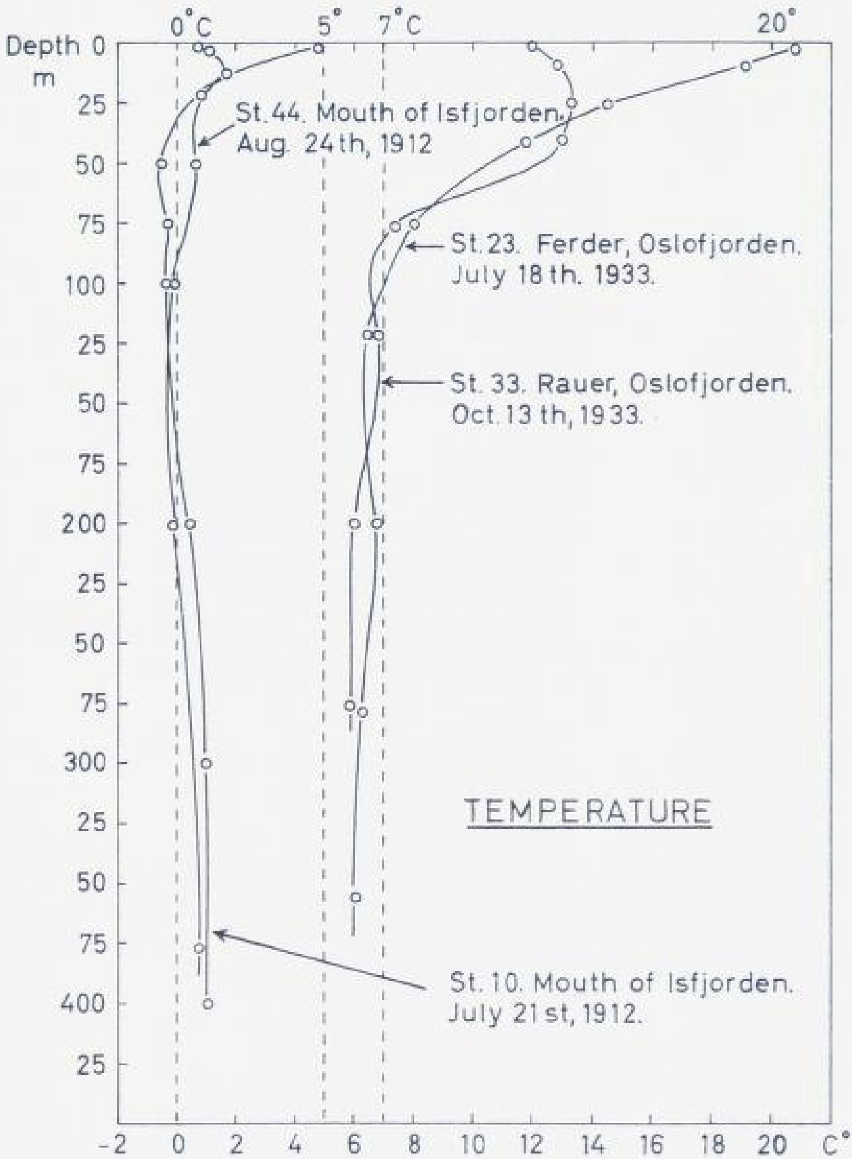


Fig. 3. Temperature distribution in the outer part of the Isfjord in Spitsbergen and in the outer part of the Oslofjord.

For the purpose of comparison figure 3 also contains diagrams for two series of temperature measurements from the outer part of the Oslofjord, recorded by Braarud and Ruud (1937, p. 46, 48), one series (St. 23, Ferder) measured on July 18th and the other (St. 33, Rauer) on October 13th, both in the year 1933. Even though these observations were made 21 years later than Nansen's measurements in the Isfjord, they may serve as a gross illustration of the difference in temperature conditions in the two fjords. The surface temperature at Ferder on July 18th, measured at 1 m depth, was 20.79° C, i. e., almost 16° C higher than at the mouth of the Isfjord on July 21st. In 75 m depht, however, the temperature at Ferder was 8.04° C whereas in the Isfjord (St. 10) it was —0.41° C at that depth, i. e. the difference was 8.45° C. At 100 m the difference in temperature between the two fjords was approximately 7.42° C, at 200 m 6.47° C (6.84°–0.37° C), at 300 m 5.30° C.

Figure 4 illustates the temperature conditions farther infjord, outside the mouth of the Adventfjord in the Isfjord (St. 46, Nansen, 1915, p. 114) and in Breiangen in the Oslofjord (St. 32, Braarud and Ruud, 1937, p. 47). The measurements in the Isfjord were made on August 26th, 1912. The measurements in Breiangen were made later, on October 11th, 1933. In the surface layer, down to 25 m, the temperature was up to

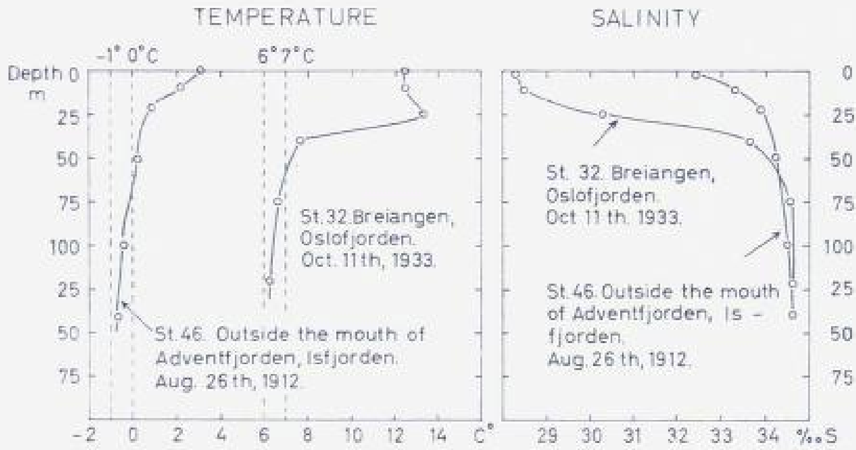


Fig. 4 Fig. 5

Fig. 4. Temperature distribution in the Adventfjord, a branch of the Isfjord, and in Breiangen, the outer middle part of the Oslofjord.

Fig. 5. Salinity distribution in the Adventfjord and in Breiangen of the Oslofjord.

12.5° C higher than in the Isfjord at corresponding depths. At greater depths, down to 120 m, the temperature difference between the two stations was approximately 7° C. Temperature measurements from the Isfjord during the winter are, unfortunately, not available.

At the time of the Ra stage the Oslofjord was represented by a wide embayment bordered by an immense continous ice wall calving into the sea. A very slight approximation towards an analogous situation may be found where the Polar current influences the waters of the Storfjord on the east side of Vestspitsbergen. This area extends northward from Latitude 77° 15′ N to 78° 40′ N between Vestspitsbergen and the islands Barentsøya and Edgeøya. Considerable ice fronts calves into this wide fjord, but its hydrography is insufficiently known. In August, 9th–11th, 1925, Brotzky (1930, p. 49) measured water temperatures at different places there at depths from 51 m to 163 m. They were all negative, —0.97° C at 51 m, —1.85° C at 163 m depth; these represented also measured extremes.

When the front of the inland ice rapidly retreated northwards in the Oslofjord area, enormous masses of cold fresh-water gushed into the fjord, certainly influencing the temperature of the fjord water. Intervals with stagnant glacier fronts, however, e. g., the time of the Ås–Ski substage, or especially the time of the Aker substage when glaciers extended their tongues down into the open fjord, may have exhibited temperature distributions in the corresponding fjord with at least some similarity to Recent conditions in some of the Spitsbergen fjords.

The summer temperatures below 50 m depth in Spitsbergen fjords vary roughly between —1° and +1° C. The temperatures in these deeper layers are probably not very different from this also during the winter. At corresponding depths in the Oslofjord they vary between 6° and 8° C. Phleger (1942, p. 1083) found by his investigation of samples from the continental slope between Chesapeake Bay and Long Island on the North American east coast a marked difference between the composition of the Foraminifera faunas in waters with temperatures above 4° to 6° C and those in waters with temperatures below this limit. Even if this limit should not be of the same importance in the Oslofjord of the past, a certain difference between the faunal composition of Late Glacial and Post Glacial deposits would be expected in consequence of the temperature differences between the waters of the corresponding stages of the fjord development.

Because of the greater temperature fluctuations in the upper layers of

Spitsbergen fjords than in the deeper parts, stenotherme species, as is the case in more temperate fjords, could be assumed to avoid the shallower bottoms. Similar conditions would be expected in the Late Glacial Oslofjord. But the amplitude of the temperature variations in the upper layers of Arctic fjords is most probably considerably smaller than the present-day, and Post Glacial, variation in the upper layers of the Oslofjord. The winter temperatures in the Spitsbergen fjords are not recorded, but Nansen (1915, p. 26) supposed that a rapid formation of ice in the autumn, protects the underlaying water from extreme cooling to some extent. The Norwegian North Polar Expedition 1893–1896 (Nansen, 1902, p. 78–101) recorded surface water temperatures in lanes or water holes in the ice of the Polar Basin. The temperature ranged from —1.95° to +2.63° C during the year. It is probably permissible, therefore, to assume that the faunal differences, caused by varying water temperature, between Late Glacial deposits from shallow water and Late Glacial deposits from deeper water are not as pronounced as with Post Glacial sediments.

Detailed investigations of hydrography and animal ecology in Scoresby Sound and the Franz Joseph Fjord districts in East Greenland (Spärck, 1933; Thorson, 1933, 1934, 1936, 1950; Madsen, 1936) provide some support to these assumptions.

Ryder (1895, cp. Thorson, 1934, p. 10) found three different water layers in Scoresby Sound: an upper layer, few metres thick, formed during the summer with positive temperatures; an intermediate layer with negative temperature underlay this; and finally, at depths below 300–400 m, a layer with again positive temperatures. The temperature distribution on July 22nd, 1933, in the middle part of Scoresby Sound, station 6, is shown diagramatically in figure 6, and is compiled from data given by Ussing (in Thorson, 1934, p. 11). In the same figure is also drawn the temperature curve for station 14, at the inner part of the fjord, measured on August 22nd, 1933. A similar temperature distribution was found in the Franz Joseph Fjord, but there the surface layer attained greater thickness, up to 25 m and even more.

The average surface temperature of these East Greenland fjords during the summer was 2.5° C. The intermediate layer, down to 300–400 m, had temperatures between 0° and —1.7° C, whereas in the deep layers temperatures between 0° and +1.7° C were measured. In October the surface layer with positive temperatures disappered, having cooled to the same temperature as that of the underlying intermediate layer. Simul-

Fig. 6. Temperature distribution in Scoresby Sound in East Greenland.

taneously ice formed, and towards springtime this was 2 m thick or more. The fjord ice broke up towards the beginning of July (Thorson, 1936, p. 10).

The marine-climatic conditions in the East Greenland fjord district are approximately equal to those of eastern Spitsbergen, whereas the conditions in the western part of Spitsbergen as less severe (Cp. Thorson, 1936; Mosby, 1938).

As to the Late Glacial climates of the Oslofjord area, Brøgger (1900–1901) did not in any detail evaluate the water temperatures corresponding to the different fossil mollusc faunas which he discovered in the Late Quaternary clay deposits there. In concordance with the tendency of his time, concerning paleoenvironmental discussions, he was more interested in the depth indications of his faunas. He agreed with Torell's assumption (Torell, 1887, p. 434) that the fauna of the Yoldia clay, with dominant occurrence of *Portlandia arctica* (Gray) and *Macoma calcarea* (Chemnitz), lived in water with temperatures between 0° and —2° C (Brøgger, l. c., p. 54). He compared (l. c., p. 650 a) the climate of the Oslofjord area at the time when the Older Yoldia clay was deposited with the present-day (1900–1901) conditions in the Kara Sea area. During the sedimentation of the Younger Yoldia clay and the Older Arca clay the climatic conditions were similar to those of western Spitsbergen and western Novaya Zemlya, whereas those prevailing during deposition of the Arca- and Portlandia clay units were compared with present-day climatic conditions of Finnmark (Brøgger l. c., p. 202–204).

The number of marine-ecological investigations has been considerably augmented since Brøgger wrote his comprehensive study. Comparing his Late Glacial faunas with the animal communities described from Greenland (Spärck, 1933; Thorson, 1933, 1934, 1936, 1950; Madsen, 1936) and Spitsbergen (i. a., Odhner, 1915; Idelson, 1930; Gurjanova, Sachs, and Uschakov, 1925; Brotzky, 1930) it is evident that the mollusc fauna of the Yoldia clay, and also of the older parts of the Arca clay, would find optimal environmental conditions within the districts of northern East Greenland mentioned above, as well as within the Spitsbergen area.

As to the temperature observations in the Spitsbergen waters it is of some importance to know that Mosby (1938, p. 54) demonstrated an increase in temperature to have taken place between the years of 1912 and 1931 in the northern part of the Hinlopen basin, between Vestspitsbergen and the Northeast Land. The temperature of the intermediate layer, 50 m to 200 m depth, was there about 1.5° C higher in 1931; in the bottom layer 200–400 m depth, it was about 1.0° C higher. Similar increase may probably be tracable also in other parts of Spitsbergen.

Salinity

The salinity distribution of the present Oslofjord exhibits similarities to the temperature distribution. The water is distinctly stratified, especially in the summer, with low salinity in the surface layer and saltier water below (Braarud and Ruud, 1937). In the uppermost 2–3 m the salinity varies during the summer between 14 ‰ and 24‰, at 25–30 m depth the salinity is about 32‰ in the summer, increasing towards the winter as the fresh-water supply from the rivers decreases. During winter the salinity varies in the surface layers between 20 ‰ and 30 ‰. At greater depths in the outer parts of the fjord, 200 m and more, the salinity is approximately 35 ‰ or slightly more.

In the deepest parts of the Skagerrak, outside the Oslofjord, the salinity is invariably above 35 ‰. This salinity is due to the heavy Atlantic water which streams into the Skagerrak through the deep Norwegian Channel. The same water masses also constitute the deep layers in the Ferder basin and also in the large basin which extends northwards to Moss–Horten (Braarud and Ruud, 1937, p. 18, 19). Occasionally Atlantic water crosses the Jeløy sill and penetrates into the deepest part of the Drøbaksund. Christiansen (1958, p. 14) found that Atlantic water may have a marked influence on the Foraminifera fauna in the Drøbak area. North Sea water, with salinity ranging between 34 ‰ and 35 ‰, is found above the deep layers in the Skagerrak. During the summer this water is somewhat diluted by intermixture with surface water, partly from river discharge, so that in the autumn the salinity is about 32 ‰–34 ‰ (Hjort and Gran, 1900; Kobe, 1934). North Sea water is quite common as far north as Drøbak. And long periods of prevailing northerly winds may, by inducing a deep water reaction current as mentioned above, bring this salt water even over the Drøbak sill and into the inner basins of the fjord. This happens only very occasionally (Beyer and Føyn, 1951). Baltic water with salinity below 32 ‰, probably between 25 and 30 ‰ (Sundene, 1953, p. 22), exists as an up to 20 m thick surface layer in the Skagerrak during the summer. This is replaced during the autumn and the winter by saltier water from the Jutland current.

The factors controlling the varying salinity of the surface water in the

Oslofjord are 1) the inflow of surface water from Skagerrak, 2) the fresh-water supply from the rivers, 3) the temperature of the water, 4) the North–South component of the wind (Sundene, 1953, p. 36).

The great increase in salinity with depth, usually greatest between 10 m and 25 m, constitutes an effective horizontal barrier against convectional vertical water exchange, especially in the inner basins of the fjord. The brackish surface water cannot be cooled sufficiently enough to overcome the greater specific weight of the saltier water below.

If salinity, or marked salinity variation, has an effect on the distribution of Foraminifera, the characteristic salinity conditions of the Oslofjord would be expected to be distinctly reflected in the composition of the Rencent faunas. Stenohaline species would not be able to inhabit the shallower bottoms of the fjord, whereas euryhaline forms would be able to live at all depths as far as they were not hindered by other critical factors. Species exclusively adapted to brackish water would be expected on the shallowest bottoms or in more or less land-locked pools and basins. Similar conditions must be expected to have influenced the fossil Foraminifera faunas from Post Glacial deposits of the Oslofjord area. Higher position of the shoreline certainly reduced the importance of some tresholds which in the present fjord bottom play an important role in circulation and salinity distribution, especially the innermost basins. It is also possible that increased evaporation from the fjord surface during dry parts of the Post Glacial Warm Interval raised the salinity to some degree, this effect probably being supported by decreased fresh-water supply from the rivers. However, the main trend in salinity distribution was presumably not greatly different from that of the present-day. Estimation of the influence of these conditions on the Late Glacial faunas, on the other hand, must take into account also the common salinity distribution in Recent Arctic fjord environment.

The salinity distribution at the mouth of the Isfjord in Spitsbergen, observed on July 21st, 1912 (Nansen, 1915, Station 10, p. 108) is presented, as a curve, in figure 7, together with the distribution at Ferder at the mouth of the Oslofjord. It appears that below a surface layer with low salinity, rapidly increasing with depths, the water masses show salinities between 34.45 ‰ and 34.83‰. The diagrams illustrate only moderate differences both in salinity distribution and salinity values between the two stations, except that the difference in salinity between surface water and deep water is greater at the mouth of the Oslofjord than at the mouth of the Isfjord. Nansen found that the intermediate water layer of

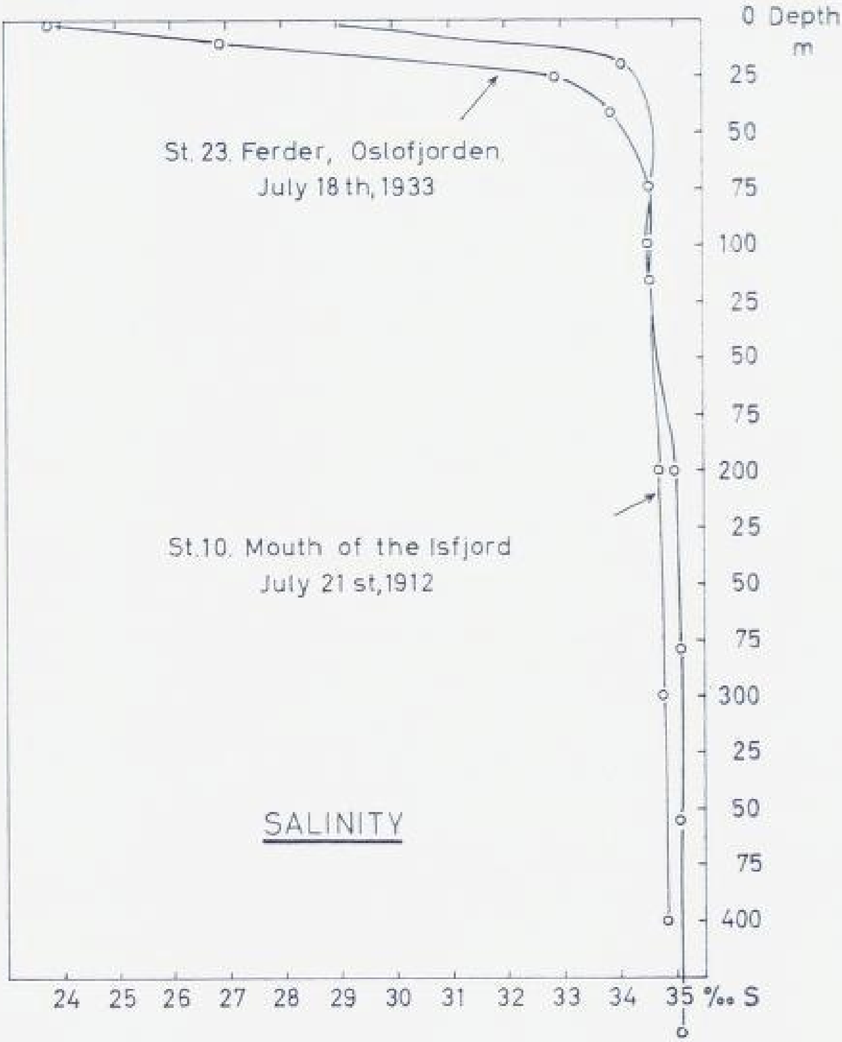


Fig. 7. Salinity distribution in the outer part of the Isfjord in Spitsbergen, and in the outer part of the Oslofjord.

the Spitsbergen fjords, with temperatures below zero, had salinities between 34.35 ‰ and 34.65 ‰, whereas the underlying strata, with positive temperatures, had salinities above 34.65 ‰. In the Sassenfjord, inner part of the Isfjord, Hjort measured, on July 27th, 1901 (Helland-

Hansen and Nansen, 1912, p. 56) a salinity of 30.77 ‰ at 0 m depth, 33.69 ‰ at 25 m, 34.38 ‰ at 50 m, and 34.50 ‰ at 80 m depth. In the Bunnefjord, the innermost part of the Oslofjord, the surface salinity over a period of 6 years varied between 18.4 ‰ and 29.8 ‰ whereas at 100 m depth it varied only between 32,8 ‰ and 33,8 ‰ during the same 6 years (Beyer, 1956, p. 1049). Also in the inner part of the fjords the salinity variation with depth is thus less pronounced in the Isfjord than in the Oslofjord. In consequense the stratification of the water masses with regard to salinity is less pronounced in the Isfjord station than in the inner Oslofjord.

This feature is considerably changed during the melting period of the sea ice on Arctic fjords. Thorson (1933, p. 17; 1936, p. 10, 86) recorded salinities of 3–4 ‰ at a depth of 3 m at Ellaø (Ella Island) in the Kong Oscar Fjord, East Greenland, during two weeks at the end of May. Madsen (1936, p. 45) stated that this effect on the tidal zone lasts for one month or even longer. He furthermore emphasized that the ice in the interior of the fjords melts almost entirely before breaking up.[1] Salinities, lethal to many species of Foraminifera, thus must be expected on the shallowest bottoms of Arctic fjords for periods long enough to kill all specimens of these species. Bradshaw (1961, p. 95) determined the lethal salinities for four shallow-water species from California on the basis of 12 hours exposures: 50 % of a population of *Bolivina vaughani* Natland was killed at a salinity of 7 ‰, 100 % at 3 ‰; 50 % of a population of *Massilina* sp. was killed at a salinity of 10–7 ‰, 100 % at 7 ‰; 100 % of the *Spirillina vivipara* Ehrenberg died at 7 ‰. The emphatically euryhaline subspecies *Ammonia beccarii tepida* (Cushman) had a lethal salinity of less than 2 ‰, but it ceased to reproduce at salinities below 15 ‰.

In addition to the dilution of the surface layer of the fjord water by melting sea ice, considerable quantities of fresh melt-water is carried into the fjords by the rivers during the melting period. This water is, as previously mentioned, often pressed down below the still unbroken fjord ice, and may thus influence deeper layers than would be expected when considering only the specific gravity of the fresh water in relation to that of the salt water (Thorson, 1933, p. 63–65; 1936, p. 87).

The salinity of the intermediate water layer in the fjord districts of northern East Greenland is 32.30–34.80 ‰, whereas the deep layers,

[1] The effect of the ice-foot upon the littoral was summarized by Feyling-Hanssen (1953).

with positive temperatures, have salinities of 34.60 ‰ to 34.95 ‰ (Thorson, 1936, p. 9).

Nansen (1915, p. 32) found that the salinity of the surface water of the Lilliehöökfjord in Spitsbergen rapidly increased towards the calving front of the Lilliehöök Glacier at the head of the fjord, being remarkably high, 34.20 ‰, at a distance of 100–200 m from the Glacier wall. This may be explained as an effect of reaction currents bringing bottom water of high salinity to the surface in front of glaciers during their melting periods. Hessland (1943, p. 47) supposed that the surprisingly rich marine animal life in front of glaciers is explained by this upstreaming saltier water which is probably rich in nutrients.

Similar conditions most probably prevailed in the Late Glacial Oslofjord during intervals with practically stagnant glacier fronts. At these times a "normal" flow of fresh-water occurred from the glacier ice during the melting periods, simultaneously creating inflow of water with high salinity along the fjord bottom. The benthonic, and epiphytic, Foraminifera fauna may in this way have been offered reasonable ecological conditions even close to the glaciers. The Late Glacial faunas contemporanous with the time of the Ra substage, the Ås–Ski substage, the Aker substage may very well reflect quite favourable, though Arctic, environment even in deposits close to the corresponding moraines.

However, during periods when rapid retreat of the ice margin took place, the hydrography was not necessarily so. There are in the Oslofjord area, as well as in many other parts of Norway, obvious indication of huge melt-water flow during Pre-Boreal time (i. a., Holtedahl, 1924). The possibility exists that this "abnormal" fresh-water supply to the fjord took place in such a way that a considerable decrease in salinity was felt even at comparatively deep bottoms. The melt-water drainage for a great part took place subglacially (Gjessing, 1960; Marthinussen, 1961), so that the fresh-water may have entered the fjord not at the surface but at some depth and under pressure. The turbulence, thus created, may have brought about such an intermixture of salt and fresh water that brackish conditions prevailed throughout the water masses even at considerable distance from the glacier fronts. The possibility of the sediment load of the melt-water having created underflow, or turbidity current, should also be taken into account. The foraminiferan benthos faunas inhabiting the fjord during retreat of the ice margin from the Ra to the Ås–Ski position, from the Ås–Ski to the Aker moraines, and especially those inhabiting the inner fjord regions when the ice melted away from the moraines of the Aker substage, may have been influenced by cold, brackish and turbid water. The melt-water certainly played a greater role in the narrower and shallower inner ramifications of the corresponding fjord.

Food

Little is known of the food requirements and food substances of Foraminifera. Myers (1943), who studied the influence of food in natural populations of *Elphidium crispum* (Linné), found that growth and reproduction in this species parallelled closely the phytoplankton cycle in the sea. Bradshaw (1961, p. 96) writes: "They (the Foraminifera) have been reported to feed upon a wide variety of food substances, including decaying vegetation, diatoms, flagellates, algal gametes, filamentous algae, organic debris, copepods, and bacteria." Phleger (1960, p. 111) regards diatoms and flagellates as the most important nutrient constituents. In his own laboratory experiments Bradshaw (l. c.) used a green flagellate for food, and he states that suspended organic matter, such a plankton, is of little value for benthonic Foraminifera until it settles out on the bottom. As a result of experiments on the effect of different concentrations of food upon growth rate and reproduction interval of *Ammonia beccarii tepida*, Bradshaw (l. c., p. 98) found that these activities appeared to increase with continuous addition of food, at least to a maximum value of 530 cells per square millimetre supplied in the experiments. He did not determine the effect of food concentrations higher than this, but assumes "that a large excess of food might be deleterious because of the high bacterial concentrations that occur when food decomposes."

In the present Oslofjord the plankton production is extraordinarily high, especially in the inner parts where the surface layers are fertilized by the sewage discharged into the fjord (Braarud and Ruud, 1937; Braarud and Føyn, 1951; Birkenes and Braarud, 1952). In the phytoplankton there is a maximum production of diatoms during March, *Thalassiosira* and *Lauderia* being the predominant genera, whereas peridinials of the genera *Ceratium* and *Prorocentrum* predominate in September. (Gaarder and Gran, 1927).

In the Post Glacial Oslofjord, before the water was contaminated by man, a normally rich plankton production is to be assumed. Lankford (1959, p. 2094) found that the deltaic marine assemblage of Foraminifera in the Gulf of Mexico was characterized by its very large standing crop.

In spite of the rapid sedimentation the number of Foraminifera per sediment unit might in that environment be many times larger than on the open shelf where sedimentation rates were considerably less. The reason for high foraminiferal productivity in areas influenced by river discharge is not known, but Lankford assumes that concentration of nutrients and trace elements from the soils of the drainage may be important. A certain part of the supply of organic matter, directly serving as food for bottom animals or secondarily by fertilizing, and thus increasing, the plankton production, is thus derived from the land. Considering the many river effluents in the inner ramifications of the Oslofjord, it seems permissible to assume a relatively rich supply of food in corresponding parts of the fjord throughout the entire Post Glacial.

The plankton production in the Skagerrak, outside the fjord, may vary considerably. Birkenes and Braarud (1952, p. 21) tentatively concluded that occurrence of huge populations of the coccolithoporid *Coccolithus huxleyi* resulted from a favourable combination of the presence of a relatively rich population in the Skagerrak and strong inflow of these waters into the fjord during spring and summer.

In Arctic fjord regions, approximately comparable with the Late Glacial Oslofjord, the food conditions are different. Thorson (1934, p. 57, 58) found richer animal communities (molluscs and polychaetes) in the Scoresby Sound fjord complex, and greater weight per square metre of the bottom in shallow water than in greater depths. He explained this by the larger content of food in the shallow water along the coasts than in waters of greater depths. The producers of organic matter in such an environment, the phytoplankton and the benthos vegetation, are almost exclusively limited to small depths. A similar decrease in the benthos fauna was found with increasing distance from the open sea (Thorson, l. c., p. 58). The shallow-water faunas were "far more luxuriant and weightier near the open sea than in the interior of the fjords." The distance from the open sea seems to be of essential importance for the amount of nutrients supplied to the benthos fauna. Spärck (1933, p. 18) recorded larger amount of organic matter in bottom samples from the outer part of the Franz Joseph Fjord, north of Scoresby Sound in East Greenland, than in samples from inner parts of the fjord. The content of organic matter was on the whole only about 10 % of that found in Danish coastal waters.

These observations verify what would reasonably be expected, viz., that only a very small part, if any, of the supply of organic matter is derived from the land in an Arctic environment. The coastal lowlands carry only a very scanty vegetation and the hinterland is covered with ice and snow.

In addition the phytoplankton[1] production which in East Greenland is limited to a period of only 1–2 months, is, specifically in the inner parts of the fjords, hindered by low transparancy of the water (Thorson, 1936, p. 10, 93). In the month of August, especially, the surface water there may be gray or milky white because of large amounts of glacial mud carried into the fjord by the melt-water. Similar conditions prevail in the fjords of Spitsbergen, e. g., the Isfjord (Cp. Feyling-Hanssen, 1953, p. 26), and is certainly of great ecological importance. The light is to a serious degree prevented from penetrating into the water, and the possibility of photosynthesis, necessary for the phytoplankton production, is brought to a minimum. Extremely dissatisfactory food conditions are in this way created in the inner reaches, or other branches, of the fjords where large glaciers, or glacier rivers, descend into comparatively narrow basins. The fjord water may there be entirely covered with opaque, muddy melt-water. As far as this situation is not compensated by food-bearing reaction currents along the bottom, these inner parts of the fjords offer extraordinarily unfavourable conditions for animal life. For similar reasons Stainforth (1952, p. 43) found that turbidity was probably the factor which controlled the abundance of arenaceous Foraminifera in ancient sediments in Trinidad.

An additional consequence of this turbidity of the water is that rocks and stones even up in the tide-water zone are always slippery with mud and thus rendered unservable as substratum for sessile forms (Feyling-Hanssen, 1953, p. 26).

It can easily be imagined that nutrient conditions similar to those mentioned above, prevailed at certain parts and at certain developmental stages in the Late Glacial Oslofjord. The sediments of the foraminiferal zone D in the northern parts of the Oslofjord area may have been deposited in exceptionally turbid water.

Oxygen

Hjort and Gran (1900) determined the content of oxygen in water samples in the Oslofjord and found that it was normal at Ferder, somewhat below normal in the deep basin at Rauer, still less at Rødtangen,

[1] The main constituents of the phytoplankton in the fjords of northern East Greenland seem to be the diatoms *Chaetoceras furcellatus, C. contortus, C. decipiens, Nitschia frigida, N. seriata,* and *Fragilaria oceanica* (Thorson, 1936, p. 85).

and less than 1 cc oxygen/liter was found in deeper parts of the Dramsfjord and the Bunnefjord. In the narrow Drøbaksund Gaarder and Gran (1918; 1927) measured oxygen contents corresponding to 77 to 115 % of saturation at the measured temperatures. Braarud and Ruud (1937) confirmed by their investigation of 1933–1934 the presence of well ventilated waters south of the Drøbaksund, the lowest oxygen content measured was 4.72 cc/l corresponding to 69.1 % of saturation. In April 8.25 cc/l was measured at 10 m depth at Ferder, corresponding to 104.1 % of saturation. At 40 m depth the oxygen concentration was 6.40 cc/l (91.1 %) but at 400 m still 6.50 cc/l (94.3 %).

In the inner part of the Oslofjord, and also in the Dramsfjord, where the renewal of the bottom water is severely hampered by shallow sills in the bottom topography, oxygen values down to zero were registered. The degree of stagnation in these inner basins is increased by the previously mentioned sewage pollution from the cities of Oslo and Drammen (Strøm, 1936; Braarud and Ruud, 1937; Braarud, 1945; Beyer and Føyn, 1951; Braarud, 1955; Beyer, 1956; Føyn, 1958). The large amount of organic matter discharged into the fjord with the sewage intensively increases the plankton production. When the plankton organisms die, they consume oxygen during the decaying processes. The consequence is total lack of oxygen in the deepest parts of the inner fjord. The present bottom there seems to be totally devoid of animal life.

Such a strong effect of human contamination on the plankton production and with that upon the oxygen concentration of the fjord water did not occur in Post Glacial time. The higher positions of the shoreline during the Holocene epoch entailed on the whole better circulation and better ventilation, even though localized basins with stagnant water certainly occurred from time to time during the continuous negative shift of the shoreline. It is also worth mentioning that Sjöstedt (1922) by his investigations in Øresund and the southern Baltic found that the oxygen content of the contact water, i. e. the water in contact with the bottom, in many cases was 0 cc/l even if it was 4 cc/l 10 cm above the bottom. The foraminiferal benthos fauna lives in the contact water and may thus be exposed to considerably lower oxygen tension than would be expected from general hydrographical records of oxygen concentrations in the basins dealt with.

At a relatively high oxygen concentration the rate of consumption caused by the respiration of a single specimen of *Ammonia beccarii tepida* was found to be independent of the oxygen concentration (Bradshaw, 1961).

But below a concentration of 1.21 cc/l (temperature 26.0° C) the rate of consumption became dependent upon the concentration. The corresponding partial pressure is termed the critical oxygen tension and is an index of ability to survive in environment of low oxygen (l. c.). Very few determinations of this value are available at the present time. Except for the environments with extremely low oxygen content of the water it is therefore difficult to have any conception of the importance of the oxygen concentration as a limiting ecological factor. It is known for many organisms, and it applies also to the Foraminifera, that the oxygen consumption increases with increasing temperature. With *Ammoni beccarii tepida* the maximum consumption occurred at approximately 35° C.

It may be assumed that species which are represented both in Late Glacial and in Post Glacial deposits of the Oslofjord area had lower oxygen consumption in the relatively cold water of the Late Glacial fjord than specimens of the same species had during the subsequent warmer Post Glacial conditions. Respiration is certainly a basic activity in Arctic environment as well as in Sub-Boreal. Presumably, however, the oxygen concentrations found in cold northern waters are, more often than in warmer waters sufficiant to maintain the necessary respiration.

Oxygen concentrations of the water of Spitsbergen fjords, measured by Nansen in the summer of 1912 (Nansen, 1915, p. 128) varied between 6.79 cc/l and 8.34 cc/l corresponding respectively to 87.3 % and 105.0 % of saturation. Mosby (1938, p. 65) in July 1931 measured in the Wahlenbergfjord, on the east side of the Hinlopen Strait, oxygen concentrations between 8.26 cc/l (100 %) 9.50 cc/l (114 %). These values are certainly not equal to oxygen concentrations which prevailed in the Late Glacial Oslofjord, but may nevertheless serve as an approximate illustration.

Hydrogen ion concentration

The hydrogen ion concentration may have an effect upon the Foraminifera. Bradshaw (1961, p. 98) found that the survival time of two species of Foraminifera decreased with increasing basic or acidic pH. *Ammonia beccarii tepida* survived for a period of 25 minutes to 75 minutes at a pH of 2.0, whereas *Spirillina vivipara* showed much shorter survival time, 2–6 minutes. It was even possible with both species under sublethal conditions to dissolve their calcium-carbonate tests without killing the animal. With specimens of *A. beccarii tepida* that had been left in water with a pH of 2.0 for 15–25 minutes nothing but the thin tectinous membrane remained to mark the outline of the test. Lankford (1959, p. 2075–2077), considering the conditions of the eastern Mississippi delta and reviewing investigations of Zobell (1946) and Stewart (1956), concluded that the primary factor controling the pH of the bottom sediment most probably is the abundance of organic material. Low pH was found especially in marsh areas rich in decaying plant material. On the other hand high photosynthetic rates may raise the pH value. Moore (1958) recorded values as high as 10.0 resulting from photosynthetic activity in tide pools.

Strøm (1936, p. 51) found quite high values of pH in surface water of comparatively high salinity, or immediately below an almost fresh surface layer, when high photosynthetic activity by phytoplankton had taken place. Otherwise the highest values were found within the upper 10 m, the lowest in the deep. However, where the surface water was brackish the most acidic pH was found there. In the deepest parts of such fjords Strøm (l. c.) found that even waters of oceanic salinity may become acid during long stagnation with development of carbon dioxide and hydrogen sulphide. The pH values in the Dramsfjord, measured in June 1933, varied between 6.85 and 7.36 (l. c., p. 41). Values from other parts of the Oslofjord are not available at the present time. Extreme values which can affect e. g. the formation of calcareous tests in the Foraminifera do probably not occur in the Oslofjord of to-day, and did most probably not occur during the Post Glacial development of the fjord.

In Spitsbergen fjords Nansen (1915, p. 130) in the summer of 1912 measured pH values between 7.93 and 8.25. Mosby (1938, p. 65) in the summer of 1931 found in the Hinlopen region, northeastern Spitsbergen, pH values between 8.20 and 8.30. Extremely low pH values is less likely in Arctic environment than in Boreal. The vegetation is usually scarce and the plankton production comparatively low. By analogy, therefore, any ecologically important pH effect was hardly exercised upon the Late Glacial foraminiferal faunas of the Oslofjord area.

An effect of low pH, which is not connected with the paleoenvironment but with the foraminiferal thanatocoenoses in the sediments, is mentioned here (Cp. introduction, p. 14): It was observed with a few borings, e. g., boring no. 2 (O 700) at Fornebo and boring no. 1 (C 63) at Årungen, that the upper samples, down to approximately 3 m core level, contained none or only very few and badly preserved foraminiferal tests. Specimens of *Elphidium* occurred with only the earliest whorl preserved, stumps of later septal walls projecting like spokes in a wheel. In others the calcareous test surface was corroded unto the tectinous base of the wall. With some of them the calcium carbonate was completely dissolved so that only the tectinous membrane remained. In the same samples, however, numerous spheres and flakes of tectinous membranes occurred. These represented specimens in which the tectinous wall base formed separate spheres or chambers so that, when the calcium carbonate was dissolved, the tectin was not capable of maintaining the form of the foraminiferal test but disintegrated into separate hollow bodies which soon collapsed. Such was the case with *Elphidium excavatum* whereas, on the other hand, the tectin base of *E. incertum incertum* was more capable of maintaining the form of the foraminifer. The occurrence of complete tectine tests in such samples is therefore not always to be expected.

It seems obvious that the upper parts of the sediments penetrated by the borings mentioned would have been subject to seepage of acid water from bogs which have formed on top of the raised marine deposits. Thicker fragments of molluscan shells from these upper parts of the Fornebo boring were all in a state of decompostion. Samples without Foraminifera, or with overrepresentation of forms which are less, or not, affected by low pH, such as *Verneuilina media, Eggerella scabra, Spiroplectammina biforms, Ammoscalaria runiana, Ammoscalaria pseudospiralis* and *Miliammina fusca* may occur in this way.

Experiments showed that hydrocloric acid and also formic acid slowly dissolved even the tectinous membrane of the foraminiferal tests (Nagy, personal information).

Sediment

Several records of dependency between the composition of foraminiferal benthos faunas and their substrata occur in the literature. In the Drøbaksund of the Recent Oslofjord Christiansen (1958, p. 73) observed that to some extent certain species of Foraminifera occurred in dominance on certain subsrata, some forms being frequent on sandy bottom, others restricted to mud bottom, and again others, especially sessile forms, being common on hard bottom. He also assumed that the grain size distribution of a soft bottom sediment would be of great importance for the distribution of arenaceous forms.

Reviewing previous investigations Phleger (1960, p. 114) found, however, that sediment type has little or no effect upon the Recent distribution of the benthonic Foraminifera (Cp. Cockbain, 1963). In several instances of good correlation between faunal assemblages and sediment texture, investigation of the foraminiferal distribution in nearby areas revealed that the apparent correlations are not laterally persitent. The same species in these adjacent areas are not restricted to, or dominant on, any particular sediment type.

The major part of *the Late Quaternary Foraminifera considered in the present study lived on a mud bottom*, since the clay sediments from which the investigated core samples were taken represent previous mud bottom. Except for the possible occurrence of displaced sessile forms, washed down into the clay sediment from stones or rock bottom, the faunas treated here possess an approximately homogeneous substratum. A few silty-sandy lamina occurring in some of the borings represent, assuming that turbidity currents are not involved, temporary sandy development of the bottom type. An apparent correlation between the occurrence of the foraminiferal ecostratigraphic zone C and silty-sandy lamina was observed in some cores. Sand and even gravel may occur in the deepest part of the borings, towards bedrock.

The foraminiferal assemblages in Münster's collection (p. 29–31) differ somewhat from the assemblages from the writer's samples. This may probably reflect sustratum dependency: Münster collected his specimens from shell beds – not from clay sediments.

The median diameter of the sampled Late Quaternary marine sediments of the Oslofjord area varies usually between 0.0008 mm and 0.0200 mm, the clay content, i. e., the percentage of particles of less than 2 microns size, between 6 % and 75 % (Selmer-Olsen, 1954; Rosenqvist, 1955 b). The old Late Glacial Yoldia clay regularly contains more coarse particles, such as sand grains, granules, and stones, than clays of other units. They were probably dropped from floating icebergs and ice pieces from the calving glacier front (Cp. Brogger, 1900–1901; Holmsen, 1951). The grain size distribution for some samples from the calssical clay units of the area, illustrated by cumulative curves, was given by Feyling-Hanssen (1954 a, b). The degree of sorting is usually smaller with Yoldia clay than with other marine clay units investigated. The density of the examined sediments usually ranges between 1.70 tons per cubic meter and 1.95 t/m^3, apparently somewhat greater with Late Glacial samples than with Post Glacial ones (Feyling-Hanssen, 1957, p. 24–26).

As to the mineral composition of the marine clays of the Oslofjord area the reader is referred to the comprehensive paper of I. Th. Rosenqvist: "Investigations in the clay-electrolyte-water system" (1955 a). Exhaustive reference is given there to older literature on the subject. Rosenqvist (1942) proved that the finer fractions, <2 microns, of the clays mainly consisted of quarts, feldspar, calcite, and magnetite in combination with high frequency of light illitic hydrous mica minerals. The high frequency of hydrous micas in the marine clays of the Oslofjord area may, according to Rosenqvist (1955 a, p. 28) be due to the outcropping of nonmetamorphic Cambro-Silurian sediments of this region. In most localities the upper 2–4 m of the raised marine clay deposists have undergone chemical wethering which has transformed this upper part into a fairly stiff so-called dry crust. Small amounts of montmorillonite found in the dry crust are assumed to have originated from chloritic or illitic minerals (Rosenqvist, 1955 b). Certain amounts of magnesium, nickel, and cobalt occur in the clays. The silty-sandy fractions of the clays contain almost exclusively unaltered rock-forming minerals.

The geotechnical properties of marine clay sediments were investigated i. a. by G. Holmsen (1930; 1938), P. Holmsen (1946; 1949), Rosenqvist (1946 a, b; 1953; 1960), Bjerrum (1954; 1955), Moum and Rosenqvist (1955), Feyling-Hanssen (1957). The marine clays of the Oslofjord area, like most of the marine clays of Norway, have through land uplift and leaching of the salt of the original pore water attained reduced shear strength and increased sensitivity. Highly slide-prone quick clays were formed in this way.

Foraminiferal zonation in borings outside the Ra ridge

Sandefjord (O 358)

Geological conditions. – The city of Sandefjord lies at the head of the 10 km long and 2 km broad Sandefjordsfjord to the west of the mouth of the Oslofjord. Towards its northern end the fjord narrows into the Framnesfjord which only is 200 m broad, further north it widens into the 1000 m broad harbour-basin of Sandefjord and Kamfjord. Larvikitic plutonic rocks outcrop at both sides of the fjord reaching heights between 60 and 100 m above sea level at the inner end (Cp. Brøgger and

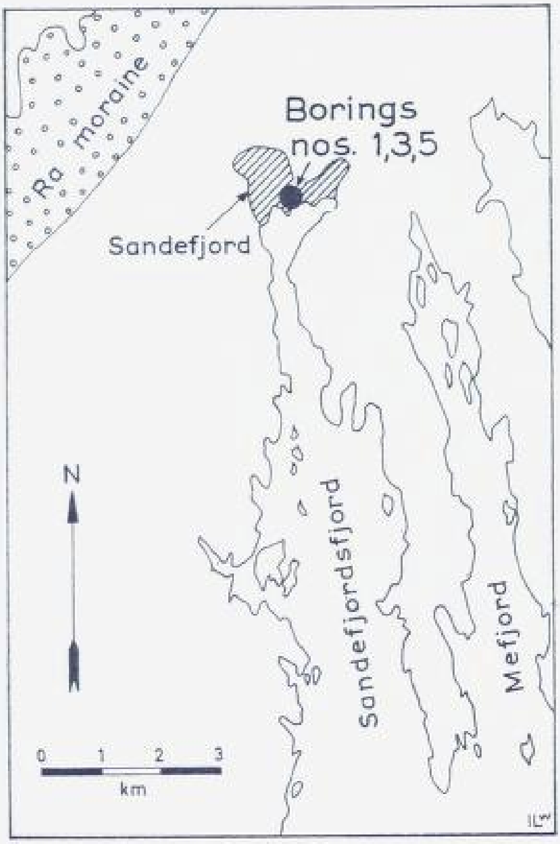


Fig. 8. The city of Sandefjord and the Ra ridge northwest of it.

Schetelig, 1926: Geological map of Tønsberg and Larvik, 1:100 000, issued by the Geological Survey of Norway). At a sea level 10–30 m higher than the present, the water masses of the now narrow and isolated inner part of the Sandefjordsfjord could communicate through sounds between numerous islands with waters to the west, north and east. Lower parts of the country are covered with marine clay and sand.

Three borings were carrid out by the Norwegian Geotechnical Institute in 1956 on a low clay flat in the southern part of the city of Sandefjord. They were situated c. 120 m from the sea and about 3 km outside the Ra ridge which runs in a SW–NE direction northwest of the city (Fig. 8). The flat terrain at the borings is situated 0.9 m above present sea level. The exact position of the borings is illustrated in figure 9.

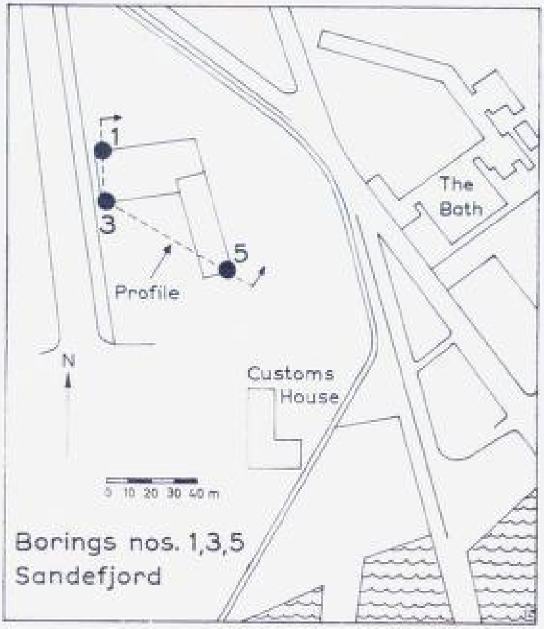


Fig. 9. Position of the borings in Sandefjord.

There is a distance of 25 m between boring no. 1 and boring no. 3, and almost 55 m between boring no. 3 and boring no. 5. Geotechnical investigations (Report O 358) revealed that the upper 3 m–5 m of the sediment consists of fine sand rich in humus. Below this was a 1 m thick layer of silty mud, in turn underlain by relatively homogeneous, soft clay, down to 25–28 m. Below this level the clay was sandy and quite firm, and probably contained scattered stones. Numerous soundings, done by the Norwegian Geotechnical Institute, all stopped against firm soil or stones at many different depths between 30 m and 60 m. Gravel layers probably also occurred at these levels. Bedrock was reached at depths of 51.75 m to 60.20 m below the surface around the position of boring no. 5.

Landslides are not known to have taken place in the locality.

Foraminifera zonation. – Boring no. 5 was 36.0 m deep and contained the most complete series of foraminiferal zones in the locality (As to the use of the term zone, see p. 17). 28 samples from this boring were analyzed micropaleontologically. The uppermost sample was taken 2.7 m below the surface, the deepest one 35.9 m below the surface. Unfor-

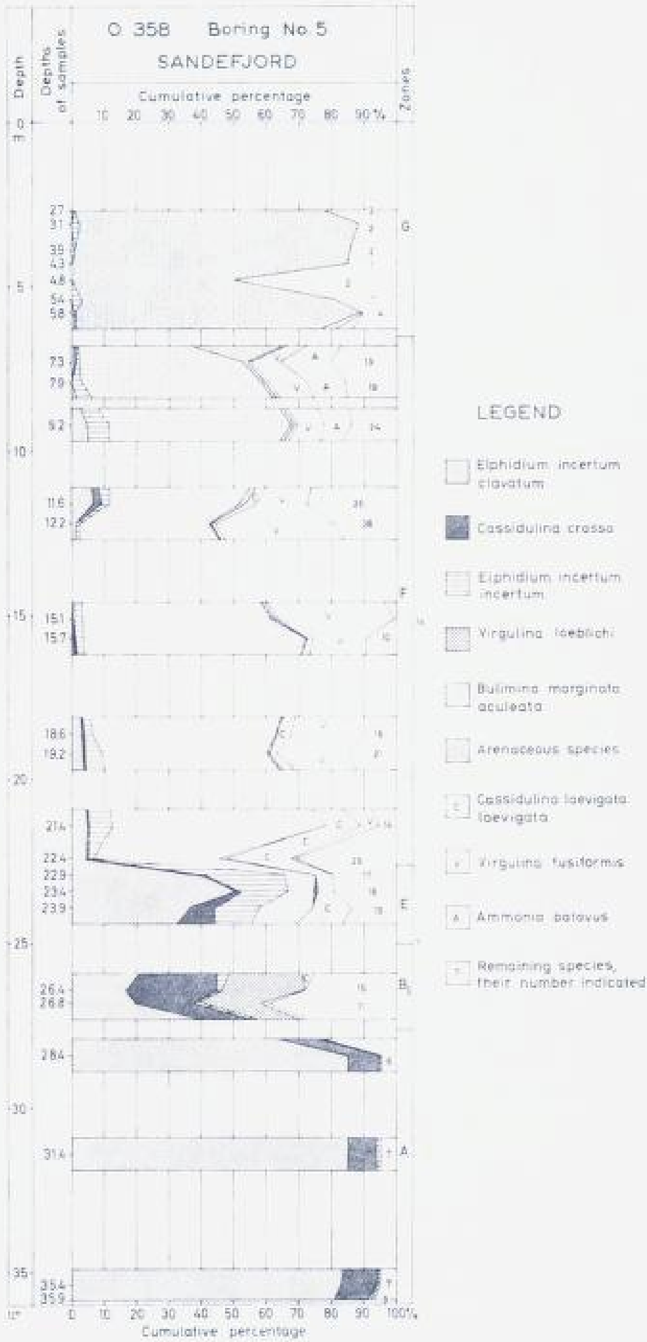


Fig. 10. Distribution and relative frequency of Foraminifera through boring no. 5 in Sandefjord.

tunately large intervals occur between some of the samples from this core. The spacing is seen from the range chart (Fig. 11) and also from the diagram of figure 10. To some degree, however, a control of the faunal development registered in this core may be obtained by comparison with the two other borings of the locality.

The weight of a dried sample was approximately 100 g, some of them weighed a little more, some a little less. Exact determination of the weight of every sample was not undertaken with this boring. The maximum number of specimens in one sample was 30 000. Otherwise the numerical content of Foraminifera was more than 10 000 in three samples, more than 5000 in 8 samples, and in 11 samples it ranged between 4000 and 700 specimens. Only the upper 6 samples, down to 5.5 m below the surface, contained really low populations, 124 specimens being the maximum and 7 the minimum per sample in this part of the core. In the range chart (Fig. 11), illustrating the distribution and frequency of the Foraminifera throughout the boring, the number of specimens per species is plotted directly for three of the upper samples whereas for all the other samples the symbols indicate percentages.

In addition to the species listed in the range chart of figure 11, the following were observed in boring no. 5 (arranged according to first appearance): *Guttulina lactea* at 35.9 m and 31.4 m depth, *Difflugia capreolata* at 35.4 m and in the three upper samples, *Lagena gracillima* at 31.4 m, 11.6 m and 2.7 m, *Lagena laevis* at 26.8 m, 23.9 m, and 7.9 m, *Triloculina oblonga* at 26.4 and 11.6 m, *Scutuloris* cf. *tegminis* and *Globobulimina auriculata arctica* at 26.4 m, *Lagena hispidula* at 23.4 m, *Quinqueloculina arctica* and *Lagena apiopleura* at 22.9 m, *Cyclogyra foliacea* at 22.4 m, *Triloculina tricarinata* at 22.4 and 12.2 m, *Rosalina globularis* at 22.4 and 11.6 m, *Bucella frigida* at 19.2 m, *Bolivina pygmaea* and *Patellina corrugata* at 18.6 m. *Textularia sagittula* at 15.7 m, *Bolivina spathulata* at 15.1 m, *Robertinoides pumilum* at 12.2 m, *Lagena clavata* at 12.2 and 7.9 m, *Biloculinella depressa* at 11.6 m, *Lenticulina rotulata* forma *cultrata* at 9.2 m, *Quinqueloculina lata* at 7.9 m, and *Pontigulasia compressa* at 3.9 m.

The total number of different Foraminifera species (subspecies and forms) in boring no. 5 of Sandefjord was 86, and in addition 3 species of Theacamoebina occurred. The Theacamoebina were counted and plotted in the diagram together with the Foraminifera. Only 9 of the Foraminifera species had arenaceous tests, the others were calcareous. The arenaceous forms occurred mainly in the uppermost part of the core; 4 of

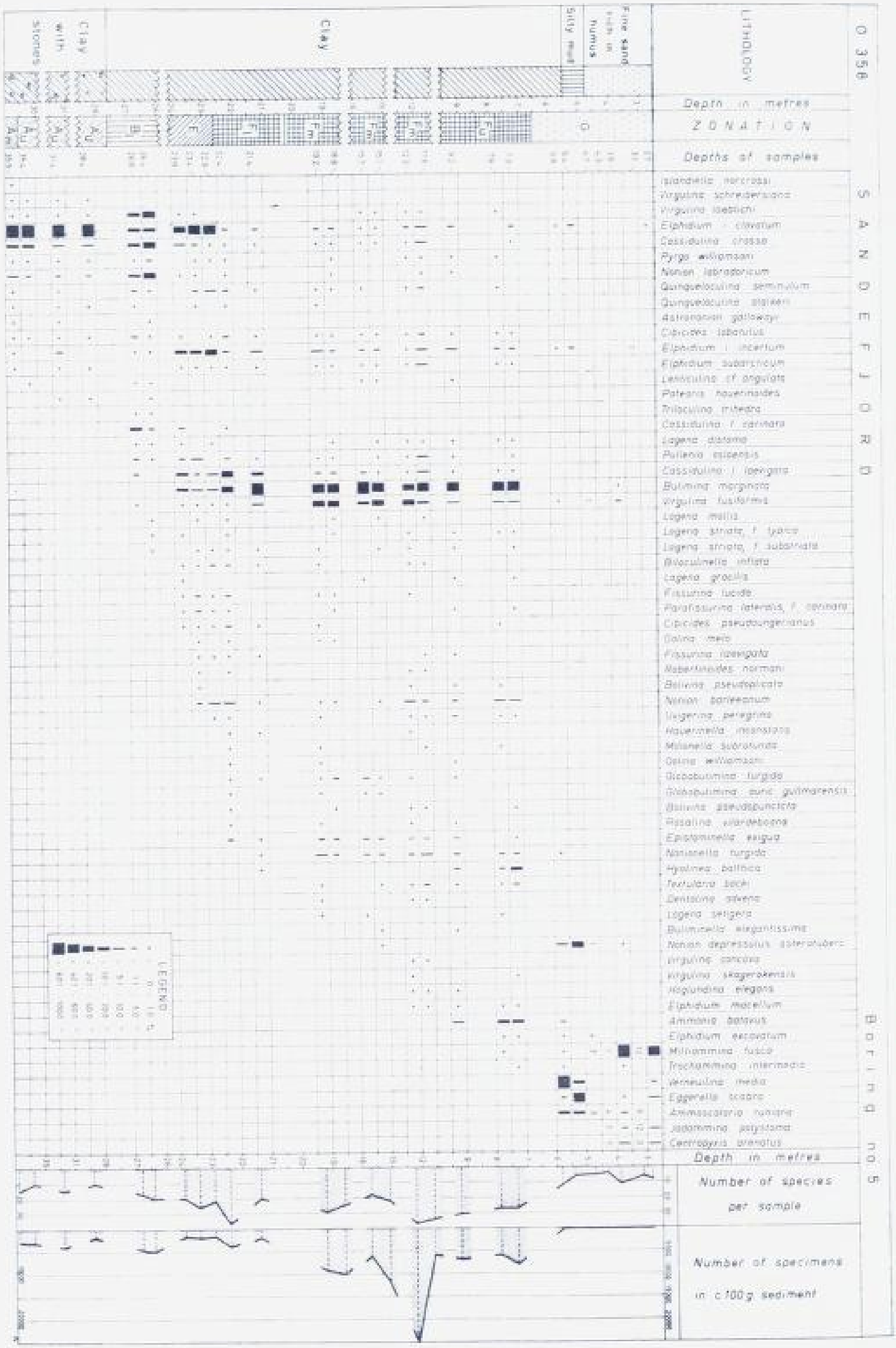


Fig. 11. Range chart for boring no. 5 in Sandefjord.

them, *Ammoscalaria runiana*, *Jadammina polystoma*, *Verneuilina media* and *Eggerella scabra*, disappered below 6 m, *Trochammina intermedia* was found down to 7.3 m, and *Miliammina fusca*, which predominated the faunas down to 3.9 m, disappeared below 7.9 m. *Textularia bocki* occurred between 7.3 m and 19.2 m below the surface, and *Textularia sagittula* only in a single sample, at core level 15.7 m. The finely agglutinated *Quinqueloculina stalkeri* occurred in some samples from 19.2 m to 31.4 m below the surface. The maximum total of different species (subspecies and forms) in one sample was 37 (core level 22.4 m). Otherwise 4 samples yielded more than 30 species each, 8 yielded between 20 and 30 species, in 9 samples there were between 10 and 20 species. Only the uppermost 6 samples contained less than 10 species each – Foraminifera and Thecamoebina taken together.

Figure 10 illustrates the cumulative frequencies of the predominant species and forms of Foraminifera in the boring, as revealed by the investigated samples. Three distinctly different divisions of the core can be recognized immediately: an upper one characterized by arenaceous forms, viz., *Miliammina fusca*, *Verneuilina media*, *Eggerella scabra*, and *Ammoscalaria runiana*, a middle part characterized by rich occurrence of *Bulimina marginata*, forma *aculeata*, and a lower part predominated by *Elphidium incertum clavatum* and with good representation of *Cassidulina crassa*. Between the *Bulimina marginata* predominance and the lowest part of the core, with *Elphidium incertum clavatum*, there is a part of the core, from 22.5 to 24.0 m below the surface, where *Bulimina marginata* is frequently present but where *Elphidium incertum clavatum* still predominates and where *Elphidium incertum incertum* is richly represented. The fossil microassemblage characterized in this way is here called *zone E*. Below this zone, in the *Elphidium incertum clavatum* part of the present core, there are two samples, between core level 26.0 m and 27.0 m, in which *Virgulina loeblichi* and *Nonion labradoricum* are frequent and *Cassidulina crassa* almost as abundant as *Elphidium incertum clavatum*. This is characteristic of the *lower part of zone B*. The faunal composition of the lowest part of the core, with marked predominance of *E. incertum clavatum*, is referred to as *zone A*. The *Bulimina marginata zone* with predominance of forma *aculeata* of this species and only few specimens of *E. incertum clavatum*, is termed *zone F*, and the upper zone, characterized by agglutinated forms, is termed *zone G*.

Closer examination of the range chart (Fig. 11) leads to subdivision of some of these zones.

Zone G is naturally divided into two subzones: G_u (G_{upper}), the upper three samples with frequent occurrence of *Miliammina fusca* and good representation of *Jadammina polystoma*, and G_l (G_{lower}) which is predominated by *Verneuilina media* and *Eggerella scabra*. *Nonion depressulus asterotuberculatus* occurs in both of the subzones but is much more frequent in the lower one than in the upper. *Ammonia batavus* and *Elphidium excavatum* occur in subzone G_l whereas *Ammoscalaria runiana* is common in the entire zone G. It is worth mentioning that the Thecamoebina, especially *Difflugia capreolata* and *Centropyxis arenatus* occur almost exclusively in subzone G_u. Scattered occurrence of *Elphidium incertum clavatum* and *incertum*, *Bulimina marginata*, forma *aculeata*, *Virgulina fusiformis*, *Nonionella turgida*, *Trochammina intermedia*, *Lagena clavata* and, of the Thecamoebina, *Pontigulasia compressa* is noted in zone G of boring no 5 in Sandefjord. The total number of different species (subspecies and forms) observed in zone G of this boring is 18, 15 species occurred in subzone G_u and 13 in G_l. 6 of the Foraminifera species of zone G are arenaceous, i. e., 40 % of the Foraminifera of the zone. There was no sample taken above core level 2.7 m in boring no. 5. If, however, zone G is assumed to continue to the surface, its thickness would be approximately 6 m, probably a little more. All samples from this zone carried considerable amounts of plant remains, particularly the upper samples. Some Diatomacea occurred at core level 3.9 m. Zone G extends through fine sand and silty mud down into the clay of the boring.

The micropaleontological analysis of the sample at core level 3.9 m of boring no. 5, Sandefjord is here presented to examplify the assemblage of subzone G_u:

Miliammina fusca	95	specimens
Centropyxis arenatus	10	–
Jadammina polystoma	5	–
Difflugia capreolata.................	4	–
Virgulina fusiformis.................	3	–
Ammoscalaria runiana	2	–
Pontigulasia compressa	1	–
Trochammina intermedia	1	–
Eggerella scabra	1	–
Bulimina marginata, forma *aculeata* ..	1	–
Nonion depressulus asterotuberculatus ..	1	–
Total	124	specimens

The whole sample was counted.

As an example of the Foraminifera assemblage of *subzone* G_I the analysis of the sample at core level 5.8 m is given below; half of the foraminiferal content of the sample was counted:

Species	Frequency	Percentage
Verneuilina media	220	67.0
Ammoscalaria runiana	55	16.7
Nonion depressulus asterotuberculatus	21	6.4
Ammonia batavus	11	3.3
Eggerella scabra	10	3.0
Miliammina fusca	3	0.9
Elphidium incertum clavatum	3	0.9
Virgulina fusiformis	2	0.6
Trochammina intermedia	1	0.3
Nonionella turgida	1	0.3
Elphidium excavatum	1	0.3
Elphidium incertum incertum	1	0.3
Total	330	100.0

Zone F, the *Bulimina marginata* zone, extends from core level 7.0 m, or probably 6.5 m, to core level 22.5 m of boring no. 5, Sandefjord, and is thus 16 m thick. It comprises samples which are much richer in Foraminifera than those of zone G. The total number of different species (and forms) in zone F of this boring is 71. Of these only 5 are arenaceous, i. e., approximately 7 %. The most common forms in this zone are *Bulimina marginata*, forma *aculeata*, *Elphidium incertum incertum*, *Cassidulina laevigata laevigata*, *Virgulina fusiformis*, *Nonion barleeanum*, *Nonionella turgida*, *Ammonia batavus*, and *Hyalinea balthica*, the most frequent listed first. *Epistominella exigua* is quite common while *Elphidium incertum clavatum* occurs sparsely in most samples. *Bulimina marginata* accounts for 38.7–68.8 % of the Foraminifera fauna in the 11 investigated samples from zone F, in 8 of these samples its frequency exceeds 50 %.

The upper part of zone F, the samples at core levels 7.3 m, 7.9 m, and 9.2 m, is characterized by simultaneous and quite frequent occurrence of *Hyalinea balthica* and *Ammonia batavus*, accounting for 15.5 % and 10.6 % respectively of the fauna at core level 7.3 m, 4.4 % and 11.6 % respectively at core level 7.9 m, and 3.4 and 8.1 % respectively at core level 9.2 m. *Virgulina fusiformis* is frequent in the three samples. The Foraminifera assemblage characterized in this way represents the *sub-*

zone F_u (F_{upper}) in the present boring. *Ammonia batavus* was not found below this subzone in the core, whereas a single specimen of *Hyalinea balthica* occurred at core level 21.4 m. *Elphidium excavatum* occurred in the two upper samples of this subzone, a single specimen counted in each, and two specimens of *Miliammina fusca* at core level 7.9 m. These two species were not found below subzone F_u. A few specimens of *Elphidium macellum* occurred in this subzone.

The analysis of the sample at core level 7.9 m is reproduced below as an example of the faunal composition of *subzone* F_u:

Species	Frequency	Percentage
Bulimina marginata, f. *aculeata*	302	55.6
Ammonia batavus	63	11.6
Virgulina fusiformis	62	11.4
Nonion barleeanum	30	5.5
Hyalinea balthica	24	4.4
Elphidium incertum incertum	17	3.1
Nonionella turgida	9	1.7
Cassidulina laevigata laevigata	5	0.9
Textularia bocki	4	0.7
Uvigerina peregrina	3	0.6
Elphidium subarcticum	3	0.6
Miliammina fusca	2	0.4
Lagena distoma	2	0.4
Lagena elongata	2	0.4
Lagena laevis	2	0.4
Cibicides pseudoungerianus	2	0.4
Quinqueloculina seminulum	1	0.2
Miliolinella cf. *subrotunda*	1	0.2
Pyrgo williamsoni	1	0.2
Lagena setigera	1	0.2
Lagena striata, f. *typica*	1	0.2
Parafissurina lateralis f. *carinata*	1	0.2
Virgulina loeblichi	1	0.2
Bolivina pseudoplicata	1	0.2
Cibicides lobatulus	1	0.2
Elphidium excavatum	1	0.2
Elphidium macellum	1	0.2
Total	543	100.3

This count represents $^1/_9$ of the sample.

The middle part of zone F of this boring, from core level 11.6 m to 19.2 m, is characterized by pronounced frequency of *Virgulina fusiformis*, this species constituting from 15.3 % to 36.9 % of the Foraminifera fauna of the six investigated samples from the mentioned interval. Predominance of *Bulimina marginata* with *Virgulina fusiformis* ranking next in frequency, is considered the characteristicum of *subzone* F_m (F_{middle}).

The highest populated sample of the core, 30 000 specimens, occurred within this subzone, viz., at 12.2 m depth. The analysis of the sample from core level 19.2 m is reproduced below as an example of a *subzone* F_m fauna:

Species	Frequency	Percentage
Bulimina marginata, f. *aculeata*	248	50.6
Virgulina fusiformis	110	22.4
Elphidium incertum incertum	28	5.7
Nonionella turgida	26	5.3
Epistominella exigua	21	4.3
Elphidium incertum clavatum	17	3.5
Cassidulina laevigata laevigata	10	2.0
Globobulimina turgida	4	0.8
Cibicides lobatulus	4	0.8
Uvigerina peregrina	2	0.4
Pullenia osloensis	2	0.4
Cibicides pseudoungerianus	2	0.4
Elphidium subarcticum	2	0.4
Textularia bocki	1	0.2
Quinqueloculina stalkeri	1	0.2
Quinqueloculina seminulum	1	0.2
Miliolinella cf. *subrotunda*	1	0.2
Biloculinella inflata	1	0.2
Dentalina advena	1	0.2
Lagena setigera	1	0.2
Lagena striata, f. *substriata*	1	0.2
Oolina melo	1	0.2
Oolina williamsoni	1	0.2
Fissurina lucida	1	0.2
Globobulimina auriculata gullmarensis	1	0.2
Cassidulina crassa	1	0.2
Nonion barleeanum	1	0.2
Rosalina vilardeboana	1	0.2
Buccella frigida	1	0.2
Total	490	100.2

This count represents $^1/_{16}$ of the sample. *Cassidulina laevigata laevigata* is quite common throughout subzone F_m but only in moderate number.

However, in the lowest part of zone F *Cassidulina laevigata laevigata* has usurped the role which *Virgulina fusiformis* played in the middle part. *Bulimina marginata* predominates, but *Cassidulina laevigata laevigata* is next in frequency. *Virgulina fusiformis* also occurs, but is only moderately represented. Only two samples with this foraminiferal assemblage occurred in boring no. 5, viz., at core level 21.4 m and 22.4 m. In the upper of the two *C. laevigata laevigata* makes 10.8 % of the fauna, in the lower 21.2 %. Predominance of *B. marginata* and high frequency of *C. laevigata laevigata* are characteristic of subzone F_l (F_{lower}). As there is a gap of approximately 3 m between the lowest F_m sample and the highest F_l sample the position of the borderline between the two subzones is not known. In the Foraminifera zone column of the range chart it has been placed in the middle of the interval mentioned above.

The micropaleontological analysis of the sample from core level 22.4 m is here given as an example of the foraminiferal composition of this subzone, F_l:

Species	Frequency	Percentage
Bulimina marginata, f. *aculeata*	170	38.5
Cassidulina laevigata laevigata	93	21.1
Nonion barleeanum	25	5.7
Elphidium incertum clavatum	20	4.5
Quinqueloculina seminulum	18	4.1
Epistominella exigua	15	3.4
Cibicides pseudoungerianus	14	3.2
Pullenia osloensis	12	2.7
Fissurina lucida	10	2.3
Biloculinella inflata	10	2.3
Cibicides lobatulus	9	2.1
Elphidium incertum incertum	5	1.1
Quinqueloculina stalkeri	3	0.7
Lagena striata, f. *substriata*	3	0.7
Virgulina fusiformis	3	0.7
Cassidulina crassa	3	0.7
Elphidium subarcticum	3	0.7
Triloculina tricarinata	2	0.5
Pyrgo williamsoni	2	0.5
Lagena striata, f. *typica*	2	0.5
Globobulimina turgida	2	0.5
Rosalina vilardeboana	2	0.5
Miliolinella cf. *subrotunda*	1	0.3
Cyclogyra foliacea	1	0.3
Hauerinella inconstans	1	0.3
Lagena distoma	1	0.3
Lagena mollis	1	0.3
Oolina melo	1	0.3
Oolina williamsoni	1	0.3
Parafissurina lateralis, f. *carinata*	1	0.3
Fissurina laevigata	1	0.3
Globobulimina auriculata gullmarensis	1	0.3
Robertinoides normani	1	0.3
Uvigerina peregrina	1	0.3
Bolivina pseudoplicata	1	0.3
Cassidulina laevigata carinata	1	0.3
Nonion labradoricum	1	0.3
Total	441	101.5

The frequent occurrence of *Quinqueloculina seminulum*, *Biloculinella inflata*, *Cibicides pseudoungerianus*, and *Epistominella exigua* in this lowest part of zone F should be noted. Subzone F_l constitutes the smallest part of zone F in this boring, being only about $^1/_8$ of the whole; subzone F_m is the largest, more than $^3/_4$ of zone F, and subzone F_u is $^1/_4$ of zone F.

The occurrence and frequency of the three subzone markers *Cassidulina laevigata laevigata*, *Virgulina fusiformis*, and *Ammonia batavus* are also indicated in figure 10, so that the subdivision of zone F appears in this illustration as well. – *Textularia bocki*, *Nonionella turgida*, *Epistominella exigua*, and *Hyalinea balthica*, together with some other species, disappear below zone F in the core of boring no. 5 in Sandefjord.

Zone E, which could be called the *Elphidium incertum* zone, is characterized by high frequency of the two subspecies of *Elphidium incertum*, viz., *incertum* and *clavatum*, and quite frequent occurrence also of *Bulimina marginata*, forma *aculeata* and *Cassidulina laevigata laevigata*. Zone E comprises 3 samples in boring no. 5, viz., at core levels 22.8 m, 23.4 m, and 23.9 m. The position of the lower boundary of the zone is uncertain because of a sample-less gap of 2 m in the boring between the lowest investigated E sample and the uppermost sample of the zone below. In the range chart (Fig. 11) the borderline has been drawn at 25 m, the thickness of the zone would thus be approximately 2 m. – The total number of different species (subspecies and forms) of this zone is 35 in the present boring. *Elphidium incertum clavatum* predominates in all the three samples, accounting for 40.5 % of the Foraminifera fauna in the upper one, 51.0 % in the middle one, and 36.6 % in the lowest. The percentage of *Elphidium incertum incertum* ranges between 24.3 and 13.6 %, whereas *Bulimina marginata* makes from 16.6% to 7.8 % and *Cassidulina laevigata laevigata* between 4.4 and 12.2 % of the fauna. Common species of the zone are furthermore *Quinqueloculina seminulum*, *Cassidulina crassa*, *Pullenia osloensis*, and *Nonion barleeanum*. *N. barleeanum* and *Cibicides pseudoungerianus* disappear below zone E; this is also the case with *Bulimina marginata* and some of the other species of the present core.

The analysis of the sample at 22.9 m depth is reproduced here as an illustrative example of the composition of the Foraminifera population in *zone E*:

Species	Frequency	Percentage
Elphidium incertum clavatum	177	40.5
Elphidium incertum incertum	106	24.3
Bulimina marginata, f. aculeta	40	9.2
Nonion barleeanum	28	6.4
Quinqueloculina seminulum	27	6.2
Cassidulina laevigata laevigata	23	5.3
Biloculinella inflata	10	2.3
Parafissurina lateralis, f. carinata	3	0.7
Cassidulina crassa	3	0.7
Cibicides lobatulus	3	0.7
Quinqueloculina arctica	2	0.5
Pyrgo williamsoni	2	0.5
Lagena gracilis	2	0.5
Fissurina lucida	2	0.5
Cibicides pseudoungerianus	2	0.5
Lagena apiopleura	1	0.2
Lagena distoma	1	0.2
Lagena striata, f. substriata	1	0.2
Fissurina laevigata	1	0.2
Uvigerina peregrina	1	0.2
Virgulina fusiformis	1	0.2
Elphidium subarcticum	1	0.2
Total	437	100.2

This count represents $^1/_2$ of the sample. Shells and fragments of the pelecypod *Nucula sulcata* Bronn occurred in the coarse fraction.

Subzone B_1, the subzone with *Virgulina loeblichi* and *Nonion labradoricum*, comprises two of the samples in boring no. 5, namely, at core level 26.4 m and 26.8 m. The total thickness of the subzone is not known because of the considerable interval between the two samples and the nearest samples of the adjacent zones above and below. In the range chart the subzone has been given an estimated extent of 2.5 m, i. e., from core level 25.0 m to core level 27.5 m.

The primary diagnostic constituent of subzone B_1 (B_{lower}) is *Virgulina loeblichi*, which exhibits remarkably high frequencies in these samples compared with its very sparse and casual occurrence outside this subzone. The second marker is the comparatively large *Nonion labradoricum*. Frequent and characteristic species of subzone B_1 are, furthermore, *Cassidulina crassa* and *Elphidium incertum clavatum*. *Cassidulina laevigata carinata* is frequent in the lowest of the two samples, and *Quinqueloculina stalkeri* and *Pullenia osloensis* should also be mentioned. The total number of species (subspecies and forms) of this unit in boring no. 5 in Sandefjord is 25, 13 of which do not occur below this subzone. *Bulimina marginata*, forma *aculeata*, which is quite characteristic in the above-lying zone E, is absent in subzone B_l of this particular boring.

The foraminiferal analysis of the sample from 26.4 m depth of boring no. 5 is presented here in order to illustrate the faunal composition of *subzone B_l*:

Species	Frequency	Percentage
Cassidulina crassa	181	28.5
Virgulina loeblichi	167	26.3
Nonion labradoricum	141	22.2
Elphidium incertum clavatum	100	16.7
Pyrgo williamsoni	11	1.7
Cassidulina laevigata carinata	11	1.7
Elphidium incertum incertum	5	0.8
Pullenia osloensis	4	0.6
Quinqueloculina seminulum	3	0.5
Cibicides lobatulus	3	0.5
Globobulimina auriculata arctica	2	0.3
Triloculina trihedra	1	0.2
Pateoris hauerinoides	1	0.2
Scutuloris tegminis	1	0.2
Lenticulina cf. *angulata*	1	0.2
Lagena distoma	1	0.2
Lagena mollis	1	0.2
Lagena striata, f. *typica*	1	0.2
Lagena striata, f. *substriata*	1	0.2
Astrononion gallowayi	1	0.2
Total	637	101.6

This count represents $^1/_8$ of the sample. The quite common occurrence of *Pyrgo williamsoni* in this subzone is noteworthy.

In the region north of the Ra ridge, but south of the Ås–Ski moraines there occurs in some borings a Foraminifera zone which the author has also referred to zone B. Its fauna is poorer in some respects and differs considerably from that of zone B in the present boring from Sandefjord. To distinguish the two from each other, the northerly development of the zone is classified as subzone B_u (B_{upper}). This subzone did not occur in Sandefjord.

Zone A, the *Elphidium incertum clavatum* zone, comprises the lowest part of boring no. 5, Sandefjord, from 28.4 m to 35.9 m below the surface. The stratigraphic border between subzone B_l and zone A is not exactly determinable in the present core because of an interval of 1.6 m between the lowest subzone B_l sample and the highest zone A sample. It is, however, probable that it coalesces with the lithologic border at core level 27.7 m between the above-lying clay and the underlying sandy clay with stones and gravel. The characterizing Foraminifera constituent of zone A is ***Elphidium incertum clavatum*** which occurs in abundance, accounting for more than 80 % of the Foraminifera fauna of the zone. Next in frequency is *Cassidulina crassa*, accounting for 8.5 %–11.0 % of the fauna of the four samples investigated from this zone. Other common species of the zone are *Pyrgo williamsoni, Virgulina schreibersiana, Nonion labradoricum*, and *Cibicides lobatulus*. The total number of different Foraminifera species (subspecies and forms) in zone A of boring no. 5, Sandefjord, was 17, and in addition *Difflugia capreolata* of the Thecamoebina occurred. Except for *Elphidium i. clavatum* and *Cassidulina crassa* most of the species were sparsely represented.

In the lowest sample of the core, 35.9 m below the surface, there was a marked increase in the frequency of *Nonion labradoricum*. This lowest part of zone A in the present core is distinguished as a particular subzone, called *subzone* A_m (A_{middle}), because in other localities a still lower subzone, A_l (A_{lower}), was recognized. The top level, only, of subzone A_m is represented in boring no. 5 in Sandefjord. The rest of zone A in this boring is classified as *subzone* A_u (A_{upper}).

The analysis of the sample at core level 28.4 m is here given as an example of the fauna composition in *subzone* A_u:

Species	Frequency	Percentage
Elphidium incertum clavatum	263	84.8
Cassidulina crassa	30	9.7
Nonion labradoricum	6	1.9
Virgulina schreibersiana	3	1.0
Elphidium subarcticum	3	1.0
Quinqueloculina stalkeri	1	0.3
Pyrgo williamsoni	1	0.3
Pateoris hauerinoides	1	0.3
Virgulina loeblichi	1	0.3
Cibicides lobatulus	1	0.3
Total	310	99.9

This count represents $^1/_6$ of the sample. *Elphidium i. clavatum* makes up almost 85 % of the fauna, in the sample from 31.4 m it makes 85.5 %.

The foraminiferal analysis of the deepest sample of the core, 35.9 m, referred to *subzone* A_m, is also presented:

Species	Frequency	Percentage
Elphidium incertum clavatum	401	80.2
Cassidulina crassa	51	10.2
Nonion labradoricum	27	5.4
Elphidium incertum incertum	5	1.0
Virgulina loeblichi	4	0.8
Virgulina schreibersiana	4	0.8
Elphidium subarcticum	2	0.4
Quinqueloculina seminulum	1	0.2
Pyrgo williamsoni	1	0.2
Guttulina lactea	1	0.2
Islandiella norcrossi	1	0.2
Astrononion gallowayi	1	0.2
Cibicides lobatulus	1	0.2
Total	500	100.0

This count represents $^1/_4$ of the sample. Two umbonal fragments of the mollusc *Portlandia arctica* (Gray) occurred in the coarse fraction of the sample together with granules and stones. We shall later on see examples of A_m faunas of more characteristic development than the present. The considerable amount of sand and gravel in the samples from zone A at Sandefjord certainly has a reducing effect upon the number of Foraminifera per unit of sample.

Boring no. 1 in Sandefjord, situated 77 m northwest of boring no. 5, is 28 m deep. It reaches down into the uppermost part of subzone A_u, and also in this boring the position of the border between zone B and zone A seems to correlate with the shift in lithology from homogeneous clay to sandy clay with stones, situated at 26.5 m depth. Zone G, however, extends from the fine-sandy uppermost part of the core through 1.3 m of silty mud down into the clay without exhibiting any distinct faunal registration of lithological changes. *Ammonia batavus* was more frequent in the lower part of zone G in this boring than in subzone G_1 of boring no. 5, and the agglutinated forms were less frequent. Decalcination had obviously taken place in this upper part of the core, since many of the calcareous specimens occurred with parts of their tectin wall base exposed. Otherwise the Foraminifera assemblages of boring no. 1 correlate well with those described from boring no. 5.

The main characteristics of zones and subzones are easily recognisable and need no repeated description. The border between zone G and zone F was found at core level 5.8 m, the transition between the subzones F_u and F_m, approximately 8.5 m, and between F_m and F_l at 16.0 m. The border between zone F and zone E was situated approximately 20 m below the surface, and that between E and subzone B_l at about 23 m. *Uvigerina peregrina* was quite common in the upper part of subzone F_u. *Höglundina elegans* occurred quite abundantly in the upper part of subzone F_m, *Nonion barleeanum* in the upper middle part, whereas *Quinqueloculina seminulum, Pyrgo williamsoni, Globobulimina auriculuta gullmarensis, G. turgida,* and *Epistominella exigua* were common towards the lower part of this subzone. Some specimens of *Cibicides pseudoungerianus* were quite conspicuous in the lower part of subzone F_l. The mollusc species *Yoldiella lenticula* (Möller) and *Ennucula tenuis* (Montagu) occurred at core level 24.7 m in subzone B_l.

Boring no. 3 in Sandefjord, located 64 m west-north-west of boring no. 5 and 25 m south of boring no. 1, was only 10 m deep and reached no further than the upper part of the subzone F_m. The foraminiferal population of zone G, especially of the uppermost samples of this boring, was very low. A few specimens of *Nonion depressulus asterotuberculatus* occurred together with *Virgulina fusiformis* towards the lower part of this zone.

Fig. 12. Profile through the borings in Sandefjord.

The foraminiferal composition within subzone F_u and subzone F_m was in complete agreement with the corresponding assemblages of the two other borings. The transition between zone G and zone F was found at 5.3 m below the surface, the border between the subzones F_u and F_m was situated at core level 9.0 m.

The foraminiferal zonation of the three borings in Sandefjord is illustrated and combined in the profile of figure 12 (Cp. fig. 9). The lithology of the deposit is also indicated. The marine limit at Sandefjord was found to be 150 m above present-day sea level (Rekstad, 1922), this position of the shoreline is probably of Pre-Boreal age.

In order to illustrate the lateral persistance of the foraminiferal zonation now presented from Sandefjord, micropaleontological results from a locality on the other side of the outer Oslofjord is treated below, viz., Valle, situated 48 km east-north-east of Sandefjord.

Valle (O 287-1)

Geological conditions. – The locality lies on the west side of the river Glomma, 6 km west-south-west of the centre of Sarpsborg and between 4 and 5 km outside, i. e., to the south of, the Ra ridge (Fig. 13). The land surface rises from the river shore, which is approximately at sea level, to 17.6 m above the river surface at the westernmost and highest boring in the locality, no. 22. Farther to the west the land reaches heights more than 100 m above sea level. It appears from the geological maps (Sarpsborg scale 1:100 000, compiled by P. Mortensen, Th. Thomassen, J. Vogt and N. Wille, issued by Den geologiske Undersøgelse 1879, and the map of the Quaternary of the Oslofjord area, scale 1:250 000, by G. Holmsen and collaborators, 1949, description by G. Holmsen, 1951) that marine clay sediments occur on both sides of the river. In higher parts of the terrain bedrock, archean gneiss, is exposed or covered only by scattered moraine.

The sketch map of figure 14 (from a part of a map of Valle constructed by Nerdrums Opmaaling) gives the topographical details of the locality and the position of the four borings treated. Three of them, nos. 1, 27, and 22, lie on a straight line, approximately in an east-westerly direction. Boring no. 31 is situated 35 m to the north of this line, but is together with the other borings, included in one profile, figure 15. The distance between the outer borings in this profile is almost 500 m. The deepest

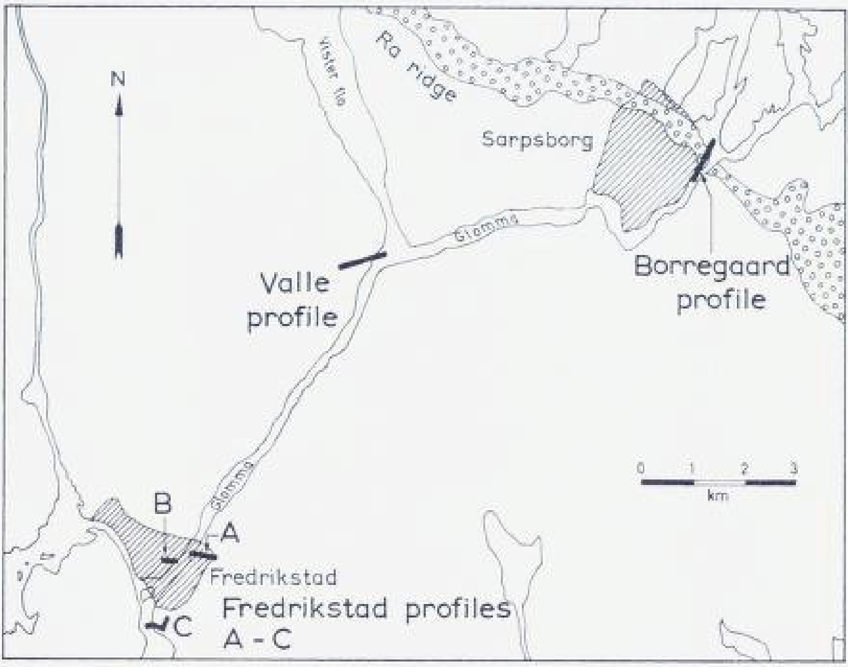


Fig. 13. Position of the described profiles along the lower course of the river Glomma.

Fig. 14. Sketch map of Valle, near the city of Sarpsborg.

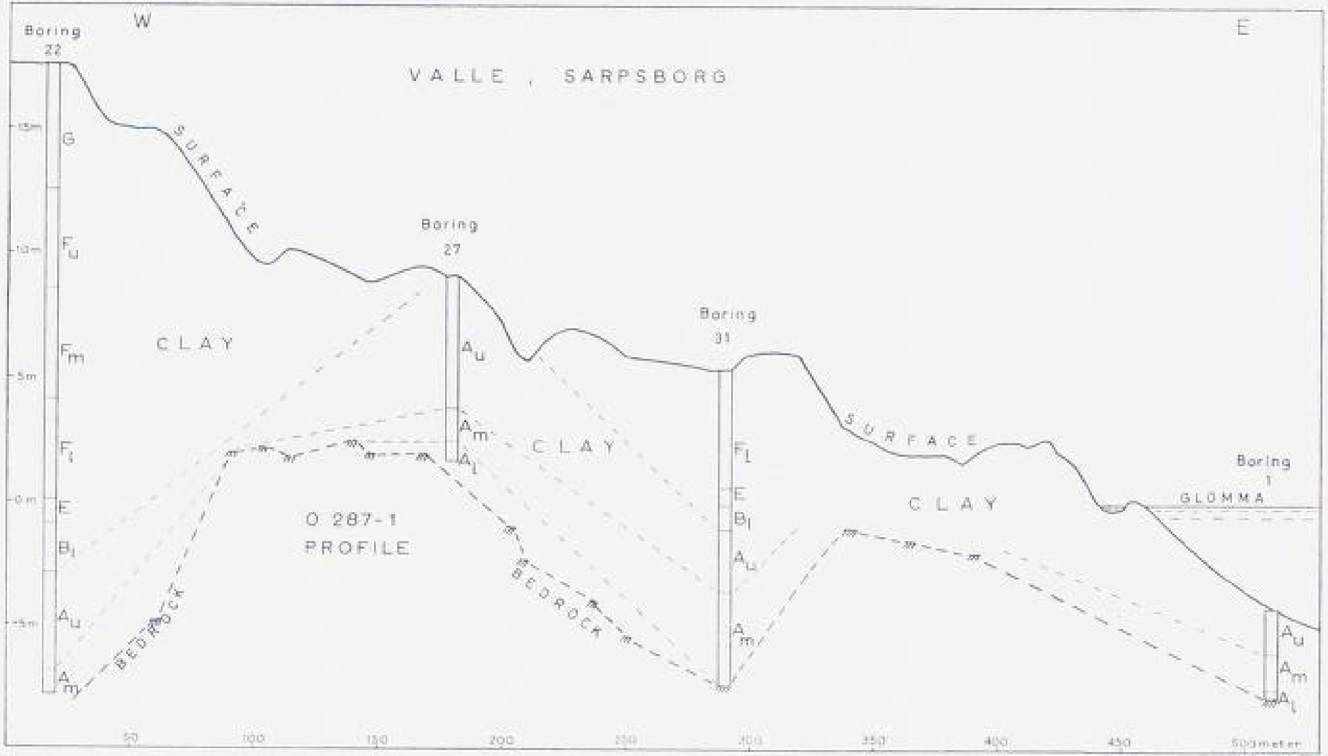


Fig. 15. Profile from Valle, with foraminiferal zonation. (Cp. fig. 14).

boring is no. 22 which reached 25 m under the surface, the shallowest no. 1, which was taken in the river bed and reached bedrock at only 3.7 m under the river bottom.

The position of bedrock in the subsurface is fairly well known from numerous soundings made by the company F. Selmer A/S. In the profile, figure 15, the relief of the surface as well as of the bedrock is strongly exaggerated, the vertical scale being 10 times the horizontal. The bedrock forms two ridges running approximately in a north-north-east direction at distances of 100 m and 300 m from the river. Farther to the west the surface of the bedrock seems to go deeper (Cp. Norwegian Geotechnical Institute, Report O 287–1). Under the river bottom the unconsolidated deposits consist of clay from river bottom to rock surface, thickness varying from 2 m to 11 m. Westward from the river and up to the plateau at about 17.5 m above the river the thickness of the sediment, which is also composed of clay, varies from 4 m to 25 m. In the upper part of the deposit a dry crust is developed. Its thickness is on an average 3 m in the higher parts and 2 m to 0.5 m in the lower parts of the locality.

Of the four investigated borings of this locality boring no. 22 revealed the most complete series of foraminiferal zones.

Foraminiferal zonation. – The surface at *boring no. 22* lies at an elevation of 17.6 m above the river which is practically at sea level. The boring is 25 m deep, it did not reach bedrock but was probably not far from it. The deposit consisted of clay throughout, and a dry crust was developed in the upper 2.5 m. 22 samples were analyzed micropaleontologically. The spacing of the samples appears in the range chart of the boring (Fig. 17) and from the diagram of figure 16. They weighed approximately 100 g each.

In addition to the species plotted in the range chart of figure 17, the following ones occurred in this boring: *Globobulimina auriculata arctica* at 24.6 m depth, *Triloculina trihedra, Oolina borealis, Guttulina dawsoni,* and *Elphidium bartletti* at 24.2 m, *Guttulina lactea* at 24.2 and 17.8 m, *Globobulimina auriculata gullmarensis* at 19.2 m, *Pyrgo comata* and *Oolina lineato-punctata* at 17.8 m, *Miliolinella subrotunda* at 17.8 and 15.2 m, *Lenticulina (R) rotulata* f. *cultrata* at 17.8, 10.1, and 6.2 m, *Angulogerina angulosa* at 17.2 m, *Bolivina albatrossi* at 17.2 and 12.7 m, *Cyclogyra involvens* at 12.7 m, *Textularia sagittula* at 12.7 m and 7.7 m, *Lagena gracilis* at 12.7 and 5.7 m, *Bolivina pygmaea* and *Globigerina bulloides* at 12.2 m, *Buliminella elegantissima, Bolivina* cf. *robusta,* and *Bolivina spathulata* at 10.1 m, *Triloculina tricarinata* at 9.6 m, *Biloculinella depressa* at 7.7 m,

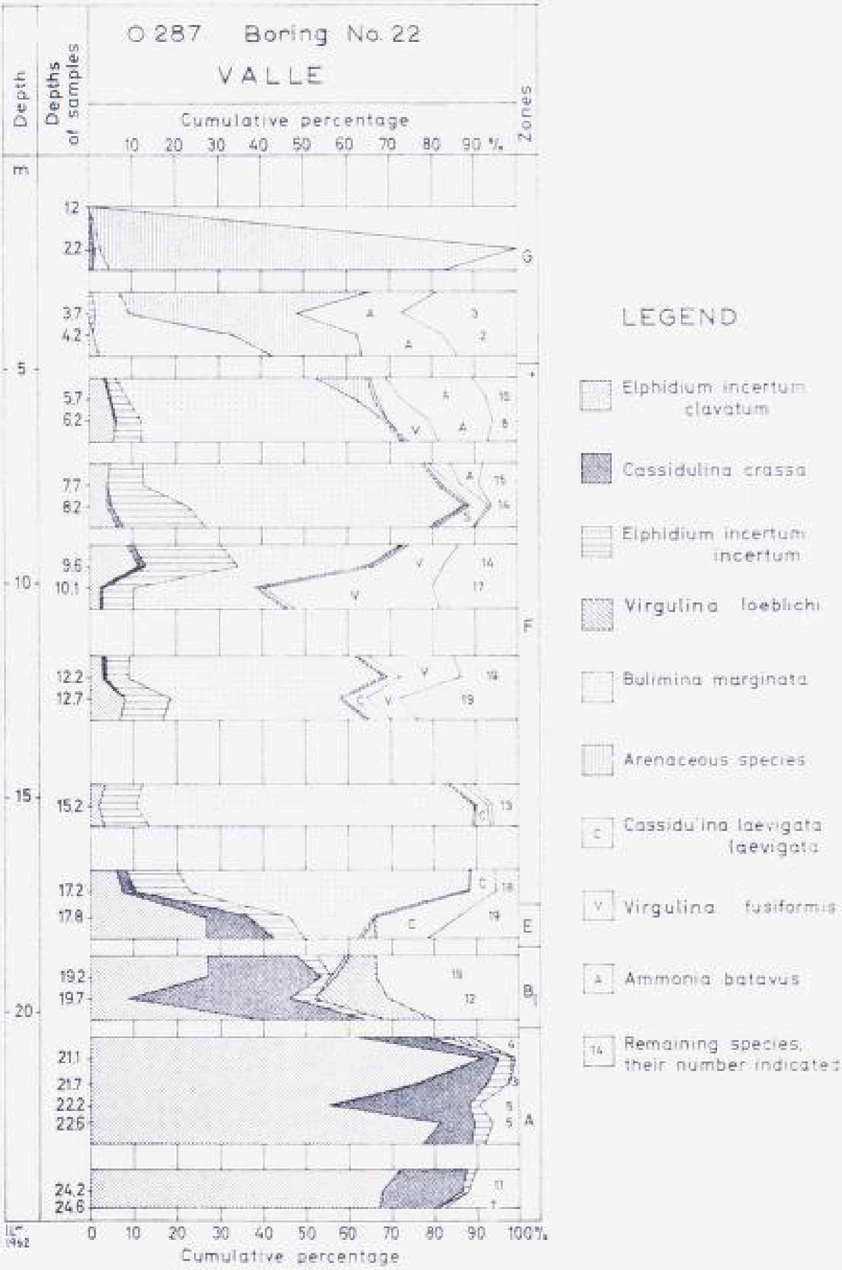


Fig. 16. Distribution and relative frequency of Foraminifera through boring no. 22 at Valle.

Capreolata difflugiformis at 6.2 m and 5.7 m, *Alveolophragmium crassimargo, Adercotryma glomeratum*, and *Virgulina skagerakensis* at 5.7 m, and, finally *Proteonina fusiformis* at 5.7 m and 4.2 m.

The uppermost sample, 1.2 m below the surface, was barren, and the following three, down to 4.2 m, were poorly populated, (78–54 specimens on the 0.10 mm screen). All specimens of Foraminifera were counted in the three last-mentioned samples. In the other samples more than 300 specimens were counted in each, in most of them more than 500. The content (in the fraction 0.10–1.00 mm) of a complete sample was extrapolated from the counted part of the fauna and is indicated in the range chart. As in boring no. 5 from Sandefjord there was a maximum of specimens per sample in subzone F_m. Another maximum occurred in subzone B_l whereas in boring no. 5 of Sandefjord there was only a moderate raise of number of specimens in this subzone. A third peak of the specimen-curve occurred with the deepest sample of the core, in the foraminiferal subzone A_m.

The number of different species (subspecies and forms) was lower than in the Sandefjord boring, 67 as a total of the investigated samples of the boring. The maximum number of species in one sample was 29 whereas in Sandefjord it was 37. But the variation in number of species from sample to sample (see chart) was fairly similar in the two borings.

As to foraminiferal zonation the two borings are easily correlateable. All assemblages from the borings of Sandefjord are recognized in boring no. 22 of Valle, not only by their primary diagnostic constituents, as illustrated in figure 16, but also by some of the more or less accessory species (Cp. range chart, fig. 17).

Subzone A_m is more typically developed in the present boring than in boring no. 5 of Sandefjord. The analysis of the sample from core level 24.6 m of boring no. 22, Valle, is therefore presented below:

Species	Frequency	Percentage
Elphidium incertum clavatum	362	68.0
Cassidulina crassa	71	13.4
Nonion labradoricum	70	13.2
Virgulina loeblichi	8	1.5
Pyrgo williamsoni	6	1.2
Islandiella norcrossi	5	0.9
Virgulina schreibersiana	3	0.6
Cibicides lobatulus	2	0.4
Globobulimina auriculata arctica	1	0.2
Bolivina pseudopunctata	1	0.2
Elphidium incertum incertum	1	0.2
Total	530	99.8

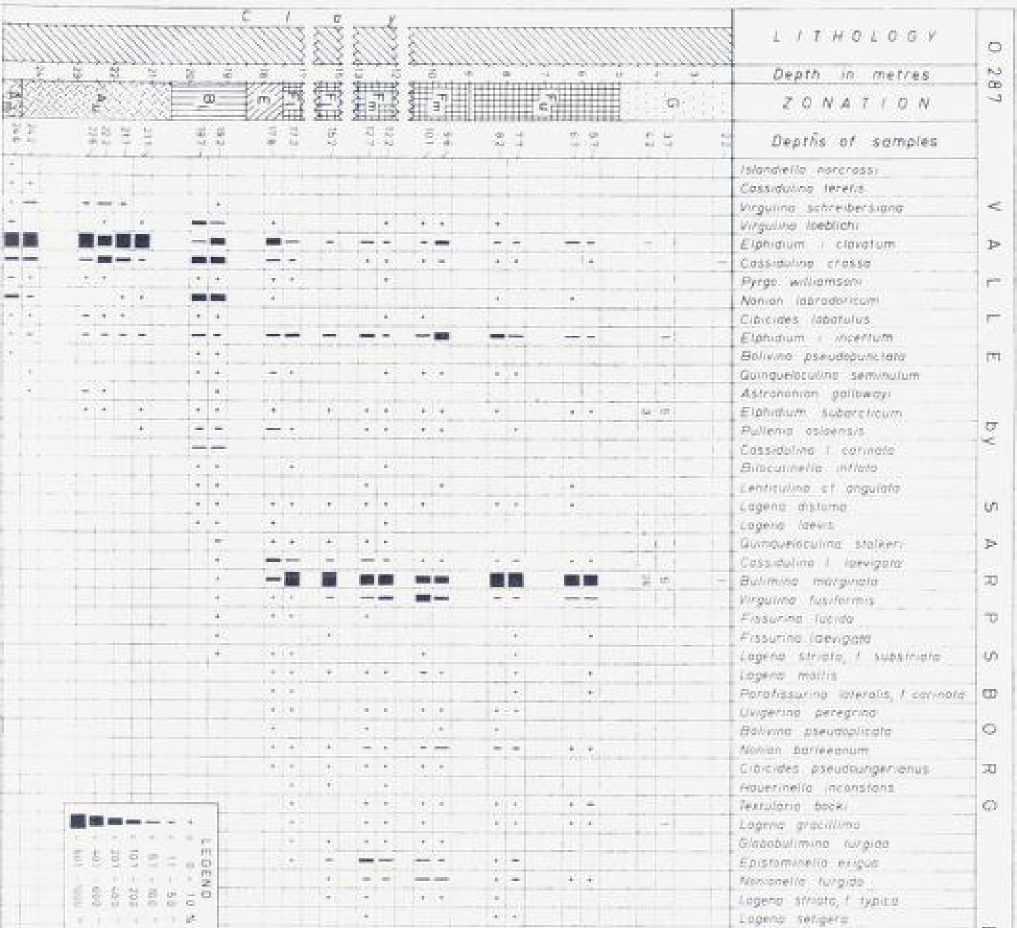


Fig. 17. Range chart for boring no. 22 at Valle.

This count represents $^1/_{30}$ of the sample. *Nonion labradoricum* is remarkably frequent, and as in boring no. 5 of Sandefjord, a similar conspicious frequency of this species is found in subzone B_I. *Islandiella norcrossi* was in both cores found only in the deepest part, and *Virgulina schreibersiana* and *Astrononion gallowayi* seem to be restricted to the deeper parts of the cores. *Quinqueloculina seminulum* is on the whole less frequent in boring no. 22, Valle, than in boring no. 5, Sandefjord. But in both borings it is most common in the upper part of zone E. *Pullenia osloensis* has a similar occurrence. As in boring no. 5, Sandefjord, comparatively high frequencies of *Cassidulina laevigata carinata* are found in subzone B_I. The distribution of *Nonion barleeanum*, *Nonionella turgida*, *Epistominella exigua*, and *Cibicides pseudoungerianus* through zone F of the present boring is also similar to the distribution and frequency of these species in the borings of Sandefjord. However, of zone G only the lower part is represented in boring no. 22 from Valle, the upper part of this zone, with *Miliammina fusca* and *Jadammina polystoma*, is absent. As the surface of the present boring at Valle lies almost 17 m higher than the surface of boring no. 5 in Sandefjord, the present locality was, in the course of isostatic recovery, raised above sea level, and sedimentation stopped there earlier than with the deposit in Sandefjord. This may have some connection with the absence of subzone G_{II}, in boring no. 22, Valle. On the other hand, there occur in the vicinity of this boring some quite large cavities in the terrain, which may indicate olde slide scars. Therefore, the possibility of the uppermost part of the deposit having in such a way been removed cannot be discounted.

A pelecypod fragment of the species *Nuculana pernula* (Müller) occurred in subzone B_I, at core level 19.2 m, a valve of *Portlandia arctica* (Gray) in subzone A_{II}, core level 21.7 m, and a fragment of *Ennucula tenuis* (Montagu) in the same subzone, core level 22.6 m. As in boring no. 5, Sandefjord, scattered occurrence of ostracod valves were noted through the core, except in zone G. Some granules occurred in the three lowest samples of the core.

Boring no. 27 located 160 m east of boring no. 22, is 7.5 m deep and its surface lies 9 m above the river. As with the other borings of Valle, the core consisted of clay throughout. Foraminiferal analyses of 8 samples from this core revealed that *zone A* was the only microstratigraphical unit present. *Elphidium incertum clavatum* dominated the faunas throughout the core, and *Cassidulina crassa* occurred quite frequently in all samples. As with boring no. 22 subdivision into a subzone A_{II} and a subzone A_m was possible, and in addition even a lower subzone, A_l (A_{lower}) was recognized. This latter unit differs from the above-lying, A_m, in showing a low frequency of *Nonion labradoricum* and in having fewer species. The number of species (and forms) reached 12 in one sample, whereas the corresponding figure for subzone A_m in this boring was 20. The foraminiferal assemblage of *subzone A_l* is on the whole similar to that of subzone A_u, as the following example, from core level 7.5 m, boring no. 27, illustrates:

Species	Frequency	Percentage
Elphidium incertum clavatum	260	86.4
Cassidulina crassa	26	8.6
Pyrgo williamsoni	2	0.7
Scutuloris cf. *tegminis*	2	0.7
Nonion labradoricum	2	0.7
Elphidium subarcticum	2	0.7
Elphidium incertum incertum	2	0.7
Cibicides lobatulus	2	0.7
Virgulina loeblichi	1	0.4
Rosalina vilardeboana	1	0.4
Total	300	100.0

This count represents $^1/_7$ of the sample.

The similarity with subzone A_u, expressed also by the very high frequency of *Elphidium incertum clavatum* is so striking that one would think of A_u as a repetition, in one way or another, of A_l. The possibility exists of a landslide having caused this. However, similar faunal changes within zone A also occur in the same succession in boring no. 1, in the river bottom (Cp. profile fig. 15), thus increasing the possibility of this succession being original.

Boring no. 1, 330 m east of boring no. 27, is situated in the river bed, the surface of the clay deposit lying 4.2 m under the water level. From river bottom to bedrock this boring is only 3.7 m deep, and consists of only one unit of the foraminiferal zonation, viz., zone A. However, all the three subzones were recognized in this core, A_u being approximately 2 m thick, A_m a little more than 1 m, and A_l about 0.5 m. Seven samples were examined and the composition of the Foraminifera fauna in three of them, one from each subzone, is presented:

Species	Percentage, subzones		
	A_l	A_m	A_u
Virgulina schreibersiana	0.3		1.5
Virgulina loeblichi	0.3	2.8	0.4
Elphidium incertum clavatum	85.0	51.2	80.1
Cassidulina crassa	11.3	22.4	10.9
Cibicides lobatulus	0.3	0.2	0.4
Nonion labradoricum	1.4	19.2	2.5
Pyrgo williamsoni	0.3	1.9	0.4
Elphidium subarcticum	0.3		0.4
Quinqueloculina seminulum	0.3	0.2	0.4
Quinqueloculina stalkeri	0.6		
Islandiella norcrossi		0.6	
Islandiella teretis		0.2	
Elphidium incertum incertum		0.4	0.7
Astrononion gallowayi		0.2	0.7
Miliolinella cf. *subrotunda*		0.2	
Globobulimina auriculata arctica		0.2	
Triloculina trihedra			1.5
Total	100.1	99.7	99.9

Another sample from subzone A_m of this boring contained 18 different species (and forms), among them *Nonion labradoricum*, *Pyrgo williamsoni*, *Islandiella teretis*, *Islandiella norcrossi*, *Triloculina trihedra*, *Cyclogyra involvens*, *Fissurina laevigata*, *Oolina williamsoni*, *Elphidium bartletti*, arranged in order of decreasing frequency.

Boring no. 31 is situated 35 m north of the profile (Fig. 14), between boring no. 1 and boring no. 27, but has been projected onto the profile. The surface at this boring lies 5 m above the river, and the boring is approximately 13 m deep.

The following foraminiferal zones and subzones were found: F_1 from the surface down to 4.7 m, E, 0.7 m thick, B_1, 1 m thick, A_u, 2.5 m, and A_m, 3.8 m thick.

From the four borings of this profile at Valle it appears that the borderlines between foraminiferal zones and subzones are to a high degree conformable with the surface of the underlying bedrock. The clay sediments have not, during the deposition, filled up the morphological depressions and basins like water, but have mantled the bedrock in such a way that its relief has been reflected in the clay surface probably to a large extent. The present outline of the surface of the deposit is due to erosion, to some extent probably also to landslides, during the negative shift of the shoreline which brought the deposits above sea level.

Boring no. 1 demonstrates that there is at present no *sedimentation* in the river Glomma at this locality. The core is fossiliferous to its top, and the top sample belongs to the preseumably old, zone A, as do the other samples of the core. The possibility that the sediments are wholly re-deposited by the river seems unreasonable because the succession of subzones is the same as found in other borings through corresponding deposits, and because the degree of consolidation of the deposit beneath the river bottom is similar to that of the zone A-deposits in the other borings at Valle. On the other hand, *the erosion* if any, must be very weak in the locality. As previously mentioned the river surface is approximately at sea level at Valle.

The thickness of zones and subzones in the borings at Valle are to be regarded as mere local values, in spite of the remarkably good correspondance which was found between boring no. 22 of Valle and the borings from Sandefjord. It must be mentioned in this connection that subzone F_{II} in boring no. 28, profile A Fredrikstad, had a thickness of 16 m, whereas zone G of boring no. 5 (O 301) at the outermost deboush of the river Glomma, was at least 18 m thick.

Due to the relatively large intervals between the samples in most of the cores, details in foraminiferal zonation may have escaped observation. Even though a considerable number of borings outside (to the south of) the Ra ridge were examined, it is nevertheless not ascertained that the complete series of microfaunal changes has been revealed.

In addition to the borings described above, two more borings, no. 13 and no. 46, from Valle were examined. The terrain at boring no. 13, 170 m southeast of boring no. 22, lay 11.6 m above the river (not on the location map of fig. 14). The boring was 14.7 m deep and contained foraminiferal assemblages belonging to subzone A_{II} and zone F. Boring no. 46 was situated in the river bed, south of boring no. 1, at a depth of 4.0 m. It was 2.8 m deep, and contained Foraminifera of zone A.

Moss (O 38-2)

As it later appears that the deeper parts of the deposits at Sandefjord and Valle have some connection with the conspicious marginal formation called the Ra, the present locality, which is situated close to this formation, should be of some interest. Unfortunately, samples from one boring only were available. Their micropaleontological evidence is consequently limited.

Geological conditions. – The boring (Norwegian Geotechnical Institute, O 38–2, no. 10) lies at the east side of the Verlebukta bay in the city of Moss on the east coast of the Oslofjord. Its surface is situated 28 m above sea level on the distal slope of the Ra ridge which, 250 m east and north-east of the boring, reaches heights of approximately 50 m.

Subsurface investigations carried out by the Norwegian Geotechnical Institute in 1959, revealed sandy and gravelly dry crust clay with a thickness of 3 m at the boring, under this sandy and gravelly clay was found to the bottom of the boring, approximately 20 m below the surface. Below 9 m, quick clay was found. The boring did not reach bedrock. Determination of the bedrock's position was rendered uncertain by large blocks which occurred in the deposit. It was estimated to lie 25 m–28 m below the surface at boring no. 10. Mechanical analysis of three samples from core levels 7.60 m, 13.55 m, and 19.50 m of this boring, revealed median diameters between 0.008 mm and 0.030 mm. They were all of normal sorting.

Foraminiferal zonation. – 11 samples from *boring no. 10* were investigated micropaleontologically. The uppermost was from core level 3.7 m, the deepest from 16.3 m. There was thus no sample from the dry crust, and none from the deepest part of the core, available for foraminiferal research. The samples weighed approximately 100 g each. They all contained foraminiferal assemblages which place them in the upper part of zone A, i. e., in *subzone* A_u.

The foraminiferal population was low in all investigated samples of the core. In total, 13 different species (subspecies and forms) were observed in the core. Most of the samples did not contain more than 5 different species, and only one sample yielded more than 1000 specimens of Foraminifera. Six samples contained only 250 specimens, or even less.

Elphidium incertum clavatum in two of the samples made 79 % of the fauna, in two other samples it occupied slightly more than 82 %. In the rest of the samples this species accounted for more than 85 % of the fauna, in two of these even more than 90 %. Of the other species *Cassidulina crassa* was the only one, together with *E. incertum clavatum*, which occurred in all the investigated samples.

This boring therefore seems to reveal deposits of at least 12.5 m thickness, belonging wholly to subzone A_{II}. Samples above 3.7 m and below 16.3 m were, unfortunately, not available, and quite large intervals occurred also between some of the investigated samples. The possibility of the uninvestigated parts of the core belonging to other units of the foraminiferal zonation cannot be disregarded.

Questions of interest are therefore: In what way do the microconditions project into the Ra ridge? Does it contain Foraminifera? And if so, are the assemblages, or the assemblage, referable to any of the zones or subzones hitherto described? Fortunately, samples from a series of borings through the Ra ridge at Borregaard, Sarpsborg, existed for micropaleontological investigation.

Borregaard (O 204)

Geological conditions. – The locality is situated on the west and northwest side of the water-fall Sarpsfossen in the river Glomma, in the eastern outskirts of the city of Sarpsborg. The regulated water-level of the waterfall is 27 m above sea level. The deposit forms a ridge with nort-west–south-east direction. It is approximately 200 m broad, on the upstream side of the Sarpsfossen it rises gently from the river shore, 27 m above sea level, to 38 m above sea level and then descends steeply to a plateau 17 m above sea level on the downstream side of the waterfall. On the crest of this broad ridge runs the Moss–Sarpsborg–Halden railway, its embankment is built up to 39 m above sea level. A parallel road lies 4–6 m lower, in the steep slope of the ridge. – This feature is a part of the Ra ridge, the most conspicuous marginal glacial formation of Norway. The steep southwestern slope of the ridge in this locality represents the rear part of a slide scar which was formed by a great land slide in the year of 1702, when the farm Borregaard with 14 persons and 200 cows were buried in clay.

The area of investigation is shown in the map, figure 18, which is an extract of the city map of Sarpsborg (Bl. 64).

Along the profile A, marked as a line on the map, and illustrated in figure 19, the Norwegian Goetechnical Institute carried out coring in five bore-holes, nos. 1, 2, 3 a and b, and 5. Their positions are indicated with rings. Another boring was made 170 m northwest of this profile, no. 13. In addition several other borings were brought down without sampling. Great difficulties were encountered by this work because the soil contained considerable amount of coarse particles, gravel and blocks.

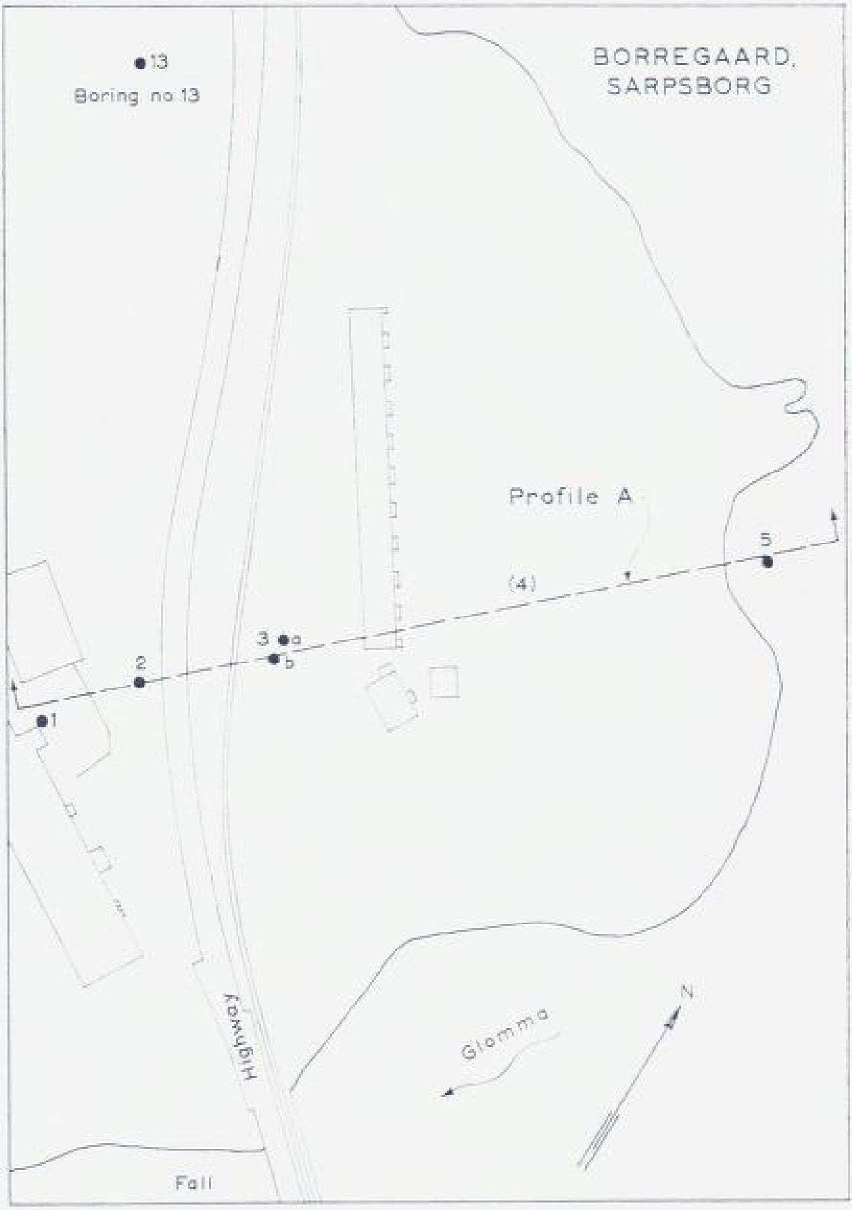


Fig. 18. Sketch map of a part of Borregaard with the investigated borings.

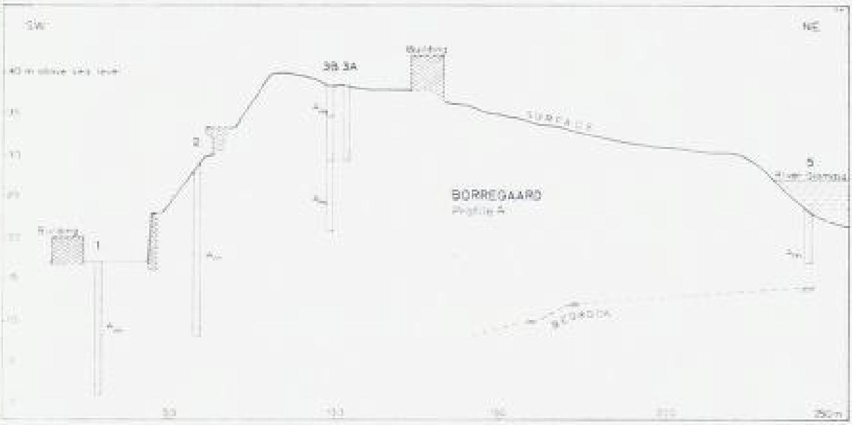


Fig. 19. Profile A, across the Ra ridge at Borregaard (cp. fig. 18).

The subsoil investigations made by the Norwegian Geotechnical Institute revealed stone-bearing clay as the most typical material of the deposit, being more stony in upper parts, less so in deeper. At *boring no. 1*, on the plateau below the southwestern hill of the ridge, under 1 m of filling, there occurred 16 m of clay with stones, at which depth the boring stopped against a large block. A sounding close to this boring was taken down to 20 m without reaching bedrock. The clay was more sensitive in lower parts of the boring, below core level 8 m, than in the upper part. The clay fraction (particles $< 2\ \mu$) amounted to 16–17 % of the soil. Similar conditions were found in *boring no. 2*, which is 20 m deep. A firm and stony clay occurred down to approximately 8 m below the surface, further down the clay was very sensitive. Bedrock was not reached. *Boring no. 3 b*, near the crest of the ridge, is 17.5 m deep. Below 1.4 m filling the soil consists of a firm and partly weathered clay with stones and some interbedded sand layers down to core level 10 m. Below that level the clay was again remarkably sensitive. A sounding down to 21 m below the surface close to boring no. 3 b did not reach bedrock. However, at the point which in figure 18 is indicated with (4), supposed bedrock was found 22 m below the surface. *Boring no. 5*, at the northeastern end of the profile, is located in the river Glomma, a short distance from the bank. Below a 0.5 m thick layer of gravel, the soil consisted of weathered stone-bearing clay approximately down to core level, 2.5 m, thereunder soft clay occurred. The bedrock is situated 9 m under the river bottom at this boring. Similar subsurface conditions were found also with *boring no. 13* outside the profile. This boring is 11.5 m deep, and bedrock was assumed at 13 m below the surface. It is finally mentioned from the Norwegian Geotechnical Institute's report (0204) that at a distance of 85 m northwest of the profile, between boring no. 3 b and point (4), the bedrock was found to lie 35 m below the surface by seismic sounding.

Foraminiferal zonation. – Samples are lacking from the uppermost part of *boring no. 1*, the highest sample originating from core level 4.8 m. Otherwise, of the Borregaard borings, this core was the one most completely sampled for foraminiferal examination. 21 core samples from this boring were analyzed micropaleontologically. All of them contained fossils of benthonic marine Foraminifera. Except for the two upper samples and for the lowest one, where sufficient specimens were not present, 300–500 specimens were counted in each sample. The result of these analyses is given in the range chart, figure 20.

The chart illustrates that the Foraminifera faunas are, from top to bottom of the core, of very uniform composition. *Elphidium incertum clavatum* predominates in all the samples, and *Cassidulina crassa* is abudantly represented in most of them. In addition the most characteristic feature with the microfaunas of this boring is the remarkable abundance of *Nonion labradoricum*, this species occurring frequently or quite frequently in all examined samples. Quite common was also *Virgulina loeblichi*, whereas other species e. g., *Virgulina schreibersiana*, *Elphidium incertum incertum* and *Pyrgo williamsoni*, were more scarce in their representation. The occurrence of *Islandiella norcrossi* in some of the samples is noteworthy. In total, 21 different species and subspecies were observed in this core. Their names and distribution appear from the range chart, figure 20. The maximum number of species in one samples was 12. The number of specimens per sample was low, between 500 and 1000 in most of the samples. The dried samples weighed from 80 g to 150 g each, but a considerable percentage of the weight must be ascribed to stones, granules, and sand of which these samples contained much more than was otherwise common with Late Quaternary core samples investigated from the Oslofjord area. As an example; a sample from core level 3.1 m of boring no. 13, situated 180 m northwest of boring no. 1 may be mentioned. Its dry weight was 160 g. After sieving, the dry weight of stones and granules on the 1.0 mm screen was 65 g and sand on the 0.1 mm screen weighed 40 g. The minerogenic fraction on the two screens thus amounted to almost 66 % of the sample's weight.

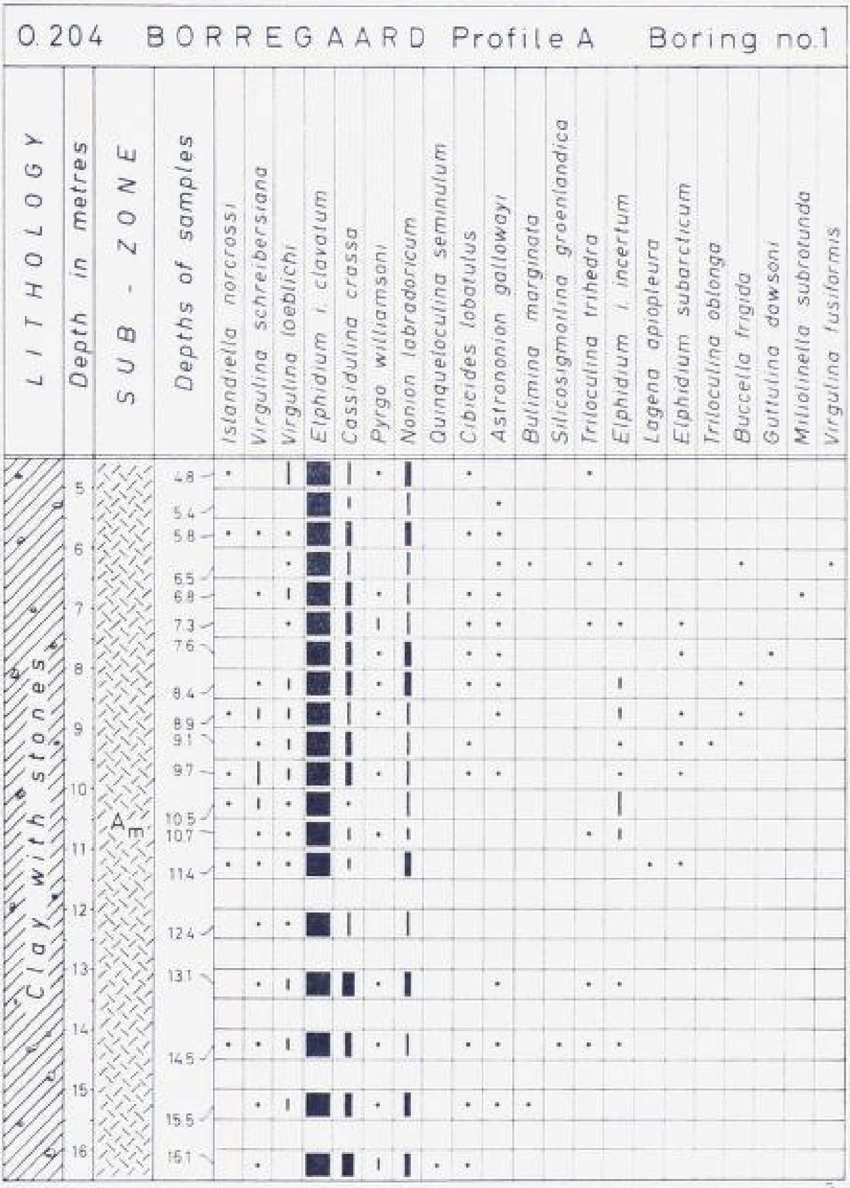


Fig. 20. Range chart for boring no. 1 at Borregaard.

The number of Foraminifera per gram sample must necessarily be low under such conditions.

In boring no. 1 the pelecypod *Portlandia arctica* (Gray) occurred in the coarse fraction of the samples at core levels 7.6 m, 9.1 m, and 13.1 m. Fragments of *Macoma calcarea* (Chemnitz) occurred at core level 7.3 m.

Comparing these results with the foraminiferal assemblages revealed in the borings at Valle, there can be no doubt about the microstratigraphical position of the deposit represented in boring no. 1 at Borregaard. This deposit belongs to one single unit in the foraminiferal zonation of the Late Quaternary sediments of the Oslofjord area, viz., *subzone* A_m.

Nine samples from the lower part of *boring no. 2* were subjected to routine examination only, countings not undertaken. All the examined samples contained Foraminifera, the populations being clearly dominated by *Elphidium incertum clavatum*, and with *Cassidulina crassa* and *Nonion labradoricum* frequently represented. *Islandiella teretis* occurred at core level 10.5 m, otherwise the species were the same as in boring no. 1. Fragments of *Portlandia arctica* were observed at core levels 9.7 m, 10.5 m, 12.7 m, 14.3 m, 15.2 m, and 19.6 m. Fragments of *Macoma calcarea* occurred 19.2 m below the surface. The result of the micropaleontological examination of boring no. 2 is that all examined samples from this core belong to subzone A_m.

Boring no. 3 b, from the crest of the ridge, exhibits almost exactly the same faunal compositions as the two borings dealt with above. 10 samples, from core level 3.1 m to 17.3 m, were analyzed. Four of them, from core level 4.0 m to core level 8.8 m, contained no Foraminifera or other objects of marine origin. On the contrary, plant remains were present in two of them. Two layers of sand and gravel, each 15 cm thick, occurred within that part of the core, and the clay was partly weathered. Some kind of disturbance seems to have taken place. A discussion as to the origin of the plant remains is not taken up here, since they are probably of much later origin than the deposit. The other samples contained Foraminifera. There were counted 500 specimens in each sample except with the top sample, 3.1 m, in which the total number of specimens was 335. The result of the analysis is that *Elphidium incertum clavatum*, *Cassidulina crassa*, and *Nonion labradoricum* dominate the Foraminifera faunas in this boring as in the previous. *Virgulina loeblichi* was commonly represented in all the fossiliferous samples, and *Pyrgo williamsoni* in two of them. *Islandiella norcrossi* occurred in five of the samples. The total number of different species (and subspecies) observed in this core was 16, the maximum number in one sample being 13. As examples of the composition of the Foraminifera fauna the analyses of two samples are given:

The sample at core level 14.6 m of boring no. 3 b contained:

Species	Frequency	Percentage
Elphidium incertum clavatum	347	69.4
Cassidulina crassa	69	13.8
Nonion labradoricum	61	12.2
Virgulina loeblichi	9	1.8
Pyrgo williamsoni	6	1.2
Virgulina schreibersiana	3	0.6
Islandiella norcrossi	2	0.4
Astrononion gallowayi	2	0.4
Cibicides lobatulus	1	0.2
Total	500	100.0

Fragments of *Portlandia arctica* occurred in the coarse fraction (> 1.0 mm) of this sample.

The fossil fauna in the sample from core level 17.3 m had the following composition:

Species	Frequency	Percentage
Elphidium incertum clavatum	350	70.0
Cassidulina crassa	60	12.0
Nonion labradoricum	58	11.6
Pyrgo williamsoni	7	1.4
Virgulina loeblichi	7	1.4
Astrononion gallowayi	6	1.2
Virgulina schreibersiana	3	0.6
Quinqueloculina stalkeri	2	0.4
Islandiella norcrossi	2	0.4
Cibicides lobatulus	2	0.4
Quinqueloculina seminulum	1	0.2
Guttulina dawsoni	1	0.2
Globobulimina auriculata arctica	1	0.2
Total	500	100.0

Fragments of *Portlandia arctica* also occurred in this sample.

In the 9.2 m deep *boring 3 a*, located 10 m north of boring no. 3 b, five samples, from core level 2.3 m to core level 8.3 m, were examined. Only one of these samples, viz., from core level 6.7 m, was without fossils. The examined neighboursamples, core levels 7,4 m and 4.9 m, yielded Foraminifera faunas of subzone A_{III}-composition, and so did the two other samples, from top and bottom of the core. Thus the barren part of the deposit is thinner in this core than in that from boring no. 3 b; its thickness is probably 3 m, whereas it attained 5 m in the neighbouring boring. This part of the deposit was weathered to some degree also in the core of boring no. 3 a.

Five samples from *boring no. 5*, in the northern end of the profile, were analyzed. All of them contained foraminiferal assemblages referable to subzone A_{III}. The deepest samples, which consisted of soft clay, core levels 4.9 m and 5.4 m, contained the richest populations found in samples from Borregaard. The sample from core level 5.4 m exhibited 16 different species and subspecies. A count of 500 specimens from this sample gave the following result:

Species	Frequency	Percentage
Elphidium incertum clavatum	215	43.2
Nonion labradoricum	170	34.0
Cassidulina crassa	67	13.4
Virgulina loeblichi	20	4.0
Pyrgo williamsoni	7	1.4
Islandiella norcrossi	6	1.2
Miliolinella cf. *subrotunda*	3	0.6
Elphidium incertum incertum	3	0.6
Astrononion gallowayi	2	0.4
Quinqueloculina seminulum	1	0.2
Triloculina trihedra	1	0.2
Globobulimina auriculata arctica	1	0.2
Virgulina schreibersiana	1	0.2
Elphidium subarcticum	1	0.2
Cibicides lobatulus	1	0.2
Rosalina vilardeboana	1	0.2
Total	500	100.2

When compared with foraminiferal populations from subzone A_I or subzone A_{II}, this fauna seems to reflect more favourable ecological conditions. In fact, it exhibits an approximation towards the faunal composition met with in subzone B_I, from which, however, it differs i. a., in the presence of *Islandiella norcrossi* and the absence of *Pullenia osloensis* and *Cassidulina laevigata carinata* which are usually common in subzone B_I.

A sample from the upper part of the boring, at core level 3.8 m, which consisted of firm clay, yielded a more moderate population. 500 specimens, approximately accounting for one half of the sample, were counted. The fauna had the following composition:

Species	Frequency	Percentage
Elphidium incertum clavatum	409	81.8
Nonion labradoricum	41	8.2
Cassidulina crassa	28	5.6
Elphidium incertum incertum	11	2.2
Virgulina loeblichi	5	1.0
Pyrgo williamsoni	2	0.4
Elphidium subarcticum	2	0.4
Virgulina schreibersiana	1	0.2
Astrononion gallowayi	1	0.2
Total	500	100.0

As in all other fossiliferous samples from the borings in this profile across the Ra ridge at Borregaard, the fauna of this particular one belongs the foraminiferal subzone A_{III}.

Boring no. 13, 180 m northwest of boring no. 1, is located on the southern, i. e., distal, slope of the Ra ridge. The boring reached bedrock at 13.5 m and was sampled down to 11.4 m below the surface. Of the Ra ridge borings this was thus the only one to yield samples near to bedrock. The terrain surface was situated 24.8 m above sea level at the boring. 13 samples from this boring were subjected to foraminiferal analysis, the highest one from 2.3 m below the surface, while the deepest one was situated at 11.2 m. Samples were lacking in an interval between 3.6 m and 6.3 m below the surface.

All investigated samples contained Foraminifera. 19 different species (and subspecies) were found in the boring, the maximum number of different species in one sample was 13. *Elphidium incertum clavatum* predominated in all the samples, as seen from the range chart of figure 21. Some of the species had only a casual occurrence and were not plotted in the chart, namely *Textularia earlandi, Laryngosigma hyalascidia*, and

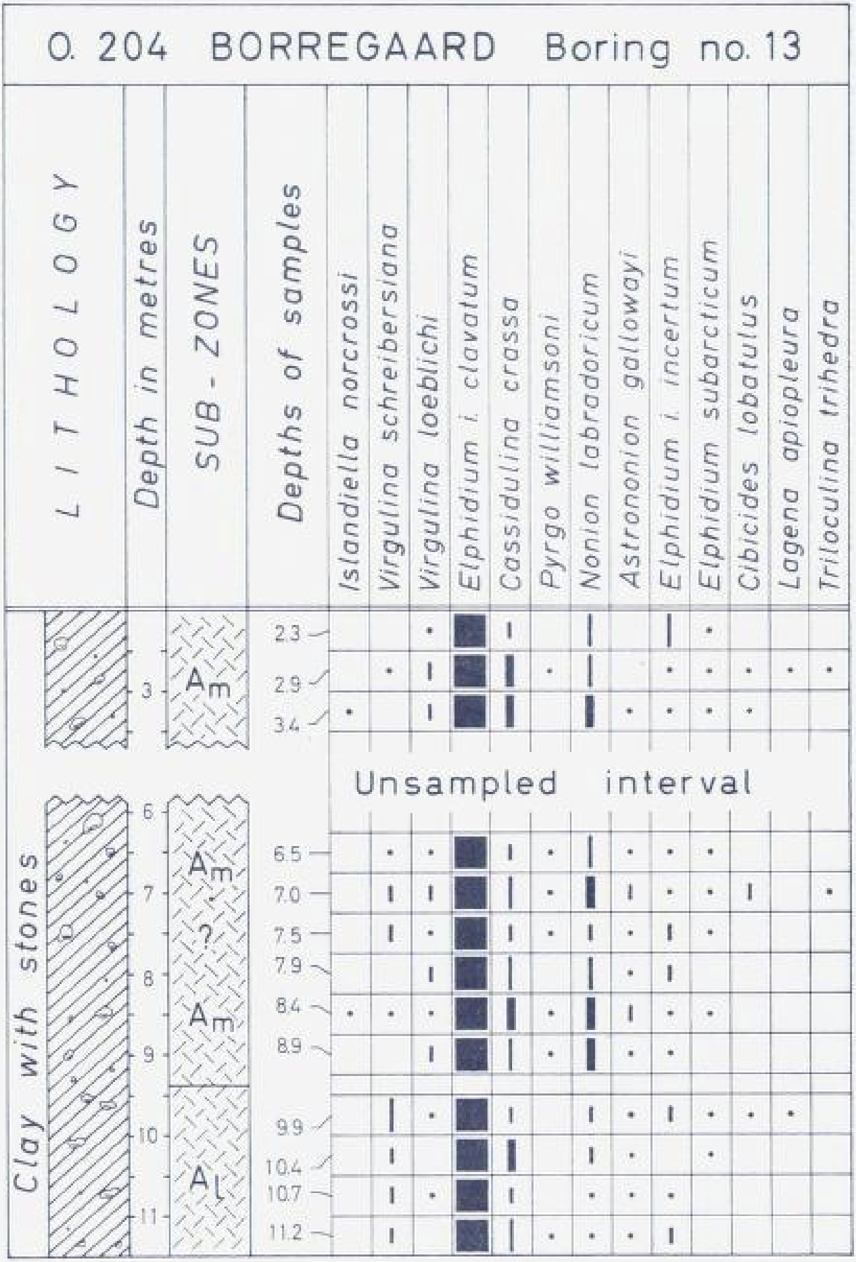


Fig. 21. Range chart for boring no. 13 at Borregaard.

Buccella frigida, which occurred at 9.9 m, *Quinqueloculina stalkeri* which occurred at 8.4 m, *Elphidium bartletti*, at 7.9 m, and *Quinqueloculina seminulum*, which occurred 3.4 m below the surface.

Down to 9 m, or a little deeper, *Nonion labradoricum* was quite frequent, and the assemblages, on the whole, were very similar to those descibed from the other borings at Borregaard, i. e., they can all be classified as *subzone* A_m. Below core level 9 m, however, the representation of *N. labradoricum* became insignificant. The frequency of *E. incertum clavatum* increased to 81–94 % of the fauna, and there was a persistant representation of *Virgulina schreibersiana*. Considering its position below subzone A_m, this lower part of the core is classified as A_l. The Foraminifera fauna of the sample from core level 7.5 m is similar to those of the lower part of the core. It may represent a short reversion to A_l-conditions at an early facies of A_m.

Thus, different from the other Ra ridge cores, boring no. 13 revealed the presence of the foraminiferal subzone A_l in deeper parts of the deposit, towards the underlying bedrock. It is assumed that A_l-layers would probably have appeared also with some of the other southerly Borregaard borings if they had been deeper.

Fredrikstad

Core material from 15 borings, all of them carried out by the Norwegian Geotechnical Institute, were examined (Cp. fig. 22 and p. 41). The height of the boring localities varied from 8.0 m above present sea level (O 168, boring no. 28) to 7.2 m below sea level (O 301–1, boring no. 7). Only four of the borings reached back into zone A, three in the northern and one in the southern part of the town. All the borings revealed remarkably great thickness of the younger parts of the deposits. Five of the borings from the southern part of the town, at the very mouth of the river Glomma, consisted of sediments almost exclusively referable to zone G, which attained a thickness of more than 15 m in this place. The sedimentation rate must have been considerable, and a core from that locality would, even with the common sampling interval of 0.5 m, be expected to reveal details in the faunal development which are lost with similar sampling interval in sediments deposited at a more "normal" rate. On the other hand, redeposition on a larger scale is to be expected with deposits at the mouth of this large river which must have eroded considerable areas of Late Glacial deposits and carried Foramini-

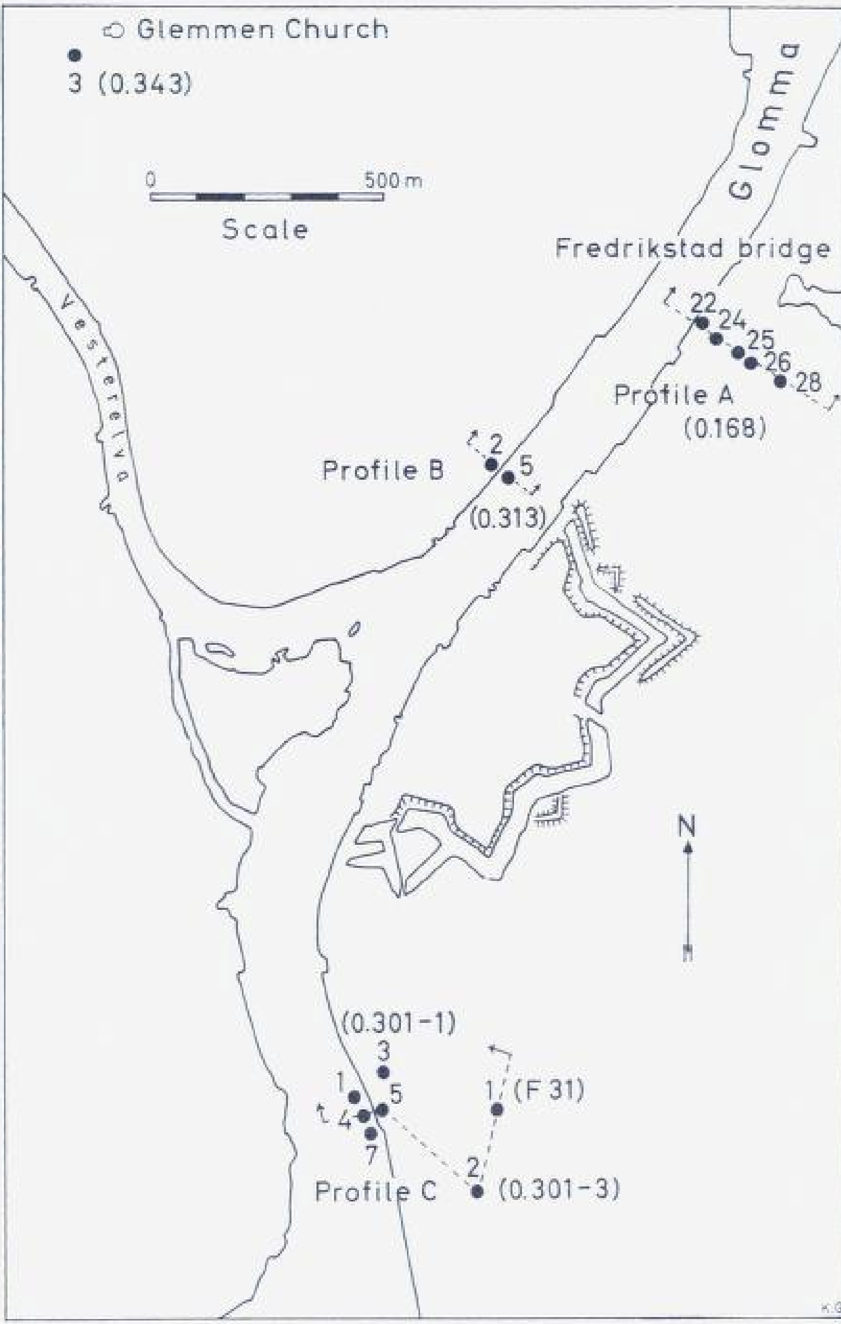


Fig. 22. Location of the investigated borings in Fredrikstad.

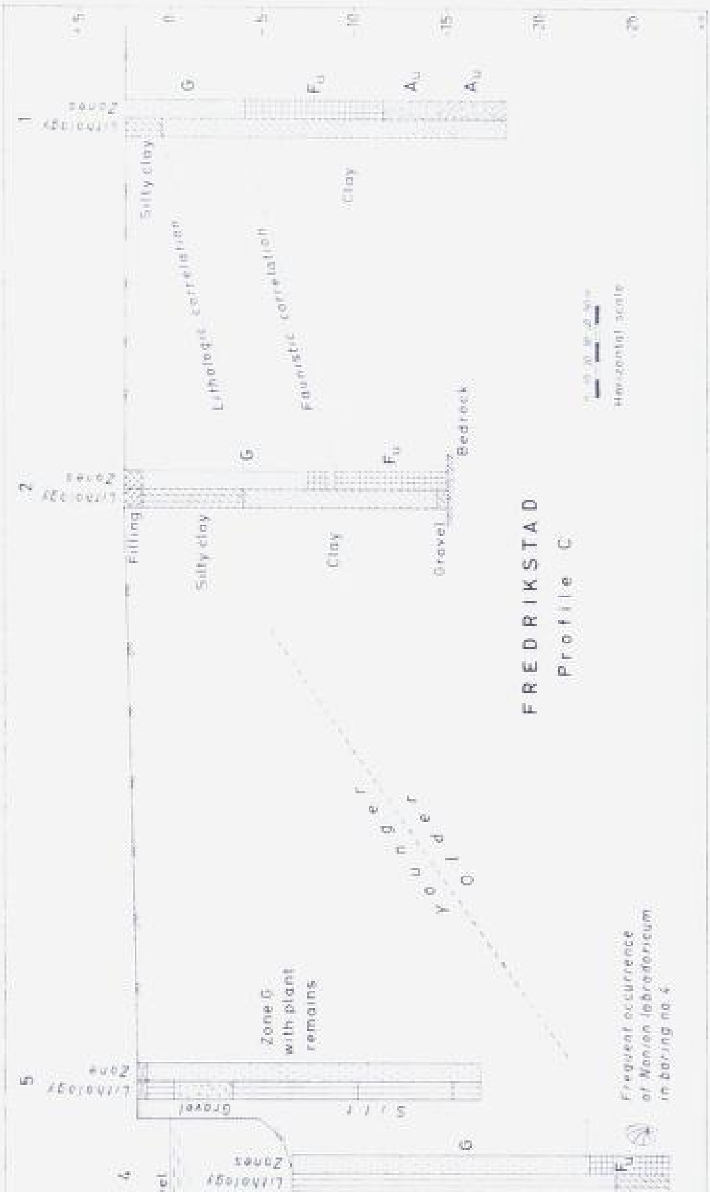


Fig. 23. Profile C, Fredrikstad.

fera from them into Post Glacial layers. The sometimes quite frequent occurrence of *Elphidium incertum clavatum* in zone G-deposits may probably provide evidence of this. Incomplete succession of foraminiferal zones, revealed by many borings in Fredrikstad, indicate that parts of the deposits were, from time to time, carried away by erosion. There occurs in three of the borings a hiatus between zone F and zone A, which may probably be explained in this way.

Ten of the borings are inserted in three profiles, the positions of which are indicated in the sketch map of figure 22. Profile A, (fig. 27) approximately at right angle to the river Glomma on its east side, contains four borings, O 168, nos. 24, 25, 26, and 28. Profile B (fig. 25) joins two borings at the western shore of the river at a distance of 500 m downstream from profile A. Profile C (fig. 23) at the very mouth of the river, consists of four borings on a broken line, 2000 m downstream from profile A. In the following account the latter is treated first.

Profile C, Fredrikstad contains three borings on the flat eastern shore of the river Glomma at its very mouth, south of the old fortress, and one boring into the river bottom just outside the newly built quay there. These borings, with lithology and Foraminifera zonation indicated, are inserted in the profile of figure 23.

Boring no. 2 (O 301–3) of profile C is the one most completely sampled, and is therefore described first. The terrain surface at the borehole lies 2.5 m above present-day water level, which is here equal to sea level, and constitutes an almost horizontal, terrace-like flat. The borehole is situated 170 m from the river. According to the core log, kept by the Norwegian Geotechnical Institute, the uppermost 1 m of the core consisted of filling, underlain by silty clay down to core level 7 m, followed by clay down to bedrock, which was reached at core level 17.5 m. Directly above the bedrock there occurred a 0.5 m thick layer with gravelly clay.

From this core 28 samples, each weighing approximately 100 g in dry state, were analyzed micropaleontologically. All samples, except the uppermost, at core level 2.2 m, contained quite rich populations of Foraminifera. The percentage distribution of Foraminifera in each sample is plotted in the range chart (Fig. 24) for the boring. The count of the uppermost sample, which contained only four specimens, is inserted in the chart with numbers. A total of 105 different species, subspecies and forms were observed in the core samples of this boring. 51 of these, which were comparatively rare, were not plotted in the chart. Their

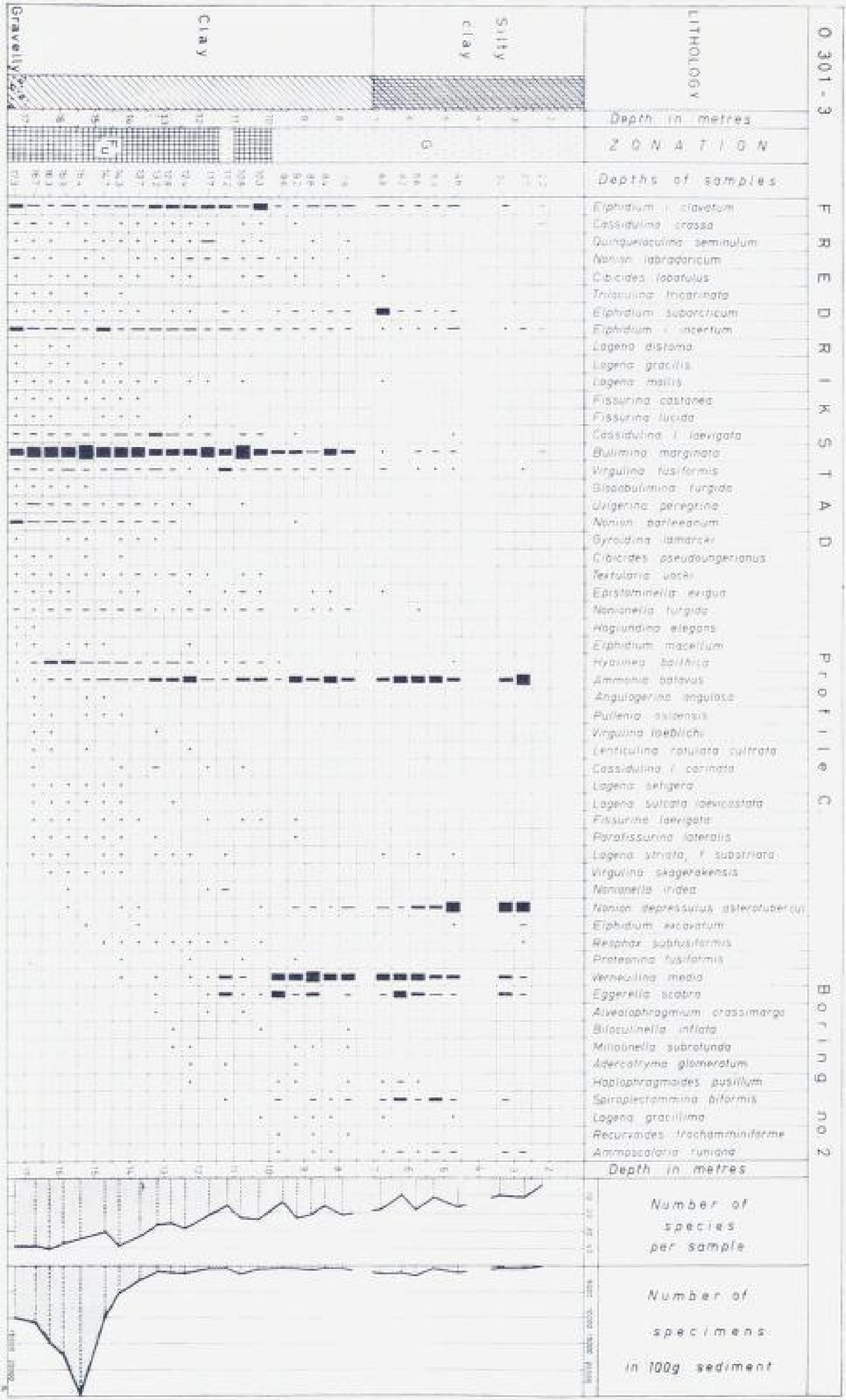


Fig. 24. Range chart for boring no. 2, profile C, Fredrikstad.

names and the depths at which they occurred are listed here: *Lagena laevis*, *Oolina hexagona*, *Oolina squamoso-sulcata*, *Islandiella norcrossi*, and *Astrononion gallowayi* in the deepest sample, *Lagena striata*, forma *typica*, and *Virgulina loeblichi* in the three deepest samples, *Buccella frigida* at 17.3, 16.7, and 15,9 m, *Bolivina pseudoplicata* at 17.3, 15.9, and 13.7 m. *Nodosaria pyrula* at 17.3 and 15.4 m. *Bolivina spathulata* at 17.3 and 13.7 m, *Textularia sagittula* and *Quinqueloculina agglutinata* at 16.7 m, *Lenticulina* (*Robulus*) *limbosus chiriguanoi*, *Amphicoryna* cf. *perversa*, and *Lagena nebulosa* at 16.3 m, *Dentalina trondheimensis* and *Parafissurina lateralis*, forma *carinata* at 16.3 and 14.3 m, *Neoconorbina williamsoni* at 16.3, 15.9, and 13.7 m, *Marginulina glabra* at 16.3, 15.9, 13.7, and 12.8 m. *Quinqueloculina lata* at 15.9 m and 13.2 m, *Dentalina advena* and *Pandaglandulina* sp. at 15.4 m, *Lagena curvilineata* at 14.7 m, *Triloculina trigonula* at 14.7 and 13.7 m, *Lagena clavata* at 14.7 and 9.3 m, *Cyclogyra involvens* at 14.3 m, *Globulina landesi* and *Nonionella auricula* at 14.3 m and 13.7 m, *Rosalina vilardeboana* at 13.7 m, *Lenticulina* (*Robulus*) cf. *gibba* at 13.2 m, *Guttulina lactea* at 13.2, 12.8, and 2.7 m, *Liebusella goësi* and *Globulina inaequalis* at 12.8 m, *Pyrgo williamsoni* at 12.8, 12.4, and 7.9 m, *Alveolophragmium nitidum* at 12.4 m, *Massilina secans* at 11.7 m, *Reophax pilulifera* at 11.7 and 5.8 m, *Hauerinella inconstans*, *Dentalina drammenensis*, and *Sigmomorphina undulosa* at 10.3 m, *Triloculina oblonga* at 10.3, 8.4, and 7.9 m, *Reophax atlantica* and *Morulaeplecta bulbosa* at 8.8 m, *Trochammina intermedia* at 8.8 m and 3.4 m, *Miliammina fusca* at 8.4 and 5.8 m, *Psammosphaera fusca* at 7.9 m, *Trochammina adaperta* at 6.8 m and, finally *Trochammina ochracea* and *Textularia contorta* at 5.8 m.

Two assemblages, F and G, were present; of F only the upper part, subzone F_u was represented.

A shallowing in the locality during sedimentation of this 17.5 m thick deposit is illustrated by the occurrence of more shallow-water species in the upper part of the core than in the lower. As such are mentioned *Ammoscalaria runiana*, *Nonion depressulus asterotuberculatus*, and *Ammonia bavatus*, all of which increase in frequency towards the top of the core. *Spiroplectammina biformis*, which is also absent in the lower part of the core, exhibits maximum frequency at 5 to 7 m depth, further upwards its abundance decreases, until at 2.7 m it is again absent. Höglund (1947, p. 164) found this sepcies, in Recent bottom samples from the Gullmarfjord, most abundant between 16.5 m and 22 m depth. Christiansen (1958, p. 64) found it between 30 m and 149 m in bottom samples from the Drøbaksund, in limited numbers. *S. biformis* seems not to thrive in the shallowest environment. The frequency distribution of *Verneuilina media* and *Eggerella scabra* in the core is in good agreement with that of *S. biformis*, and with their Recent bathygraphic distribution in the Drøbaksund and in the Gullmarfjord. *Verneuilina media* occurred below 10 m depth and in the Gullmarfjord was found most commonly between 34 and 67 m, whereas *Eggerella scabra* was most abundant between 10 m and 70 m in the Drøbaksund and down to 60 m in the Gullmarfjord. Both of these species, especially *E. scabra*, can thrive in shallower water than *S. biformis*, and, accordingly, retain their high frequency further up in the present core than the latter species.

On the other hand, some species were not able to live in the shallower water in which the upper part of the present sediment was deposited. One such species is *Nonion labradoricum*, which occurs in the deeper part of the core and disappears in the upper. Others, of the more common species, are *Uvigerina peregrina, Cassidulina laevigata laevigata*, and *Hyalinea balthica*. Almost all species of *Lagena* and *Fissurina* are limited to the lower part of the core, an exception being *Lagena striata*, forma *substriata*. *Nonion labradoricum* is present in most samples approximately up to core level 8 m. Between 12.5 m and 10 m core level it is less rare than in the other samples. It was probably about to flourish as the water became too shallow for its existance. This species is frequent in the present Oslofjord, and was recorded by Kiær (1900) as *Nonionina scapha*. The shallowest bottom on which he obtained it, was 18 m. His dredgings in water shallower than that were, however, very few.

The range chart (Fig. 24) for the present boring (No. 2, profile C, Fredrikstad) reveals peculiar trends in the frequency distribution of *Verneuilina media* and *Eggerella scabra*. *V. media* has its first appearance at core level 14.3 m, while *E. scabra* first appears at core level 13.2 m. Both are very scarce up to 11.5 m. At 11.2 m, however, they become frequent, *V. media* accounting for 11.5 % of the fauna and *E. scabra* for 16.8 %. Only one specimen of *Hyalinea balthica* occurred in that sample and *Cassidulina laevigata laevigata* was absent. Simultaneously *Spiroplectammina biformis* appeared for the first time. A marked decrease in the number of specimens and also in number of species is observed. This sample would be classified as zone G. In the two samples, lying immediately above, however, the analyses reveal assemblages again typical for subzone F_{II}. More specimens of *Hyalinea balthica* are present and *Cassidulina laevigata laevigata* reappears. At core level 9.6 m the zone G-assemblage is re-established and continuously developed further upwards.

This oscillation in the vertical frequency distribution may indicate a deepening of the water at core level 11 m, interrupting the otherwise continuous shallowing-up. Such an eventual transgression lasted only for the time required for the deposition of 1 m of sediment, from approximately 11 m core level to 10 m. The bathygraphic considerations outlined above may give a slight indication of the age of this event. The present terrain surface at boring no. 2, 2.5 m above present-day sea level, does not represent the sea level contemporaneous with deposition of sediments now found 10–11 m deep in the borehole. Even the uppermost investigated samples of the core were probably deposited at some depth greater than indicated by their level in the core. The water depth at the time of the first flourishing of *Verneuilina media* and *Eggerella scabra* was probably not less than 20 m. The shoreline would thus be situated at least 11–12 m above the present, i. e., we would be back in Sub-Boreal time, at least.

Another possible explanation of the break in the frequency distribution is that it is caused by displaced material. Material somewhat older than that at core level 11.2 m may have slid down upon it. A transgression would be expected to be indicated also in near-by borings, e. g., in boring no. 1 of profile C. This was not the case. But, on the other hand, core samples were, unfortunately, lacking in the interval at which such and indication would be expected.

Boring no. 1 (F 31) of profile C in the city of Fredrikstad penetrated lithologically similar sediments as boring no. 2, only that the border between clay and silty clay was situated somewhat higher in the core of boring no. 1. At the same time the borderline between zone F and zone G of the Foraminifera zonation was situated correspondingly higher in this core. Boring no. 1 was the only one in profile C which proved the presence of old sediments in the subsurface, zone A-assemblages occurring in the lower part of the core. The subzones A_u and A_m were present, not A_l. However, the boring did not reach bedrock.

Boring no. 4 (O 301–1) of profile C is located in the bed of the mouth of the river Glomma, 6.6 m below sea level. The major part of the core consisted of silt, below this a silty clay, of the same type as in the upper parts of borings nos. 1 and 2, occurred.

Most of the samples from the upper part of boring no. 4 contained zone G-assemblages, but in between there were some with zone F-assemblages. Most probably this is an indication of secondary disturbance of the sedimentary succession, which is reasonable in view of the location of the boring close to the steep river shore, only a few metres from the quay. In the lower part of the core zone G is persistent until subzone F_u takes over at core level 16 m. This zone border, however, seems not to be time-correlatable with the border G/F in the borings nos. 1 and 2.

There is, namely, a remarkably high frequency of *Nonion labradoricum* in the F_u-samples as well as in the lower G-samples of boring no. 4. As an example is presented the analysis of sample O 301–1–40 at core level 20.3 m:

Species	Frequency	Percentage
Elphidium incertum clavatum	129	20.5
Nonion labradoricum	122	19.4
Virgulina fusiformis	112	17.7
Bulimina marginata	90	14.3
Elphidium incertum incertum	73	11.5
Verneuilina media	43	6.8
Ammonia bavatus	29	4.6
Nonion depressulus asterotuberculatus	8	1.3
Cassidulina laevigata laevigata	6	0.9
Proteonina fusiformis	3	0.5
Nonionella turgida	3	0.5
Hyalinea balthica	3	0.5
Quinqueloculina lata	2	0.3
Elphidium subarcticum	2	0.3
Dentalina advena	1	0.2
Lagena mollis	1	0.2
Lagena striata, f. substriata	1	0.2
Pullenia osloensis	1	0.2
Epistominella exigua	1	0.2
Total	630	100.1

This flourishing of *N. labradoricum* is hardly accidental, since it occurs in seven neighbour-samples in the lower part of the core. On the contrary, it seems reasonable to talk about a *Nonion labradoricum layer* in this core. *N. labradoricum*, which may occur in all marine Late Quaternary sediments of the Oslofjord area, except those deposited in very shallow water, and which flourished in subzone A_{III} and subzone B_I, may have had a third flourishing period in more recent times. Its quite moderate representation in the higher-lying borings, no. 2 and no. 1, of profile C probably indicates that those parts of the deposits are older than those penetrated by boring no. 4. Or, at least, that the ancient sea bottom at

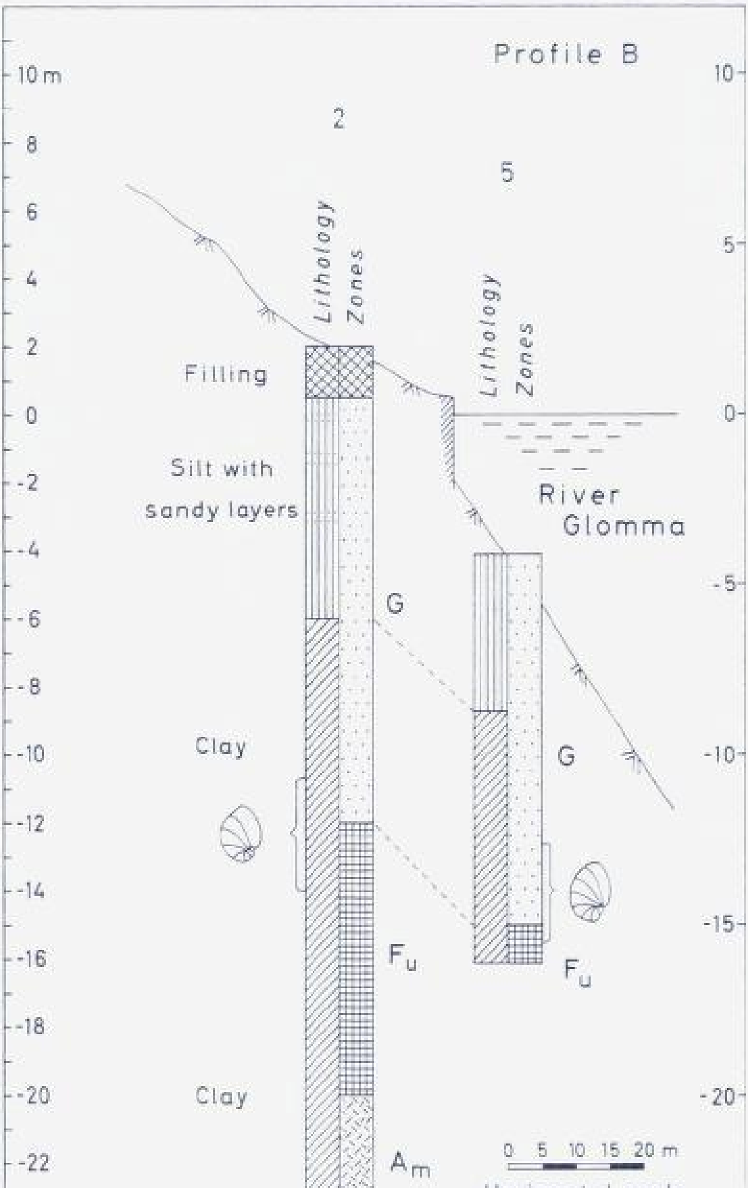


Fig. 25. Profile B, Fredrikstad.

the borings nos. 1 and 2 had already become too shallow for *N. labradoricum* as the time of its third flourishing arrived. The lithology of the mentioned cores provides some support to this view. The silty clay which occurs towards the top of the cores of boring no. 1 and no. 2 is overlain by 17.5 m silt in boring no. 4. This silt occurs also in boring no. 5, but is absent in the two other borings (Cp. fig. 23). This would mean that the transition between zone F and zone G in boring no. 1 and no. 2 is older than the faunistically corresponding transistion in boring no. 4.

Profile B, Fredrikstad, comprises two borings, one on the sloping west side of the river and one into the river bottom just outside. The profile is given in figure 25, its position appears from figure 22.

Boring no. 2 (O 313) of profile B is that located on land. The terrain surface at the boring lies 2.0 m above the mean water level of the river, which is approximately equal to mean sea level, and the boring was 26 m deep. Bedrock was found 27.2 m below the surface at this locality. The uppermost 1.5 m of the core consisted of filling underlain by 6.5 m of silt with sandy layers. Below core level 8.0 m the deposit consisted of clay. The deepest part, from 25.5 m to 26.0 m, was sandy. This boring was incompletely sampled, but a foraminiferal range chart (Fig. 26) was nevertheless constructed from analyses of the 21 available samples. Their spacing appears in the chart. All of them contained Foraminifera, totalling 99 different species, subspecies and forms. In addition to the Foraminifera entered in the chart, the following were observed in the boring: *Triloculina oblonga*, *Triloculina trihedra*, and *Rosalina vilardeboana* in the two deepest samples, *Miliolinella* cf. *subrotunda* and *Lagena semilineata* in the deepst one, at 25.6 m, *Quinqueloculina stalkeri* at 25.6 and 23.6 m, *Lenticulina* (*Robulus*) cf. *angulata* and *Fissurina lagenoides*, forma *tenuistriata* at 24.2 m, *Islandiella teretis* and *Patellina corrugata* at 24.2 and 23.6 m, *Oolina melo* and *Globobulimina auriculata arctica* at 23.6 m, *Textularia sagittula*, *Lenticulina* (*R.*) cf. *gibba*, *Lagena sulcata laevicostata*, *Astrononion tumidum*, and *Buccella frigida* at 21.2 m, *Biloculinella depressa*, *Rosalina globularis*, *Bolivina pseudoplicata*, and *Bolivina albatrossi* at 21.2 and 20.7 m, *Fissurina laevigata* at 21.2, 20.7 and 18.6 m, *Oolina williamsoni* at 21.2 and 17.2 m, *Lagena striata*, forma *typica* at 21.2 and 15.7 m, *Cyclogyra foliacea*, *Lenticulina* (*R.*) *limbosus chiriguanoi*, *Lenticulina* (*R.*) *rotulata* f. *cultrata*, *Nodosaria pyrula*, *Dentalina trondheimensis*, *Lagena clavata*, *Lagena laevis*, *Lagena setigera*, *Lagena sulcata sulcata*, *Fissurina marginata*, *Angulogerina angulosa*, *Valvulineria minuta*, and *Elphidium macellum* at 20.7 m, *Neoconorbina williamsoni* at 20.7 and 18.6

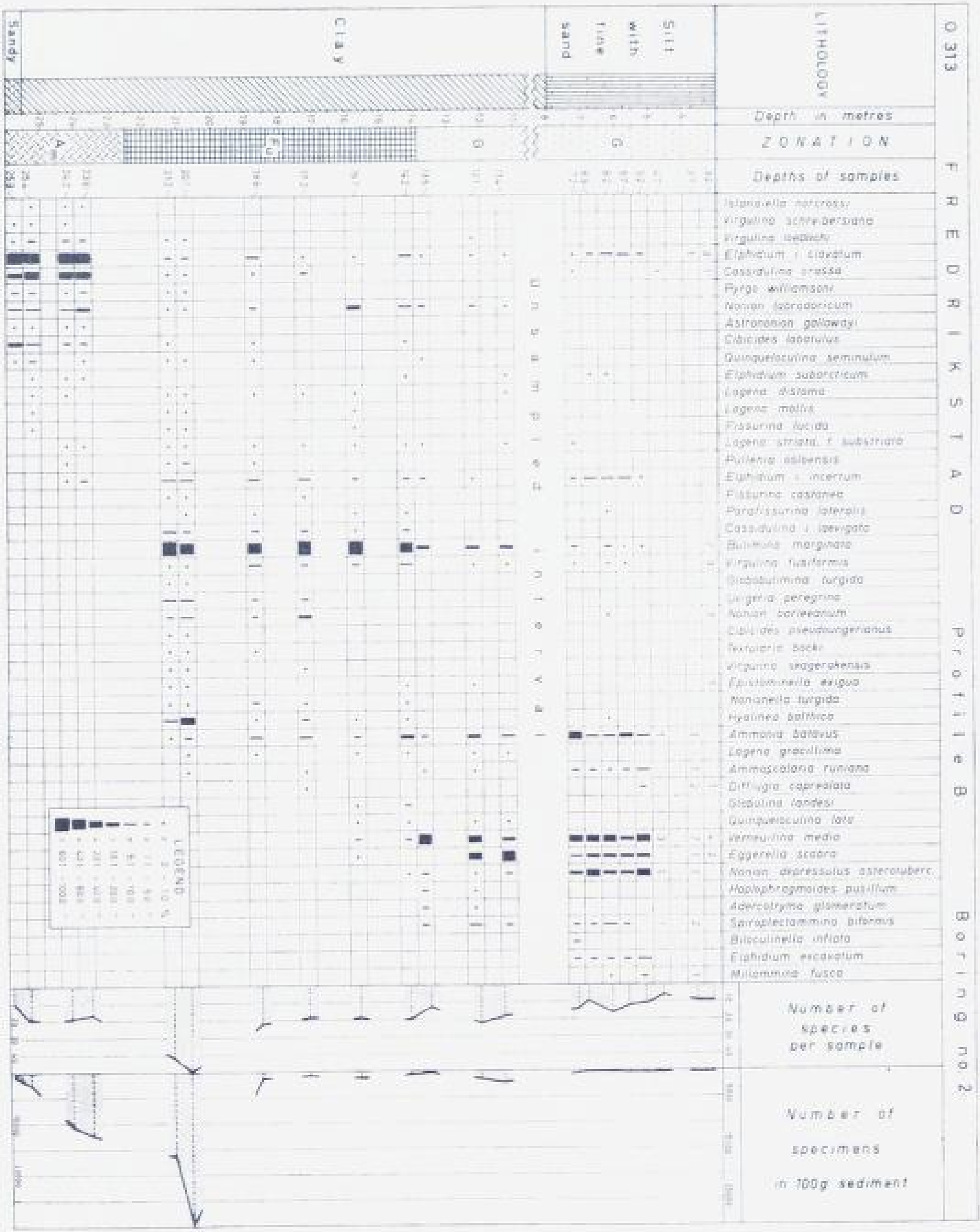


Fig. 26. Range chart for boring no. 2, profile B, Fredrikstad.

m, *Bolivina spathulata* at 20.7 and 17.2 m, *Parafissurina lateralis*, forma *simplex* and *Nonionella iridea* at 18.6 m, *Globulina landesi* at 15.7 and 14.2 m, *Guttulina lactea* at 14.2 m, *Reophax subfusiformis* at 13.6, 11.9, and 11.4 m, *Alveolophragmium crassimargo* at 11.9 and 11.4 m, *Trochammina intermedia* at 11.4 and 4.7 m, *Recurvoides trochamminiforme* at 11.9 m, and *Buliminella elegantissima* at 5.7 m. Three units in the Foraminifera zonation were represented, viz., G, F, and A; of F only subzone F_u and of A only subzone A_m. The zonation has thus much in common with that of boring no. 1 of profile C, except that zone G is thicker in the present core and that a layer with remarkably high frequency of *Nonion labradoricum* occurs towards the top of subzone F_u and in the lower part of zone G. This would, according to the considerations made about boring no. 4 of profile C, indicate that the transition F/G also in this boring is younger than the corresponding transition in the borings nos. 1 and 2 of profile C.

Boring no. 5 (O 313) of profile B is located into the river bottom, the top of the boring being situated 4.1 m below mean water level. This boring was 12 m deep and reached through zone G into the uppermost part of subzone F_u. Also that boring revealed a distinct *Nonion labradoricum layer* at the transition between F and G.

Profile A, the northernmost investigated profile in the city of *Fredrikstad*, comprises four borings on the east side of the river Glomma, located at Fredrikstad bridge. Lithology and Foraminifera zonation are indicated in the profile of figure 27.

Boring no. 28 (O 168) is 25.2 m deep, its surface is situated 8 m above sea level (water level). It did not reach bedrock, and only young sediments are represented, viz., zone G and zone F. Indication, possibly of a depth oscillation, occurs at core level 10 m. The sample at core level 11.65 m reveals the transition between F_u and G, sample 11.15 m must be classified as zone G, but at 9.65 m an F_u-assemblage reoccurs. On the other hand, fissures occurred in the sediment at these levels, secondary disturbance of the original sedimentary succession is, therefore, not precluded. *Boring no. 26* is 18.5 m deep, its surface being situated 1.8 m above sea level. Besides the zones G and F also subzone A_m was represented. *Boring no. 25* had its surface situated 0.9 m above sea level, and was only 8.9 m deep. Zone G and subzone F_u occurred. *Boring no. 24*, nearest to the river, reached bedrock 19.8 m below the terrain surface which was situated 1.5 m above water level. The following zones and subzones were present: G, F_u, F_l, B_l, A_u, and A_m.

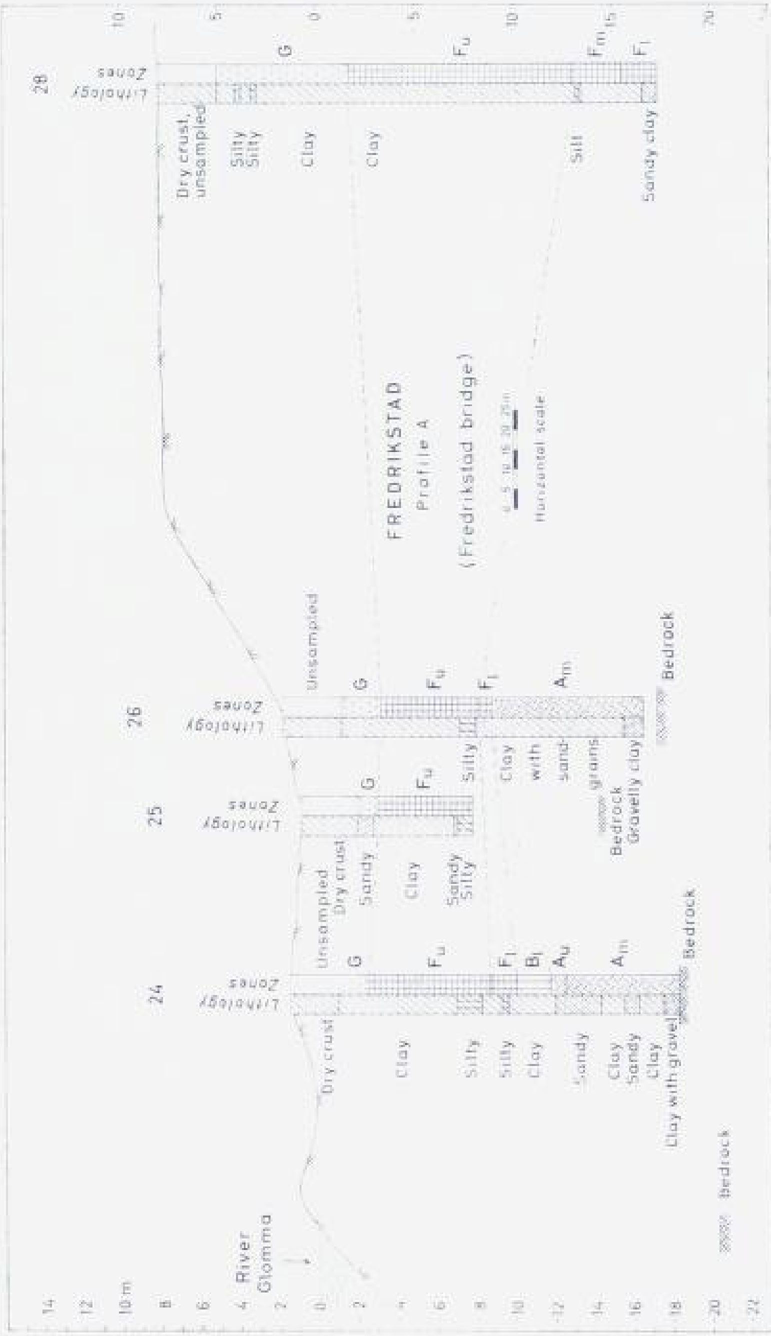


Fig. 27. Profile A, Fredrikstad

None of these borings revealed any young layer with remarkable high frequency of *Nonion labradoricum*. Some specimens of this species occurred at the transition between zone F and zone G in boring no. 28, but were not nearly as frequent as in the previously described *Nonion labradoricum* layers. As it appears from figure 27, the present terrain outline of the western part of the profile is probably the result of erosion. The original surface was probably 8 m above present sea level at the borings nos. 24–26 as well as at boring no. 28. This is indicated also by the position of the borderline between zone G and F in the four borings. The borings in Fredrikstad thus seem to indicate that a late *Nonion labradoricum layer* probably does not occur in deposits with the present surface higher than 2.5 m above sea level (borings nos. 1 and 2 of profile C, and all the borings of profile A).

Boring no. 3 (O 343), at *Glemmen Church*, Fredrikstad, confirms the above result. The terrain surface is there situated 6.7 m above sea level and the boring was 7 m deep. Bedrock was found 10.5 m below the surface. Only zone G and the upper part of zone F, of the Foraminifera zones, were present; the zone border was situated 4 m below the surface. The fossil faunas were quite rich, especially the F_u-faunas, with approximately 30 different species and forms per sample, and about 6000–10 000 specimens per 100 g sample (dry weight). But of *Nonion labradoricum* no sample contained more than 2 specimens.

Onsøy

This locality is situated 7 km west of Valle and approximately 8 km outside, southwest of, the Ra ridge. Five borings were carried out by the Geotechnical Laboratory of the Norwegian Railroads. One was 18 m deep, one 14 m, and three 10.5 m deep. The two deepest comprise slide material in their upper parts. Only the deepest boring penetrated the old subzone A_u and reached into subzone A_m. None of the borings reached bedrock. Zone B was not observed, but samples were lacking in the interval in which that unit would be expected. Zone E was present, its thickness, however, undetermined. Subzone F_u was 7 m thick and zone G 4 m. In the 14 m deep boring subzone F_l was 3 m thick and subzone F_m also 3 m. The three 10.5 m deep borings only reached into subzone F_m. *Uvigerina peregrina* was frequent in the lower parts of subzone F_u where it occurred together with *Höglundina elegans*.

In the lowest-lying boring, no. 21, the surface of which was situated

3.3 m above sea level, there was found in the upper part of subzone F_u, at core level 6.0 m, a certain increase in the frequency of *Nonion labradoricum*, however, not on a scale comparable with that of the *Nonion labradoricum layer* described from Fredrikstad. *Elphidium incertum incertum* was quite frequent in all F and E samples.

Halden (O 953)

The city of Halden is situated at the right-angled junction between the sound of Svinesund and the Iddefjord east of the mouth of the Oslofjord. This waterway forms a furrow of considerable depth in the gently sloping peneplain of the area. Archean rocks outcrop, or are more or less moraine-covered, on both sides of the furrow. The Ra ridge is found approximately 35 km northeast of the city, running in NW–SE direction. 4 km east of the city the Femsjø lake is dammed by the Ra ridge, and there an apparent bipartiation of the ridge occurs, a second ridge running towards the SSE (Fig. 28).

Samples from the lower part of a boring in the sea bottom of the harbour of Halden, north of the northern end of the island of Sauøya, were micropaleontologically investigated. The boring, no. 1, reached bedrock 40.2 m below the sea bottom which was situated 6.1 m below sea level. Samples were available only from core level 20 m downwards. They were handed over to the author by the Norwegian Geotechnical Institute, who carried out that part of the boring. The core log reports clay from core level 20.0 m to core level 24.8 m, underlain by fine sand to 26.0 m, then silty clay down to 26.8 m, then 8 m of fine, somewhat silty, sand down to approximately 35 m, then 0.5 m of silty clay, and from 35.5 m to bedrock again clay. This clay contained some sand just above the bedrock. The sediment above core level 20 m was previously geotechnically investigated by the Norsk Teknisk Byggekontroll. They found silty sand and clay up to core level 7 m. Above that level the major part of the deposit consisted of saw dust. Samples of the sediment above core level 20 m were not available when the present investigation took place. The particle size distribution was analyzed in eight samples from the lower part of the core (Norwegian Geotechnical Institute, Report O 953, 2. Nov., 1960), and the median diameter (50 % passage), read from the grade size distribution curves, is plotted to the left in the present range chart for boring no. 1, Halden (Fig. 29).

Foraminifera counts of 13 samples, weighing from 100 g to 180 g in

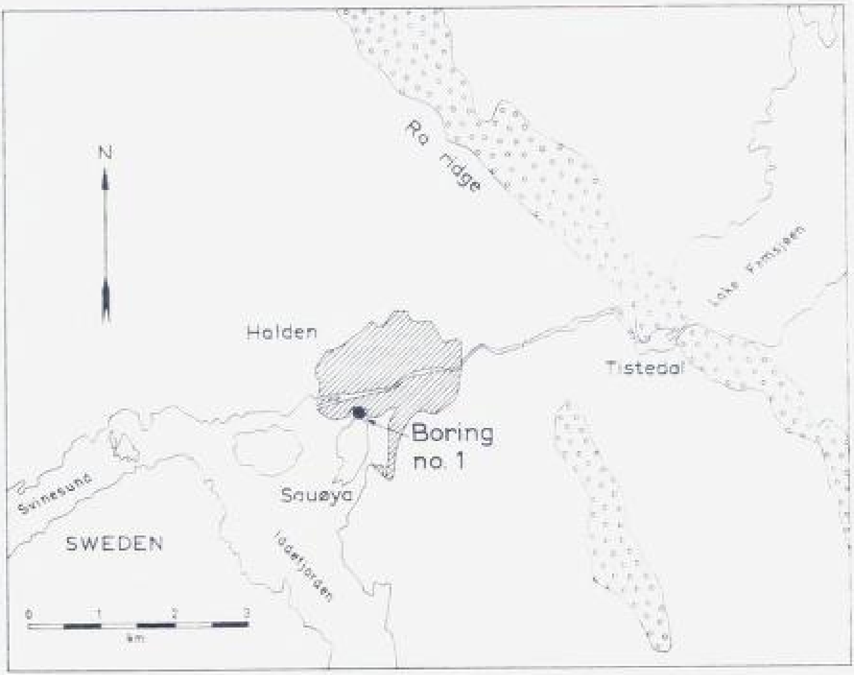


Fig. 28. The city of Halden with location of boring no. 1.

dry state, were undertaken and the result visualized in the range chart of figure 29. The uppermost sample was from 20.2 m below the sea bottom, the deepest one from core level 39.8 m. All of them contained Foraminifera. The number of different species and forms per sample ranged from 6 to 22, the number of specimens per 100 g sediment (dry weight) from 100 to 31 500. Percentage symbols were applied throughout this chart. As a total, 41 different species, subspecies, and forms were observed in the core.

In addition to the species inserted in the chart, the following ones occurred in the investigated samples: *Pseudopolymorphina novangliae* at 37.2 m, *Quinqueloqulina agglutinata*, *Lenticulina* (*Robulus*) cf. *gibba*, and *Bolivina pseudopunctata* at 33.2 m, *Lenticulina* (*Robulus*) cf. *angulata* and *Lagena mollis* at 26.2 m, and *Textularia bocki*, *Cassidulina l. carinata*, and *Nonionella auricula* at 23.8 m.

The clay samples, from the upper and from the lower part of the investigated core, contained assemblages referable to zone A, i. e., of similar composition as found in that unit of the Foraminifera zonation of the

Fig. 29. Range chart for boring no. 1 at Halden.

Late Quaternary sediments around the Oslofjord. *Elphidium incertum clavatum* predominates and *Cassidulina crassa* is richly represented. Most of these samples contain also a considerable number of specimens of *Nonion labradoricum* together with *Virgulina loeblichi* and one or two specimens of *Islandiella norcrossi*, and are, on the whole, similar to samples from subzone A_m. The relatively high frequency of *Bulimina marginata*, forma *aculeata* and the occurrence of *Virgulina fusiformis* in the lowest sample of the upper clay (core level 23.8 m), are, however, strange in such an assemblage. One sample from the upper clay (core level 20.8 m) and one in the lower (core level 37.8 m) showed A_u, or A_l, composition.

The Foraminifera faunas of the bed of fine sand, lying between the above-mentioned clays, were of quite different composition. One count is presented below as an example, viz., that of the sample at core level 29.2 m:

Species	Frequency	Percentage
Elphidium incertum incertum	44	32.0
Elphidium incertum clavatum	28	20.3
Nonion labradoricum	26	18.8
Elphidium excavatum	21	15.2
Virgulina loeblichi	5	3.6
Elphidium subarcticum	4	2.9
Cassidulina crassa	3	2.2
Cibicides lobatulus	3	2.2
Bulimina marginata, f. *aculeata*	2	1.5
Quinqueloculina seminulum	1	0.7
Pullenia osloensis	1	0.7
Total	138	100.1

Among the Foraminifera the relatively frequent occurrence of the shallow-water species *Elphidium excavatum* is remarkable as is also the increased frequency of *Elphidium incertum incertum*. Fragments of the barnacle *Balanus balanoides* were frequent in the $>$ 1.0 mm fraction of this sample.

The sample below this, at core level 29.7 m, contained a Foraminifera fauna of very similar composition, only that another shallow-water species, *Nonion depressulus asterotuberculatus*, joined the assemblage, accounting for 8.4 %, while one small specimen which had to be classified as *Ammonia batavus* occurred. *Bulimina marginata*, forma *aculeata*, which otherwise predominates in the Post Glacial assemblages of zone F in the Oslofjord area, occurred in all samples from the sand bed, but was really frequent only towards the lower part of the bed, at core level 32.8 m, where it accounted for 15.2 % of the fauna.

The scarcity of samples from this core renders the interpretation of faunal sequences extremely difficult. Samples at core levels less than 20 m should probably have provided possibility of a relative dating, and samples from the lower part of the upper clay, between 23.8 m and 26.2 m, and from the lowest part of the 8 m thick sand deposit, between 33.2 m and 37.2 m, would have contributed to a safer interpretation of the interbedded shallow-water section. The Foraminifera assemblages of zone A type in the clay do not assert that these parts of the core are contemporaneous with other zone A deposits from the Oslofjord area. It can only be assumed that these parts of the core represent sediments deposited under environmental conditions similar to those prevailing during deposition of other zone A deposits. As it appears in the subsequent chapter of the present paper, these conditions must have been Arctic. The interbedded fine sand with shallow-water indicators would probably have to be explained as displaced. As have been widely discussed in recent years such an emplacement may have been caused by submarine turbidity currents. A submarine relief considerable enough to arise such currents is certainly present in the area discussed, and, as the presumably displaced assemblages occur almost exclusively with the sand and not with the clay of the core, it seems more reasonable to think of turbidity current as possible mechanism of movement than of submarine land slide.

However, among the species and forms of the shallow-water assemblages, presumed to be displaced, there occur indicators of more temperate water than that into which the clays were deposited. Thus, the two shallow-water forms, *Nonion depressulus asterotuberculatus* and *Elphidium excavatum* are not recorded in Recent Arctic or even Sub-Arctic faunas. Earland (1936, p. 58) recorded *E. excavatum* from the Weddell Sea, but did not give any illustration of it. Hessland (1943) and Brotzen (1951) recorded *E. excavatum* from Late Glacial deposits on the Swedish west coast. Any description or illustration of these Late Glacial specimens was, however, not given, and the possibility exists that they may represent a species closely related to the above-mentioned. I have myself, observed in Recent bottom samples from Spitsbergen *E. excavatum*-like specimens which, however, differed from this species by their greater number of retral processes. *Virgulina fusiformis* was recorded from Iceland by Terquem and Terquem (1886), but that record was questioned by Nørvang (1945). This species is found near the British Isles, in the Skagerrak and on the Swedish west coast, on the European side of the Atlantic. *Epistominella exigua* seems not to occur in cold waters and *Bulimina marginata*, forma *aculeata* seems to be a form preferring temperate waters (Nørvang, 1945). *Elphidium incertum incertum*, according to its high frequency in Post Glacial sediments, scarcity in Late Glacial sediments, seems to be a Boreal or Boreo-Lusitanian form rather than an Arctic one. Finally, the presence of one small specimen of *Ammonia bavatus* is mentioned, even though not much weight should be attached to that occurrence.

The presence of a fauna component indicating temperate water makes it difficult to explain the sandy part of the core as displaced. It seems unlikely that such a shallow-water assemblage could have existed simultaneously with the thermophobous fauna of the lower clay, even if lower temperatures are naturally to be expected with greater depths. The difference in temperature seems to have been too great, the difference in depth too little. *Nonion labradoricum*, which occurs in the clays as well as in the interbedded sand, prefers, at least in northern waters, depths of less than 100 m or even less than 60–75 m (Phleger, 1960, p. 76), but seem to avoid the shallowest bottoms, shallower than approximately 15 m, at least under temperate conditions.

The distribution pattern of the thermophilous forms as well as of the shallow-water forms seems to indicate an oscillation of water depth, as well as of water temperature. The decrease of depth seems to have culminated with deposition of the layers now situated at core level 29.5 m. The shallow-water indicators are most frequent at that level, the number of species and forms as well as the number of specimens is at a minimum whereas the median diameter of the sediment is at a maximum. The temperate conditions, which were introduced together with the appearance of shallow-water species in the Foraminifera assemblages, seem, however, to have lasted during the subsequent redeepening of the water, at least until the deposition of the clay layers which are now to be found at core level 23.8 m, according to the frequency distribution of *Bulimina marginata*, forma *aculeata* and *Virgulina fusiformis*. There seems to be a natural decrease of the percentage of *B. marginata*, forma *aculeata* in the shallowest samples. Detailed granulometric investigation should probably have provided some aid to the solution of the problem.

If the sand section of the core was the result of a turbidity current, one would generally expect decreasing particle size from bottom to top. The exact reverse is found in the three investigated samples of the sediment, and in the biogenic fraction the larger particles, i. e., the larger Foraminifera, occur in the upper part of the sand section rather than in the lower.

The repitition of zone A-assemblages above the sand section was probably caused by a land slide with slide plane at core level 25 m, approximately. However, the clay assemblages above the sand section contain a considerable number of species and forms which do not occur in the lower clay, a fact which make such an explanation dubious.

The age of the apparent oscillation is unknown. It may not be younger than Younger Dryas age, probably older.

Slagenstangen (3986)

This locality is situated on the west side of the Oslofjord, 12 km south of Horten, and is, partly, formed as a marginal ridge of glacio-marine origin. This ridge belongs to the previously mentioned Tjølling–Slagen–Onsøy–Borge substage of the regional ice recession in the area and is older than the Ra substage. Core material from six borings, on the ridge as well as just north of it, was kindly donated to the writer by the Norsk Teknisk Byggekontroll, which carried out geotechnical investigations in the locality. The samples were micropaleontologically examined – with meager result, however.

The samples from the deepest boring, 27.4 m, on the ridge yielded no Foraminifera. The other borings from the ridge contained faunas of zone A composition. In one of these borings, no. 350, the subzones A_l and A_m were present. Zone A in the other ridge borings seemed to be represented only by subzone A_l. All samples from this ridge contained a great deal of sharp gravel with the clay.

Boring no. 527 was taken north of the Slagen ridge, and its surface was situated 13 m below sea level. The upper part of this boring contained Foraminifera assemblages of zone G composition, whereas those of the lower part were referred to subzone A_u.

Review of the zonation in the southern part of the area

The Foraminifera zonation described from the borings in Sandefjord (p. 75–93) was recognized, wholly or partly, in other borings outside the Ra ridge. A considerable number of species contribute, by their occurrence and vertical variation in frequency, to this zonation. However, only a limited number are numerous enough to be of regional importance. In the diagram of figure 30 the zones and subzones from A_{lower} to G_{upper} are characterized by 23 selected species, subspecies and forms, the normal range and relative frequency of which are visually indicated. The selection is subjective and could have been different. E.g., *Islandiella teretis* could have been inserted as characteristic of zone A and *Höglundina elegans* as characteristic of zone E and lower subzones of F, and *Cassidulina laevigata carinata* and *Pullenia osloensis* could have been omitted. The purpose of such a simplified range chart is to provide rapid information of the zonation in the sediments of the area, and should thus contain enough species to characterize the zones and subzones but not more.

In connection with this chart a short review of the zonation in marine Late Quaternary sediments in the southern part of the Oslofjord area is given below. For information about occurrence and range of other species and forms than those inserted in the present chart, the reader is in most cases referred to the previous pages, especially to the decsription of boring no. 5 in Sandefjord (p. 77–91) and boring no. 2 of profile C in Fredrikstad, or to the range charts for borings in the southern part of area.

Zone A, the *Elphidium incertum clavatum* zone, is predominated by that subspecies, which account for 60–100 % of the fauna. *Cassidulina crassa* is frequent, and *Quinqueloculina stalkeri*, *Virgulina schreibersiana*, *Astrononion gallowayi*, and a few *Elphidium incertum incertum* occur in most samples. Zone A is subdivided into three subzones, A_{lower}, A_{middle}, and A_{upper}. The middle subzone, A_m, is characterized by frequent occurrence of *Nonion labradoricum* and in addition *Pyrgo williamsoni*, *Virgulina loeblichi*, *Islandiella teretis*, *Islandiella norcrossi*, and *Cibicides lobatulus* occur. Single specimens of *Virgulina fusiformis* and *Bulimina marginata*, forma *aculeata* were occasionally observed in subzone A_m. Whereas the subzones A_l and A_u contain, on an average only 4–10 different species and forms, subzone A_m may contain 20. The number of specimens is usually also considerably greater in this subzone than in the other two.

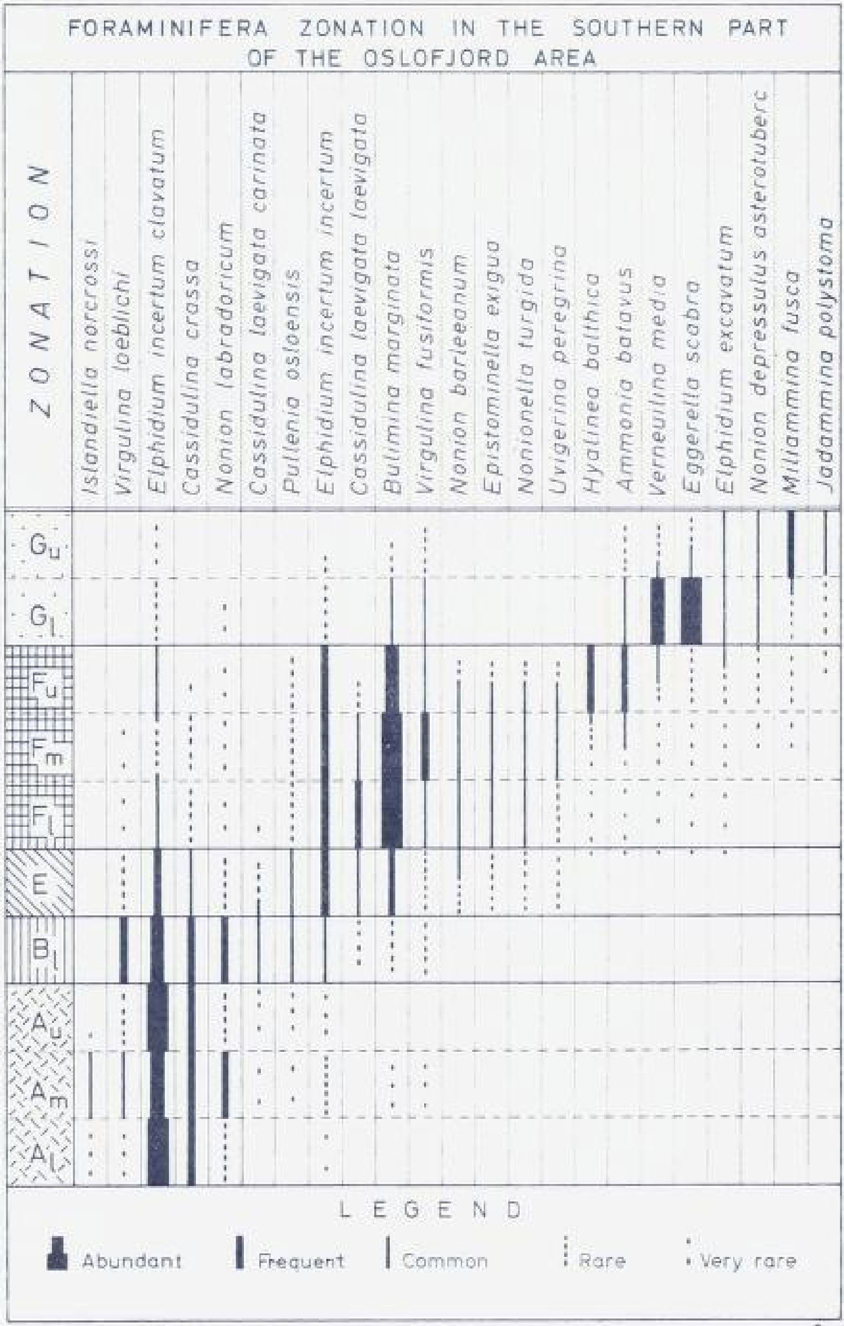


Fig. 30. Simplified range chart for the southern part of the Oslofjord area, with average range and frequency of 23 selected species of Foraminifera.

Subzone B_l, the subzone with *Virgulina loeblichi* and *Nonion labradoricum*, is still characterized by an abundance of *E. incertum clavatum* and *Cassidulina crassa*, but they are usually not as frequent as in the previous zone. *Virgulina loeblichi* and *Nonion labradoricum* are almost as frequent as these. *Pyrgo williamsoni, Cassidulina laevigata carinata, Pullenia osloensis, Elphidium incertum incertum* and *Cibicides lobatulus* are usually common in subzone B_l, and *Virgulina fusiformis* and *Bulimina marginata*, forma *aculeata* occur, though rarely. The number of different species and forms is considerably greater than in zone A. In the region north of the Ra ridge there occurred in some borings an assemblage which was classified as the upper part of zone B, B_u. That subzone was not recognized in the samples investigated from the area south of the Ra.

Zone E, the zone with *Elphidium incertum incertum* and *E.i. clavatum*, is characterized by these two subspecies of *Elphidium*, almost equally frequent, accompanied by *Bulimina marginata*, forma *aculeata*. *Cassidulina laevigata laevigata* is also quite frequent, and *Quinqueloculina seminulum* is common in most samples. The number of different species (subspecies and forms) per sample is greater than in the previous zones and so is usually also the number of specimens. The Foraminifera fauna of this zone is, on the whole, to be characterized as Atlantic Boreal.

Zone F, the *Bulimina marginata* zone, is predominated by *Bulimina marginata*, forma *aculeata*, while *Elphidium incertum incertum* is frequently represented. A sharp decrease in frequency of *E. incertum clavatum* and *Cassidulina crassa* has taken place, and Atlantic Boreal and even some Atlantic Mediterranean species occur commonly, such as *Amphicoryna scalaris, Angulogerina angulosa, Uvigerina peregrina, Nonionella turgida, Nonion barleeanum, Epistominella exigua, Höglundina elegans.*

Low-lying zone F deposits with high frequency of *Nonion labradoricum* and very low content of *Elphidium incertum incertum* are supposed to be of Recent age.

The following subdivision of zone F was convenient: F_{lower} characterized by frequent occurrence of *Cassidulina laevigata laevigata*, F_{middle}, with high percentage of *Virgulina fusiformis*, and F_{upper}, characterized by *Ammonia batavus* and *Hyalinea balthica*.

Zone G, predominated by arenaceous shallow-water species, is composed of sediments with more or less poor faunas. *Verneuilina media* or *Eggerella scabra*, or both of them, dominate, whereas *Ammoscalaria runiana, Virgulina fusiformis, Nonion depressulus asterotuberculatus, Ammonia batavus*, and usually also *Elphidium excavatum* are common. In some localities an upper part of zone G was recognized. This subzone, G_u, abounds in *Miliammina fusca*, and *Jadammina polystoma* may be frequent.

Low-lying deposits, which in deeper parts of zone G exhibited high percentage of *Nonion labradoricum* were supposed to be of Recent origin.

Interpretation of the foraminiferal zonation in the southern part of the area

The upper unit

In connection with the discussion below, and in order to support them, the reader is reminded of the consideration about depth, temperature, salinity, etcetera, made in the chapter on paleoenvironment (p. 49).

The investigation of the Recent fauna of Foraminifera in the Oslofjord (Risdal, in press) will most certainly provide an answer to the important question: To what extent does the foraminiferal zonation, demonstrated in Late Quaternary deposits of the Oslofjord area, reflect facies differences? A priori the lateral persistence of the zonation, the tendency of the zones to occur in similar sequence in quite widely separated borings, would seem to indicate that they are *depth zones* because a regional land elevation of considerable magnitude took place in the area during Late Quaternary time (Cp. p. 22). The ancient fjord became everywhere gradually shallower. Marine deposits now raised above sea level once passed the littoral zone and would normally be expected to carry littoral deposits on top, whatever the age of the deposit may be. Coarse-grained littoral or shallow-water deposits were not considered in the present study, since sands were easily lost with the core-sampler applied, and they usually yield few Foraminifera. However, in sheltered bays or inlets, which must have occurred numerously in the Oslofjord area with its turbulent topography, fine-grained sediments may have been deposited even in the tidewater zone, as it also happens to-day in many localities along the fjord. Such sediments would therefore be expected in the upper part of many of the investigated cores.

The assemblages of *zone G* doubtless indicate shallow water (Feyling-Hanssen, 1957, p. 14). *Nonion depressulus asterotuberculatus*, is known mainly to inhabit the tidewater zone, the littoral proper (Bartenstein, 1938; van Voorthuysen, 1960; Richter, 1961). *Quinqueloculina lata* and

Elphidium excavatum have a similar habitat, and the North Sea form *Ammonia batavus* occurs in abundance in shallow water, even though it may also inhabit greater depths (i.a., Richter, 1961; van Voorthuysen, 1960). High frequency of arenaceous forms, e.g., *Ammoscalaria runiana, Verneuilina media, Eggerella scabra, Spiroplectammina biformis,* and other, indicates, in general, shallow water, even though these and other of the arenaceous species are recorded also from greater depths (Höglund, 1947; Christiansen, 1958). *Miliammina fusca* is, at least in temperate waters, an ubiquitous marsh form, and *Jadammina polystoma* which together with *M. fusca* characterized the upper part of zone G in boring no. 5 in Sandefjord, seems to be restricted to the littoral (Bartenstein and Brand, 1938; Parker and Athearn, 1959; Todd and Low, 1961).

It must be mentioned, that the specimens identified as *Elphidium incertum clavatum* in the zone G samples of the borings have much in common with *Elphidium gerthi* (van Voorthuysen) and with *Elphidium selseyensis* (Heron-Allen and Earland), i.a., as figured by Richter (1961, fig. 1). They show also some affinity to *Elphidium poeyanum* (d'Orbigny) as figured by Closs and Barberena (1962).

The Foraminifera faunas of samples from the upper part of many borings from the Late Quaternary of the Oslofjord area resemble the Recent ones from the shallowest water of the Dollart-Ems estuary in the Netherlands (van Voorthuysen, 1960, pt. 3). The comparatively great frequency of *Miliammina fusca* and the presence of *Jadammina polystoma* in the upper part of zone G in Sandefjord was probably caused by considerably reduced salinity in the uppermost waterlayers. These species seem to be of less importance on the tidal flats of the Netherlands. In this respect the upper zone G assemblages rather resemble the fauna from the brackish water of the Jade Bay in northern Germany (Bartenstein, 1938).

The foraminiferal assemblage classified as G_u seems not only to provide indication of shallow water, but was most probably controlled by decreased salinity as well. Marsh conditions, almost, may have occurred in Sandefjord during the latest part of the subaquatic development of that locality. In more exposed localities a G_u development of the Foraminifera fauna is not to be expected. However, as the shallow water to which zone G, as a whole, seems in general to be restricted, exhibits great variation in salinity (p. 62), the constituents of the lower part of zone G are expected to be euryhaline.

In order to support a further discussion of zone G, the reader is referred to the description, profiles, and range charts of the foraminiferal distribution in the borings from the city of Fredrikstad (p. 115–129). They seem to illustrate that two kinds of lower G assemblages occur, viz., one with rich occurrence of *Nonion labradoricum* and one in which this species is only scarcely represented or not present at all. It was assumed that the rich occurrence of *N. labradoricum* was caused by a comparatively late flourishing of this species, and that low G faunas without frequent occurence of this species originate from a time previous to that flourishing – provided they existed at depths sufficiently great enough for *N. labradoricum* to live.

Since the borings in Fredrikstad, being situated at the debouchure of the river Glomma, would probably comprise sediments deposited in water of low salinity, the frequent occurence of *N. labradoricum* there could probably be considered a brackish-water phenomenon. This is, however, unreasonable, as assemblages without or only with few, *N. labradoricum* also occurred there. Furthermore, in other localities with rich *N. labradoricum* representation, any indication of, or reason for, decreased salinity could not be found. There thus occur G-assemblages which were formed before a late flourishing of this species as well as such developed after that event.

Zone G-assemblages with high frequency of *N. labradoricum* seem, in general, to occur only with the lowest-lying deposits, an observation which is confirmed by investigations in the northern part of the Oslofjord area, in and around the city of Oslo. These deposits are young, as they were deposited in shallow water and have presumably been involved in only a small part of the Holocene land rise, or shoreline displacement, of the area. As, in addition, *N. labradoricum* is to be regarded as a northerly species (Nørvang, 1945), it is tempting to consider the late flourishing of this species in the Oslofjord area as a result of the profound climatic deterioration which is known to have concluded the Sub-Boreal age and which became characteristic of the Sub-Atlantic. According to this, Recent Foraminifera faunas of the Oslofjord with zone G-composition would be expected to contain a considerable number of specimens of *N. labradoricum* if the waterdepth is sufficiently great enough for that species. A zone G-fauna, on the other hand, older than Sub-Atlantic age, i.e., older than 2400 years, is expected to yield only few specimens of that species even if the depth was great enough. Future investigations will probably clarify this.

The greatest height to which deposits with zone G-assemblages are, on the whole, found in the Oslofjord area is 55 m above sea level, viz., at Riser in Hobøl, 17 km northeast of the Ra ridge at Moss. This height compared with the Holocene shoreline displacement known from Oslo (p. 23) reveals that Foraminifera faunas of this composition occurred in the Oslofjord area at least as early as the middle part of Atlantic time.

In one locality, viz., at Årungen in Ås, 25 km south of the centre of Oslo, there occurred in a boring with surface situated 30.2 m above sea level zone G-faunas with rich representation of *Nonion labradoricum*. This observation calls for great caution with respect to an interpretation of the abovementioned late flourishing of this species.

As to the water depth at which zone G-assemblages are being developed, information is provided by some submarine borings of the present study, i.a., the submarine borings in Fredrikstad. The uppermost samples of the borings with surfaces from 6.4 m to 7.2 m below sea level all contained zone G-faunas. The uppermost sample of the submarine boring (no. 527) at the north side of Slagenstangen yielded also a general zone G-fauna. The water depth was there 13 m and the sample was taken 1 m under the bottom surface. The count of this sample is given below. The sample weighed 100 g in dry state, and the counted part of the specimens represents 1/13 of the sample:

Species	Frequency	Percentage
Eggerella scabra	197	65.7
Verneuilina media	50	16.7
Miliammina fusca	30	10.0
Ammoscalaria pseudospiralis	10	3.3
Reophax subfusiformis	5	1.7
Ammoscalaria runiana	2	0.7
Ammonia bavatus	2	0.7
Alveolophragmium crassimargo	1	0.3
Trochammina intermedia	1	0.3
Cassidulina crassa	1	0.3
Nonion depressulus asterotuberculatus	1	0.3
Total	300	100.0

A Foraminifera fauna of quite typical zone G-composition was there formed at a water depth of 14 m, at least. Attention is called also to the absence of *Nonion labradoricum*. The sample is most likely young enough for this species to be richly represented, but the water depth was probably too small.

A submarine boring at Herøya (61/40, boring no. 2), not far from Skien, west of the outer part of the Oslofjord, did not yield any zone G fauna. This boring was taken at a water depth of 21,9 m. The uppermost sample with Foraminifera originates from 3.9 m under the bottom surface, as the overlying deposit consisted of industrial filling. *Eggerella scabra* and *Verneuilina media* were frequent, but *Bulimina marginata*, forma *aculeata* predominated, and *Hyalinea balthica* was richly represented. This sample is thus to be classified as subzone F_u.

The few examples presented here suggest that zone G is a shallow-water development of the Foraminifera fauna – formed, in general, at water depths less than 25 m. Additionally, subzone G_u indicates low salinity. Zone G-composition may be recognized with Recent faunas as well as with Post Glacial ones, at least as old as Atlantic age. It has, however, not been observed in Late Glacial sediments, and is consequently restricted to the Holocene in the Oslofjord area.

The middle units

As already mentioned, a broad study of the Recent Foraminifera faunas of the Oslofjord will probably teach us more about the faunal restrictions, e.g., to what extent F and E of the Holocene foraminiferal zonation were controlled by depth. It is highly probable, e.g., from the rich occurrence of *Ammonia batavus*, that subzone F_u represents a compositively shallow-water development of the zone F-complex. The appearance of *Uvigerina peregrina* and *Nonion barleeanum*, among others, towards lower parts of subzone F_u, indicates deepening of the water within this subzone. From the frequent occurrence of *Virgulina fusiformis* together with *Bulimina marginata* in subzone F_m, compared with the types of bathymetric distribution of Foraminifera in the Gullmarfjord (Höglund, 1947, p. 295) it would seem that this subzone probably represents sediments deposited at approximately 40–60 m depth. If regionally elevated water temperature prevailed at the corresponding time, the F_m-assemblages probably lived somewhat deeper. Subzone F_l, with *Cassidulina laevigata laevigata*, and zone E may represent successively deeper biotopes. If not the abundance of species belonging to the genus *Elphidium* in zone E is to be interpreted as an indication of shallower water than that of subzone F_l.

However that may be, the Foraminifera faunas classified as F and E beyond doubt lived under marine-climatic conditions considerably more favourable than those which seem to have prevailed during deposition of zone A and zone B in the Oslofjord area. It is difficult to determine whether the conditions were also more favourable than those of the present Oslofjord since the Recent fauna of the fjord is almost unknown. F-faunas with rich representation of *N. labradoricum*, and simultaneously with very poor representation of *Elphidium incertum incertum* may be of Sub-Atlantic origin, formed after the decline of the Post Glacial Warm Interval, whereas the more common F-faunas with few, or none, *N. labradoricum* and frequent occurrence of *E. incertum incertum* are Warm Interval formations.

No Arctic Foraminifera fauna, hitherto known, exhibits a composition which in any way resembles those of zone F, even though quite many of the species may be represented (Cp. i.a., Kiær, 1909). The faunas at Iceland (Nørvang, 1945) and those from northern Norway (Kiær, 1900, 1908) do not fit in the pattern of zone F-assemblages. However, Kiær (1900) recorded *Bulimina marginata* as being frequent at some Southwest Norwegian localities, and Schaudinn (1896) and Nørvang (1942) found this species, together with *Cassidulina laevigata* and *Hyalinea balthica*, to be very common in Recent mud samples from the vicinity of Bergen on the west coast. In Höglund's paper (1947, p. 310, 311) there are given complete foraminiferal counts of four Recent samples from the Gullmarfjord on the Swedish coast, two from 45 m depth and two from 55 m. They all exhibit elements of the Oslofjord zone F-assemblages but contain more agglutinated specimens. The commonest species of the Gullmarfjord samples are listed below, being listed as far as possible, in order of frequency:

Gullmarfjord, depth 45 m	Sample 1	Sample 2
Species	Percentage	Percentage
Bulimina marginata	20.6	14.2
Anomalina balthica	12.7	9.3
Eggerella scabra	12.1	9.3
Cassidulina laevigata	11.0	8.2
Virgulina fusiformis	3.0	9.8
Textularia tenuissima	6.7	9.4
Nonion cf. *labradoricum*	8.7	8.3
Elphidium sp.	6.1	8.2
Nonionella cf. *turgida*	3.1	2.8
Proteonina fusiformis	2.9	2.3
Haplophragmoides glomeratum	0.9	1.1
Textularia bocki	0.9	1.1

The counts of the two other samples, which were given in number of specimens by Höglund, are transformed here to percentages:

Gullmarfjord, depth 55 m	Sample G 12	Sample G 13
Species	Percentage	Percentage
Virgulina fusiformis	18.0	22.4
Textularia tenuissima	18.0	13.4
Anomalina balthica	11.6	13.4
Nonion cf. *labradoricum*	9.0	7.8
Bulimina marginata	5.4	8.9
Nonionella cf. *turgida*	6.3	1.1
Cassidulina laevigata	3.6	5.6
Eggerella scabra	5.4	4.5
Recurvoides trochamminiforme	2.2	3.8
Haplophragmoides glomeratum	2.2	2.7
Elphidium spp.	2.2	1.6
Proteonina fusiformis	1.3	1.1
Globobulimina turgida	0.9	1.6
Spiroplectammina biformis	0.9	1.3

The high frequency of *Nonoin labradoricum* is remarkable with these faunas, and the frequency of *Bulimina marginata* is lower than in ordinary F-faunas from the Holocene of the Oslofjord area.

Greater similarity with ordinary zone F-faunas, especially with respect to the predominance of *Bulimina marginata*, is demonstrated by some of the Recent faunas from the west of Scotland (Heron-Allen and Earland, 1916 b). As an example is listed the most common species in a sample of grey mud (No. 21) from Loch Hourn, Inverness, dredged at a depth of 60 fms (110 m). The assumed Oslofjord area equivalents are listed to the right of the names used by Heron-Allen and Earland. The frequency indications, C(ommon), V(ery) C(ommon), etc., are those used by Heron-Allen and Earland:

Bulimina elegans	(*Bulimina marginata*)	VVC
Bulimina pupoides		VVC
Bulimina marginata		VVC
Bulimina aculeata		VC
Bulimina fusiformis	(*Virgulina fusiformis*)	VVC
Nonion umbilicatula	(*Nonion barleeanum*)	VVC
Operculina ammonoides	(*Hyalinea balthica*)	VVC
Lagena laevigata	(*Fissurina laevigata* ?)	VC

Rotalia orbicularis	(*Ammonia batavus*)	VC
Textularia conica		C
Nonion depressula	(*Nonion depressulus*)	C
Nonionella turgida	(*Nonionella turgida*)	C
Pulvinulina karsteni		C

Specimens of the genus *Bulimina* made 98 % of this assemblage. Many of the other clayey samples from the west of Scotland also exhibited similarities with our Holocene zone F faunas. The dominant as well as the majority of the less frequent species in the Recent samples from the West Scotland archipelago are recognized in zone F deposits of the Oslofjord area.

Among the megafossils accidentally occurring in zone F-samples from the Oslofjord area are shells of *Ostrea edulis* (Linné), *Glossus humanus* (Linné), *Corbula* (*Varicorbula*) *gibba* (Olivi), *Nassarius reticulatus* (Linné), i.e., species which are considered characteristic of Post Glacial Warm Interval deposits.

The greatest height above present-day sea level to which zone F-assemblages were, on the whole, found in the Oslofjord area is, as for zone G, 55 m (at Riser in Hobøl). According to the Holocene shoreline displacement, this would mean that zone F assemblages existed in the Oslofjord area at least as far back as the middle part of Atlantic age, most probably even earlier since samples from heights between 55 m and 80.0 m (Bryn), where F was absent, have not been micropaleontologically examined.

Foraminifera assemblages referable to zone E were recognized at greater height, viz., 96.8 m above sea level in boring no. 1 at Kolbotn (O 823). This would mean that this composition of the Foraminifera fauna may be found in sediments as old as Boreal age. Zone E contain most of the species which are also found in zone F, and exhibits, on the whole, an Atlantic Boreal character. *Hauerinella inconstans*, *Quinqueloculina seminulum*, *Miliolinella* cf. *subrotunda*, *Pyrgo williamsoni*, *P. comata*, and *Biloculinella inflata* are common members of the E fauna, and so is *Cibicides pseudoungerianus*. On the other hand, many of the species and subspecies from the underlying zones, A and B, maintain their representation i zone E. Characteristic is the heigh frequency of *Elphidium incertum clavatum* and *Cassidulina crassa*. Thus, even though the faunal difference between zone B and zone E is the sharpest one met with in the whole sequence of units in the foraminiferal zonation, zone E has kept the character of a transition zone between B and F. This is beautifully demonstrated by the mutual frequency of the two subspecies of *Elphidium incertum:* Whereas *E. incertum clavatum* predominates in zone B, this subspecies intermingles, apparently with many transitions, with *E. incertum incertum* in zone E, and, finally, this latter subspecies have become clearly more abundant in zone F.

The many new species, and subspecies, of Foraminifera appearing in zone E, compared with the faunas of the previous zones, seem to indicate that the zone border B/E is controlled by increased water temperature in the Oslofjord of the corresponding time. Such an amelioration may have caused a sharply increased immigration of new species to the area. The border E/F is more indistinct, However, there occur in the faunas of zone F more thermophilous species than in zone E, and many of the thermophilous species, already occurring in zone E, exhibit increased frequency in zone F. For this reason, also this zone border should probably be considered thermally controlled, but other factors, e.g., depth, may as well have been involved.

The lower units

Depth zonation of Foraminifera assemblages is not necessarily controlled by corresponding differences in water pressure. More likely, as has been widely assumed in recent years, different water temperature at different depths is the deciding ecological factor (i.a., Pokorný, 1958, p. 120). A marked temperature stratification of the water masses is found in the present Oslofjord (p. 54), and similar conditions may have existed also at earlier stages in the marine development of the area. Long-term regional temperature fluctuations, which are known to have taken place during Late Quaternary time, shifted the temperatures at the different depths towards higher or lower values according to the tendency of the fluctuation. By this a Foraminiferal assemblage which, on an average, characterized a certain depth zone during one period, may have become indicative of another depth zone, deeper or shallower, during the next. Examples of this type are provided by Arctic shallow-water species which under lower latitudes inhabit greater depths – and conversely. Radical climatic changes, however, must have shifted the assumed foraminiferal depth zones out of reach of the depth range represented in the basin dealt with. An Arctic climate, which certainly prevailed in the Oslofjord area before and during the formation of the Ra ridge, conveyed to the water of what was then the Oslofjord, temperatures favourable only for Arctic Foraminifera assemblages. Similar assemblages may be found under climates similar to present Oslofjord conditions, but then probably only at depths greater than those found in the Oslofjord. Our Late Pleistocene, and probably also Early Holocene deposits are therefore expected to carry Foraminifera assemblages which have very little, if any, resemblance to any living population of the Oslofjord.

Such are the faunas of zone A, probably also those of zone B. Recent faunas with similar composition are, at least to date, not found in the Oslofjord. Arctic Recent faunas of Foraminifera, on the other hand, demonstrate considerable similarity with Pleistocene and Early Holocene faunas of the Oslofjord area, as illustrated below:

In 1950 the author collected some samples of silty clay from some anchorages in *Spitsbergen*. The samples were taken quite primitively, simply by collecting the mud which adhered to the anchor when it was weighed. As the anchor may have dug quite deep in the bottom, it is not certain that the samples are purely Recent. Attempts at separating living specimens from dead were not made.

A sample from the south side of the Van Keulenfjord, not far from the tongue of the Penck Glacier, collected on August 8th at a depth of 10 m, contained the following Foraminifera:

Species	Frequency	Percentage
Elphidium incertum clavatum	289	48.1
Cassidulina crassa	201	33.5
Textularia earlandi	62	10.3
Nonion labradoricum	28	4.6
Quinqueloculina stalkeri	14	2.3
Alveolophragmium crassimargo	1	0.2
Gordiospira arctica	1	0.2
Islandiella teretis	1	0.2
Buccella frigida	1	0.2
Astrononion gallowayi	1	0.2
Protelphidium orbiculare	1	0.2
Total	600	100.0

A sample from the inner part of Trygghamna (Safe Haven) at the north side of the mouth of the Isfjord, collected on August 20th at a depth of 18 m, revealed a similar fauna:

Species	Frequency	Percentage
Elphidium incertum clavatum	378	63.0
Cassidulina crassa	126	21.0
Quinqueloculina stalkeri	29	4.8
Nonion labradoricum	24	4.0
Textularia earlandi	12	2.0
Astrononion gallowayi	12	2.0
Pyrgo williamsoni	7	1.2
Guttulina dawsoni	5	0.8
Cibicides lobatulus	3	0.5
Triloculina trihedra	2	0.3
Islandiella teretis	1	0.2
Elphidium subarcticum	1	0.2
Total	600	100.0

A glacier was calving into the fjord 300 m from this locality.

The proportionally high frequency of *Elphidium incertum clavatum* and *Cassidulina crassa* in these two samples is similar to zone A samples from the Oslofjord area, and the other species, except for *Textularia earlandi* and *Gordiospira arctica* Cushman, are quite common in zone A. The comparatively rich occurrence of *Nonion labradoricum* may be compared with subzone A_m. But the considerable frequency of agglutinated forms, such as *T. earlandi* and *Quinqueloculina stalkeri* in the Spitsbergen samples, was not recognized neither in zone A nor in zone B of the Oslofjord area. It seems, on the whole, preposterous to expect detailed similarities between Pleistocene faunas of the Oslofjord area and Recent Arctic faunas, especially as the depth at which the Late Glacial Foraminifera of the outer Oslofjord area lived, is unknown. Brøgger (1900–1901) stated that the Yoldia clay, corresponding to zone A, (Cp. next chapter), was deposited at a depth of approximately 25 m. According, however, to the present view (Holtedahl, 1924) Yoldia clay now positioned at present-day sea level, was deposited at a depth corresponding to the height of the marine limit of the locality, i.e., approximately 150–190 m for the localities here discussed. This may account for the low population of agglutinated forms in zone A samples – if not secular selective decomposition is responsible (p. 14). Additionally, local differences of environment certainly affect the composition of the Foraminifera assemblages. Thus, a Recent sample from the innermost part of the Isfjord, viz., the Adolfbukta at the head of the Billefjord in Spitsbergen, taken at 15 m depth, was predominated by *Cassidulina crassa* closely followed by *Cibicides lobatulus*, whereas *Elphidium incertum clavatum* took third and *Nonion labradoricum* fourth place in frequency. In total, 16 species occurred in the sample, all of them, except *Textularia earlandi*, well known from zone A. A Recent sample from the inner part of the Wijdefjord, Spitsbergen, depth 8 m, was also dominated by *C. crassa*, *Astrononion gallowayi* was second in frequency, *E. incertum clavatum* third and *Alveolophragmium crassimargo* fourth. There were 33 species identified in this sample, all of them, except *Textularia earlandi*, *Gordiospira arctica* and *Trochamminella atlantica* F. Parker, known from the Late Glacial of the Oslofjord area.

Three Recent bottom samples from East Greenland, collected by the present author in August, 1951, in the same primitive way as the Spitsbergen samples, were all predominated by *Islandiella teretis* whereas *E. incertum clavatum* and *C. crassa* occupied the two subsequent places on the counting lists. The samples were from Antarctichavn in the King Oscar Fjord, depth 20 m, Mackenzie Bay in the Franz Joseph Fjord, depth 10 m, and Kap Stosch in the Clavering Fjord, 28 m. *Nonion labradoricum* was scarce, it occurred in two of the samples, 3 specimens in Mackensie Bay and 2 at Kap Stosch. There were few arenaceous Foraminifera in the samples. Most of the Foraminifera occurring in the Recent samples from Greenland are also found in Late Glacial deposits of the Oslofjord area.

The marine-climatic conditions of East Greenland, north of Angmagssalik, are considered more severe than those of western and northern Spitsbergen (Feyling-Hanssen, 1953). *Portlandia arctica*, the index fossil of the Yoldia clay among the molluscs, occurs in both regions.

This brief comparison illustrates that the Foraminifera assemblages of zone A are to be considered as Arctic faunas their constituents and composition having been controlled by the low bottom temperatures which prevailed in the Late Pleistocene Oslofjord. This was to be expected already from the occurrence of *Portlandia arctica* in many zone A samples. – The subunits of zone A will be dealt with further in connection with a discussion of the Ra ridge at Sarpsborg (Borregaard).

Immigration of a considerable number of new species and subspecies has taken place in zone B. Subzone B_1 in addition to the species which it has in common with zone A, comprises species which are not, or only meanly, represented in pure Arctic faunas (Cp. Ellinger, 1914; Cushman, 1948). The characteristic form, *Virgulina loeblichi* was rare in the author's

Recent samples from Spitsbergen and Greenland, and *Cassidulina laevigata carinata*, *Pullenia osloensis*, *Virgulina fusiformis*, *Bulimina marginata* and *Elphidium incertum incertum* were absent. One reason for this may be the relatively small depths at which the writer's Arctic samples were taken. More likely, however, the zone B-assemblages, especially those of subzone B_l, required milder marine-climatic conditions for their existence. Not as mild as those of the Icelandic waters, however. Nørvang's records of Foraminifera from the fjords and coasts of Iceland, specifically those from the southern and eastern coast of the island, comprise many species which do not appear until zone E in the Late Quaternary of the Oslofjord area. Such is the case also with the Recent faunas recorded from the Tromsø area in northern Norway by Kiær (1908). In either of these records it is, somtimes, difficult to obtain satisfactory comparison because the recorded species were not figured. Furthermore, apart from the difficulties created by different position and exposure of the compared areas, considerations of this kind would be fully valid only if the time factor of the immigration process is disregarded. The ecological environment of the Oslofjord during zone B times were probably capable of maintaining a fauna of Icelandic type if only the corresponding species had been offered time enough to immigrate. The possibility of zone B, or subzone B_l, representing a certain depth zone of the Late Glacial Oslofjord is difficult to determine as the ecology of Arctic Foraminifera is, on the whole, not sufficiently well known.

Various environmental factors seem to have been involved in the development of the foraminiferal zonation. A stepwise amelioration of the marine-climatic conditions presumably enforced the transition from zone A to zone B, most probably also the transition from B to E, and even from E to F. These zones seem to be primarily thermally controlled, even though other factors may also have affected them. Climatic deterioration, on the other hand, may have contributed ecologically to the formation of the younger F and G assemblages, those with frequent occurrence of *Nonion labradoricum* and very poor representation of *Elphidium incertum incertum*. The subzones within zone F seem to be primarily bathyally conditioned. This seems indisputable in the case of subzone F_u. Zone G is a clear shallow-water assemblage, limited though, to temperate water. Subzone G_u is a shallow-water assemblage influenced by lowered salinity, probably also by somewhat stagnant water.

The upper and lower subzone of zone A probably represents Arctic assemblages influenced both by decreased salinity and bad food conditions (Cp. p. 66 and p. 174).

The number of different species and subspecies of Foraminifera increases, on the whole, from lower to upper parts in the cores dealt with, zone G excepted. Stages of increased immigration of new forms seem to have occurred at the transition from one zone to another. Emigration, on the other hand, seems not to have taken place on the same scale. Therefore, when first a species has appeared in the fauna, it does not seem likely to disappear again. Its frequency may however vary, and may even decrease to nearly accidental occurrence. Very seldomly species, occurring in older sediments, may not be observed in the younger.

Correlation with other classifications

It is of great interest to investigate if any correlation exists between the units of the Foraminifera zonation presented here and the units of the well-known sequence of mollusc zones established for the Late Quaternary marine clay sediments of the Oslofjord area by Brøgger at the beginning of this century (Cp. p. 24). An introductory investigation of this kind was made by the present author in 1954 (Feyling-Hanssen, 1954 a, b; 1955). Samples of *Yoldia clay*, *Arca clay*, and *Isocardia clay*, partly collected and classified by Brøgger himself, were micropaleontologically examined. The samples of Yoldia clay all appeared to be predominated by *Elphidium incertum clavatum* with *Cassidulina crassa* frequently represented. The samples of Arca clay were also dominated by these two species, to a lesser degree though, and *Virgulina loeblichi* (referred to as *Virgulina* cf. *davisi*) and *Pullenia osloensis* (*Pullenia quinqueloba minuta*) were characteristic. In the samples of Isocardia clay, finally, there was a pronounced predominance of *Bulimina marginata* and *Elphidium incertum incertum*, *Cassidulina laevigata laevigata*, and *Nonion barleeanum* (recorded as *N. pompilioides*), among others, frequently occurred. Only two samples of *Scrobicularia clay* were examined. They contained only a few arenaceous forms, *Verneuilina media* and *Eggerella scabra* being the most frequent. These classical samples originated from the southern as well as the northern part of the Oslofjord area.

In a later paper (Feyling-Hanssen, 1957) the units of the foraminiferal zonation were briefly correlated with Brøgger's units in the following way: The foraminiferal assemblages classified as zone A were referred to Brøgger's Yoldia clay, zone B were correlated with the *Arca clay*, zone E roughly with the Mytilus and Cyprina clay, the Cardium clay and the

Ostrea clay, zone F with the Isocardia clay and parts of the Scrobicularia clay, and zone G, finally, with the Scrobicularia clay. This correlation was cited by Holtedahl (1960, p. 388).

As discussed in the author's paper (Feyling-Hanssen, 1954 a), a correlation between Brøgger's mollusc zones and the units of the Foraminifera zonation is, at least in some cases, ambiguous. One reason for this is that Brøgger's scheme, especially in its original form, appears to be too detailed. Its different units are not always recognizable in the field (Cp. Feyling-Hanssen, 1957, p. 16). Thus, a sample from Oslo, designated as Cardium clay on the basis of many shells of *Cerastoderma edule* (Linné) in it, contained a Foraminifera fauna of F_{II}-type, whereas a sample from Fredrikstad, rich in valves of *Arctica islandica* (Linné) and thus reminiscent of the older Cyprina clay (Mytilus and Cyprina clay), contained Foraminifera which were also referable to subzone F_{II} or even to zone G (Feyling-Hanssen, 1954 a, p. 121). A clay sample from Ringvold brickwork in Bærum, near Oslo, was classified as Arca clay because it contained numerous valves of *Bathyarca glacialis* (Gray) and *Pseudamussium septemradiatus* (Müller) together with *Nuculana pernula* (Müller). However, *Arctica islandica* and *Cerastoderma edule* also occurred in that sample. Even *Glossus humanus* (Linné), *Corbula* (*Varicorbula*) *gibba* (Olivi), *Ostrea edulis* (Linné), and *Aporrhais pespelicani quadrifidus* (Da Costa), among others, occurred together with the above-mentioned species in this deposit, i.e., characteristic constituents of the Post Glacial Isocardia clay occurred together with characteristic species of the Late Glacial Arca clay. For such reasons exact correlation, unit by unit, is hardly possible between Brøgger's mollusc zones and the Foraminifera zonation of the present study. Some observations in addition to the previous attempts at correlation are given below.

Zone A were readily recognized in all investigated samples of Yoldia clay from the Oslofjord area. Radiocarbon datings of mollusc shells from micropaleontologically examined samples of Yoldia clay from this area revealed ages from 11200 ± 200 years before present (1950) to 9950 ± 300 years before present. The main part of this formation seems thus to be of Younger Dryas age. Interpretation of the subzones of zone A is attempted in connection with a discussion of the Ra ridge at Sarpsborg (Borregaard) in the next chapter.

Foraminifera faunas of zone A type were previously recognized in two samples of Yoldia clay from the Oslofjord area by Kiær (Cp. p. 28 of the present paper).

Outside the Oslofjord area a similar fauna of fossil Foraminifera was recorded by Kiær (1908, p. 18) in clay, with *Portlandia arctica*, from Tromsdalen clay pit, near Tromsø in northern Norway. The present author recognized zone A assemblages in a number of borings in the city of Trondheim, central part of Norway. Four of these borings were described in 1957 (p. 40). Similar assemblages also occurred in the deeper parts of a series of borings in the valley of Namdalen, north of Trondheim (Feyling-Hanssen, 1959b and 1961, Reports to the Norwegian Geotechnical Institute, Oslo). At Lundetre, Os by Bergen, on the west coast of Norway, H. Holtedahl collected clay with *Portlandia arctica*, *Saxicava* (*Hiatella*) *arctica* (Linné), and *Balanus balanus* (Da Costa). This sample was radiologically dated at 10 050 ± 250 years before present (Nydal, 1962, p. 171). Its fauna of fossil Foraminifera was richer than most of the other samples of this type, probably due to the west-coast-position of the locality. *Elphidium incertum clavatum* occurred in abundance, followed by *Cassidulina crassa* and *Astrononion gallowayi*. *Cibicides lobatulus* and *Protelphidium orbiculare* were common. 27 different species and subspecies were recognized in that sample. M. Marthinussen collected a clay sample with *P.arctica* at Steinsdal, Sømna (Vik) in Helgeland, between Namsos and Bodø. That sample was radiologically dated at 10 300 ± 250 years before present (Nydal, 1960, p. 86) and contained more specimens of *Virgulina schreibersiana* than of *E. incertum clavatum*. Otherwise the fauna fits well in zone A. Assemblages strongly reminiscent of zone A were, furthermore, found in the deeper part of a boring in the harbour of Bodø, at the Polar circle. In many of those samples, however, *Cassidulina crassa* outnumbered *E. incertum clavatum*. A sample from Bodø brickworks, 6 m above sea level, contained 49 % *E. incertum clavatum*, 39 % *C. crassa*, and 6.5 % of *Virgulina schreibersiana*. Also this sample, which was collected by T. Soot-Ryen, contained valves of *P. arctica*. B. G. Andersen collected clay samples with marine molluscs in the county of Troms, around the city of Tromsø. A sample from Brøstadbotn, collected 10 m under the terrain surface, which was situated 50 m above sea level, contained numerous valves of *Portlandia arctica* but only the following Foraminifera:

Elphidium incertum clavatum	45	specimens
Guttulina dawsoni	4	–
Cassidulina crassa	2	–
Elphidium subarcticum	2	–
Cibicides lobatulus	1	–
Quinqueloculina sp.	1	–

This sample had a minimum age of 10 700 years. A sample from Bjorelvnes, collected 10 m under the terrain surface, which lay 60 m above sea level, contained the following Foraminifera:

Species	Frequency	Percentage
Elphidium incertum clavatum	152	58.5
Elphidium incertum incertum	47	18.1
Cassidulina crassa	37	14.2
Buccella frigida	10	3.9
Astrononion gallowayi	3	1.2
Elphidium cf. *excavatum*	2	0.8
Elphidium subarcticum	2	0.8
Cibicides lobatulus	2	0.8
Biloculinella inflata	1	0.4
Virgulina schreibersiana	1	0.4
Virgulina loeblichi	1	0.4
Nonion labradoricum	1	0.4
Protelphidium orbiculare	1	0.4
Total	260	100.3

This sample contained numerous valves of *Macoma calcarea* (Chemnitz), and was radiologically dated at 10 500 ± 400 years before present (Nydal, 1959, p. 77). A sample from Breivikeid, rich in *P. arctica*, was dated at 11 500 ± 400 years before present (Nydal, 1960, p. 85), and yielded the following foraminiferal assemblages:

Species	Frequency	Percentage
Elphidium incertum clavatum	389	97.1
Guttulina dawsoni	7	1.7
Cassidulina crassa	1	0.3
Elphidium incertum incertum	1	0.3
Elphidium subarcticum	1	0.3
Buccella frigida	1	0.3
Total	400	100.0

These samples were collected by B. G. Andersen, and submitted for dating by him. Also in Lyngen and Nordreisa there has been found Pleistocene clays with Foraminifera assemblages of zone A-composition. – Even if many of these samples from different parts of Norway are of

Younger Dryas age, this need not necessarily be the age of such faunas. Their primary indication seems to be paleoclimatical, they probably lived under circumstances similar to those of zone A in the Oslofjord area.

Similar faunas are recorded also from localities outside Norway. Munthe (1896) listed the fossil Foraminifera in a sample of Yoldia clay from Tjörn island on the Swedish west coast, which fauna had much in common with zone A in the Oslofjord area (Cp. Feyling-Hanssen, 1954a, p. 116), whereas the faunas in Yoldia clay from Västgötaslätten (Munthe, 1901, cp. also Munthe, 1896) seem not to be consistent with the Foraminifera faunas of the Yoldia clay from the Oslofjord area. Hessland (1943) did not record any foraminiferal fauna from the Late Quaternary of Bohuslän, Southwest Sweden, with composition similar to our A-faunas. The reason may be that he dealt mainly with deposits of the shallowest water. Brotzen (1951), in the lowest part of the Late Glacial of a boring through clay deposits at Surte, near Gothenburg on the Swedish west coast, found fossil Foraminifera faunas with composition very similar to that of zone A, specifically similar to subzone A_{II} and A_{I}. *Elphidium incertum clavatum* predominated (60–100 %) and *Cassidulina crassa* was quite frequent. *Nonion labradoricum* occurred, and in a few samples also *Elphidium incertum incertum*. The genera *Pyrgo* and *Virgulina* were also represented. A closer comparison is difficult because Brotzen did not describe nor illustrate the species. The good correspondence between zone A of the Oslofjord area and the lower Late Glacial of the Surte boring may indicate similar environmental conditions during deposition of these layers in the two localities, but not necessarily similar age. Madsen (1895a) found that *Polystomella striatopunctata* var. *incerta* (probably = *Elphidium incertum clavatum*) occurred in all Danish Pleistocene strata investigated by him, but that it was very frequent only in deposits with an Arctic or Boreal fauna (Cp. also Munthe, 1897; Madsen, 1895 b, 1900). In a boring from Inder Bjergum in Southwest Jutland Buch (1955) found faunas with a high frequency of *Elphidium incertum clavatum* and which also contained species well known from the Late Glacial of the Oslofjord area. However, *Streblus beccarii* also occurred with these faunas, thus giving them a composition which is unknown among zone A-faunas of the Oslofjord area. The part of the core in which these faunas occurred, was interpreted as interglacial, of Mindel/Riss age. In Boulder Clay from Altcas, England, Wright (1904, p. 367) found that i.a., *Streblus beccarii* was very rare, but was found with abundant specimens of *Cassidulina crassa* (Cp. also Munthe, 1898). Macfadyen

(1932) in his paper on Foraminifera from East Anglia reviewed previous work on British Pleistocene Foraminifera. He regarded *Elphidiella arctica* (= *Elphidium arcticum*) as characteristic of the Lower Pleistocene deposits. That species was, however, not found in the Boulder Clay of Wexford Coast of Ireland (Macfadyen, 1940; cp. also Baden-Powell, 1938). Also van Voorthuysen (i.a., 1950c), who in a series of papers dealt with the Plio – Pleistocene boundary in the Netherlands, emphasized the presence of *Elphidiella arctica*. Some of the species typical for the Late Glacial of the Oslofjord area also occurred there. *Elphidium incertum clavatum* was found quite frequently, especially in the Amstelien (Oldest Pleistocene) of a boring at the Hague (1950a; cp. also 1949 a). However, these Early Pleistocene faunas from the Netherlands were quite different from the Late Pleistocene faunas from the Oslofjord. In this connection it must be mentioned that the Himi strata of the Toyama sedimentary basin in Japan, comprise an *Elphidium* – *Cassidulina* zone with frequent *Elphidium incertum clavatum* and other species which in Recent time inhabit Arctic seas. The Himi strata are considered to be of Pliocene age (Chiji, 1961).

H. Holtedahl (1959) and Lange (1956) recorded Late Glacial faunas similar to those of the Oslofjord area from submarine core samples from the Norwegian Sea and Skagerrak.

Zone A in the Oslofjord area is distributed south of, as well as into, the Ra ridge, as is also the Yoldia clay, according to Brøgger (1900–1901). In addition, however, assemblages referable to subzone A_{II} were found in borings in Rakkestad, at Askim and in Holmestrand. These localities are situated between the Ra ridge and the moraines of the Ås–Ski substage. This would mean that such assemblages existed in the Oslofjord also after the margin of the inland ice had left the Ra position. If the Yoldia clay, in accordance with Brøgger's concept, is considered not to be younger than the Ra ridge, subzone A_{II} is probably to be correlated with the oldest part of the Arca clay. It is, however, equally possible that the Yoldia clay, with *Portlandia arctica*, may occur in the lowest parts of Late Glacial marine clays also north of the Ra ridge.

Zone B, or more correctly, *subzone B_I*, is recognized in most samples of *Arca clay* from the southern and middle part of the Oslofjord area. A good illustration is provided by the following count of the Foraminifera in a sample from the clay pit of Sandefjord brickworks. This sample was collected and designated as Older Arca clay by Brøgger himself:

Species	Frequency	Percentage
Cassidulina crassa	166	29.9
Elphidium incertum clavatum	105	18.9
Nonion labradoricum	103	18.5
Cassidulina laevigata carinata	53	9.5
Virgulina loeblichi	52	9.4
Elphidium incertum incertum	29	5.2
Cibicides lobatulus	16	2.9
Bulimina marginata	10	1.8
Virgulina schreibersiana	7	1.3
Pullenia osloensis	5	0.9
Quinqueloculina seminulum	2	0.4
Lagena distoma	2	0.4
Elphidium subarcticum	2	0.4
Quinqueloculina stalkeri	1	0.2
Pyrgo williamsoni	1	0.2
Lagena striata f. substriata	1	0.2
Astrononion gallowayi	1	0.2
Total	556	100.3

Another sample of Arca clay, collected by Øyen in 1898 on the east bank of the river Glomma at Søreng in Eidsberg, between the Ra and the Ås-Ski moraines, was submitted for dating by O. Holtedahl. The result of the dating was 9750 ± 250 years before present (Holtedahl, 1960, p. 376; Nydal, 1962, p. 168). The locality, Grønsund, Søreng, was described by Sars (1865, p. 22) and by Brøgger (1900–1901, p. 142–144). The dated sample, which contained shells of *Pseudamussium septemradiatus* (Müller) together with *Bathyarca glacialis* (Gray) and *Yoldiella lenticula* (Möller), belongs, according to Brøgger (l. c.), to the youngest part of the Arca clay in that locality, and is consequently also younger than the above-mentioned sample from Sandefjord. The fossil fauna of Foraminifera from the 9750 years old Arca clay from Eidsberg had the following composition:

Species	Frequency	Percentage
Elphidium incertum clavatum	276	61.9
Cassidulina crassa	81	18.1
Nonion labradoricum	31	7.0
Virgulina loeblichi	21	4.7
Pullenia osloensis	13	2.9
Quinqueloculina seminulum	6	1.3
Cibicides lobatulus	5	1.1

Pyrgo williamsoni	4	0.9
Alveolophragmium crassimargo	1	0.2
Quinqueloculina stalkeri	1	0.2
Biloculinella inflata	1	0.2
Lenticulina cf. *angulata*	1	0.2
Lagena mollis	1	0.2
Guttulina lactea	1	0.2
Globobulimina auriculata arctica	1	0.2
Virgulina schreibersiana	1	0.2
Cassidulina laevigata carinata	1	0.2
Astrononion gallowayi	1	0.2
Total	447	99.9

No record of Foraminifera from Older or Middle Arca clay from the Oslofjord area is found in the literature. A sample from Sandefjord was examined by the present author (1954a), but the result was given as an average composition of six samples of which five were from the Younger Arca clay around the city of Oslo. In the city of Trondheim Foraminifera assemblages of similar composition as subzone B_I occurred in several borings (Feyling-Hanssen, 1957, p. 39–44), though the zone which was there called C appears to correlate better with subzone B_I of the Oslofjord area than does zone B in Trondheim. Nordgaard (1907, p. 37) collected a sample of Arca clay from the brickworks of Baklandet in Trondheim and listed the foraminiferal species in it (identified by H. Kiær). Quantities were not indicated, but the species may all occur in subzone B_I. From Arca clay at Langenes on the west side of the island Tromsøy, near the city of Tromsø, Kiær (1908, p. 19) recorded a Foraminifera fauna with frequent *Polystomella striatopunctata*, *Cassidulina crassa*, and *Nonionina scapha*, and *Virgulina schreibersiana* (probably *Virgulina loeblichi*) in abundance. Other aquaintances from subzone B_I also appear on Kiær's list.

In the Surte-boring, near Gothenburg, (Brotzen, 1951, p. 62) similarities with subzone B_I were found in zone 3 and 4.

The assemblages classified as B_{II}, occurring in front of the Ås–Ski moraines and northwards to Oslo, are discussed later (p. 180–183).

Zone B, in addition to being the foraminiferal equivalent to the Arca clay and its variants in the outer Oslofjord area, is most probably in many instances also contemporaneous with Brøgger's *Mytilus and Cyprina clay*. Direct comparison of the Foraminifera fauna of a sample of Mytilus and Cyprina clay with that of subzone B_I will in most cases show little similarity between the two because clay with *Mytilus edulis* was in general deposited in shallow water, whereas with zone B or subzone B_1 it was probably not the case. A few examples were given by the present author (1954a, p. 120). *Elphidium incertum clavatum* and *Cassidulina crassa* occurred in samples of Mytilus clay and in addition, *Elphidium subarcticum, E. incertum incertum, E. excavatum, Protelphidium orbiculare, Elphidiella arctica, Nonion depressulus asterotuberculatus, Nonion labradoricum,* and *Cibicides lobatulus*. Radiocarbon datings of mollusc shells in Mytilus and Cyprina clay from the outer Oslofjord area have, as yet, not been undertaken, such clays being rare or absent in that part of the area. Inmost localities the Arca clay is followed directly by the Isocardia clay without any interbedded transitional sediment.

It is, on the whole, quite probable that the Mytilus and Cyprina clay represents merely a shallow-water facies of the Arca clay. In this connection it is emphasized that Brøgger (1900–1901) did not describe this clay from the southern part of the Oslofjord area where his localities were all situated at small altitudes. From the northern area, around the city of Oslo, where the relief is sharp, he found Mytilus and Cyprina clay in several localities. With one of these occurrences, viz., at Bekken, Vettakollen in Oslo, 185 m above sea level, Brøgger (l.c., p. 170–174) expressed the view that the Mytilus and Cyprina clay was a shallow-water deposit contemporaneous with the Arca clay, deposited at greater depth. In his stratigraphic chart (l.c., p. 650a), however, the Mytilus and Cyprina clay is inserted as a formation younger than the Youngest Arca and Portlandia clay.

The dated sample of Arca clay from Søreng in Eidsberg belongs to the Middle Arca clay in Brøgger's scheme, mainly distributed between the Ra ridge and the Ås–Ski moraines. Its age places it in Pre-Boreal time of the Blytt-Sernander sequence. The younger parts of this clay most probably reach into Boreal age. Mytilus clay from Strømmen (Cp. later, p. 188), east of Oslo, 147 m above present-day sea level, was radiologically dated at 9500 ± 200 years before present (submitted by Rosendahl; cp. Nydal, 1962, p. 169), samples of shore gravel with *Mytilus edulis* at the marine limit in Oslo, 221 m above sea level, had ages of 9450 ± 250 and 9250 ± 250 years before present (Holtedahl, 1960, p. 377; Nydal, 1960, p. 86, 87, T 119A, T 119C), *Mytilus* shells from Lutvann, near Oslo, 200–201 m above sea level, were dated at 9250 ± 300 years before present (Nydal, 1962, p. 168). Brøgger (1900–1901, p. 650a) considered such occurrences to be contemporaneous with the Youngest Arca and Portlandia clay. Accordingly, zone B is here, for its main part,

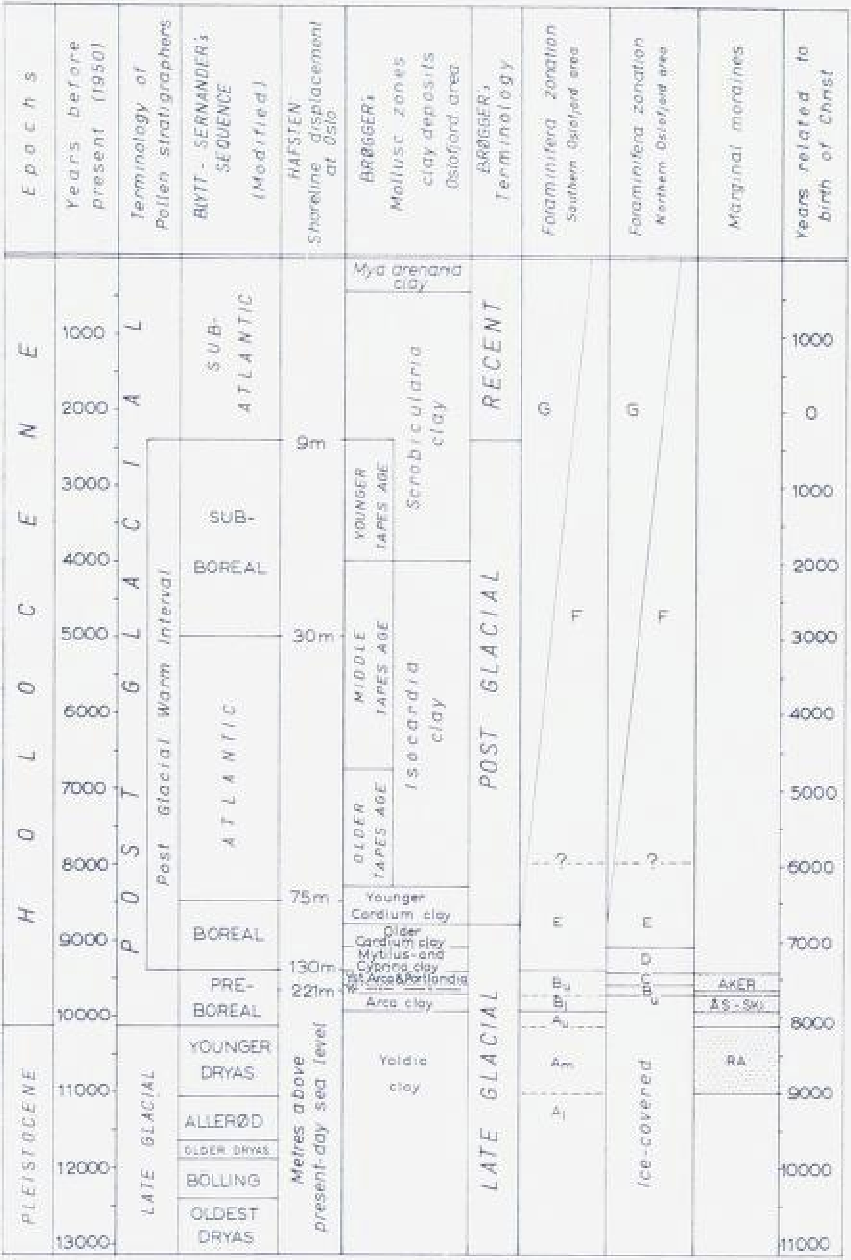


Fig. 31. Tentative correlation. 'Yst. Arca & Portlandia' means Youngest Arca & Portlandia clay; 'Yr. Arca & Portlandia' means Younger.

assumed to be of Pre-Boreal age. (Cp. correlation chart of fig. 31, p. 162; see also Feyling-Hanssen, 1963).

Hydrothermically zone A and B belong in the Late Glacial. The subsequent zones are of Post Glacial character.

Zone E was recognized in a sample of Older Cardium clay from Havnens brickworks approximately 100 m above sea level, in Oslo. That sample was radiologically dated at 9100 ± 180 years before present (Holtedahl, 1960, p. 385; Nydal, 1960, p. 87), and contained the following Foraminifera:

Elphidium incertum clavatum	53	specimens
Cassidulina crassa	14	–
Elphidium incertum incertum	11	–
Bulimina marginata	11	–
Pullenia osloensis	4	–
Elphidium subarcticum	3	–
Quinqueloculina stalkeri	1	–
Parafissurina lateralis, forma *simplex*	1	–
Nonion depressulus asterotuberculatus	1	–
Buccella frigida	1	–
Total	100	specimens

This locality was described by Brøgger (1900–1901, p. 286, 287). A sample of Cardium clay from Torshov, Oslo, (Pal. Mus. coll.) contained *Elphidium incertum incertum*, *E. incertum clavatum*, *Bulimina marginata*, *Elphidium subarcticum*, *E. excavatum*, *Oolina hexagona*, *Ammonia batavus*, and *Virgulina fusiformis*.

However, a sample with *Acanthocardia echinata* (Linné) (= *Cardium echinatum*) from Hvalstad railway station, not far from Oslo, abounded in *Ammonia batavus* and contained in addition *Eggerelle scabra*, *Miliammina fusca*, *Jadammina polystoma*, *Elphidium excavatum*, *E. subarcticum*, *E. incertum incertum*, *E. incertum clavatum*, *Nonion depressulus asterotuberculatus*, *N. barleeanum*, *Bulimina marginata*, *Virgulina loeblichi*, *Cibicides pseudoungerianus* and a species of *Trochammina*, i. e., a shallow-water assemblage most probably of later origin than is assumed here for zone E. As mentioned on page 154, a sample of Cardium clay from Oslo contained a foraminiferal assemblage of F_{II}-type, also demonstrating that abundant occurrence of *Cerastoderma edule* or *Acanthocardia echinata*, or both, in a sediment is not necessarily associated with foraminiferal faunas of zone E-type. It seems quite reasonable that Boreo-Atlantic pelecypods like the above-mentioned would not, when once immigrated into the area, restrict themselves to a narrow stratigraphic unit, like the Cardium clay; more likely they would maintain their populations as long as favourable ecological environment prevailed. According to the general Post Glacial geological record, conditions favourable to these species have prevailed ever since Boreal time, and prevail continuously in the Oslofjord to-day. Brøgger was certainly aware of this, he listed species characteristic of the Cardium clay from several deposits younger than that unit. But many of his successors were inclined to rapid classification of clay deposits into Brøgger's scheme upon, in many cases, superficial ascertainment of conspicuous pelecypod species in them. Samples classified in that way are found in many collections. When such samples are submitted for radiocarbon dating, the results may give many a surprise to the submitter.

Zone E, being characterized by the appearance of several foraminiferal species which did not occur in Late Glacial deposits, and being situated between the Late Glacial zone B and the Post Glacial zone F, evidently related to the Isocardia clay, is here assumed to be of Boreal age, as far as assuming that it is not of facies character and thus able to occur also in younger sediments. As zone B conditions probably extend into the early part of Boreal age, zone E would belong in the later part of that unit, most probably reaching into the earlier part of Atlanticum. These assumptions are in good keeping with the heights above present-day sea level to which zone E has been recognized (p. 147 and fig. 31).

Zone F was readily recognized in samples of *Isocardia clay* from the southern as well as from the northern part of the Oslofjord area (Feyling-Hanssen, 1954a). A sample of Isocardia clay from Valle brickworks, collected by Brøgger in 1899, was radiologically dated at 6570 ± 150 years before present (Holtedahl, 1960, p. 385; Nydal, 1960, p. 87). It contained the following Foraminifera:

Bulimina marginata	44	specimens
Ammonia batavus	33	–
Elphidium incertum incertum	16	–
Elphidium subarcticum	12	–
Elphidium incertum clavatum	11	–
Cibicides lobatulus	5	–
Nonion depressulus asterotuberculatus	2	–
Hyalinea balthica	2	–
Dentalina advena	1	–
Total	126	specimens

This rather poor fauna seems to belong in the upper part of zone F. Its age places it in the middle part of Atlanticum.

Previous records of Foraminifera from deposits in the Oslofjord area probably correlatable with the Isocardia clay were listed on the pages 25–31. Kolderup (1907, p. 149, 156, 167, and 173) recorded Foraminifera (identified by H. Kiær) from four Post Glacial shell beds in the Bergen area. They all represent shallow-water occurrences, not directly comparable with assemblages from clay deposits, but many of the species are known from zone F in the Oslofjord area. Øyen (1911, p. 142) mentioned *Rotalia beccarii* (probably *Ammonia batavus*) from Post Glacial deposits at Sve, 35 m above sea level, in the Trondheim area, and Monsen (1935) listed Foraminifera from shell beds of Tapes age from Rødøy in Helgeland, northern Norway. They both represent shallow-water occurrences. *Quinqueloculina seminulum* and *Cibicides lobatulus* were frequent and *Rotalia beccarii* (*Ammonia batavus* ?) among others, occurred. Among the foraminiferal species from Post Glacial deposits near Tromsø, recorded by Kiær (1908), are also some which are known from zone F in the Oslofjord area. The composition of the faunas is quite different, however, and many of the zone F-species are not represented there. This is reasonable in view of the considerable difference in latitude between the two areas. For the same reason Foraminifera faunas from the Post Glacial Warm Interval of Spitsbergen (Heron-Allen, 1931; Bowen, 1954; Feyling-Hanssen, 1964, in press), are very different from zone F-faunas in the Oslofjord area.

The upper samples from the Surte-boring, near Gothenburg, (Brotzen, 1951, p. 62) display great similarity with zone F, especially the samples of zone 7 (Cp. Feyling-Hanssen, 1954a, p. 124), while even in Post Glacial deposits from the English Fenlands (Macfadyen, 1938, p. 415) many zone F-constituents from the Oslofjord area are recognized.

Zone F is in the Oslofjord area, no doubt, related to the Isocardia clay, and like this referable to the Post Glacial Warm Interval proper, Atlantic and Sub-Boreal time in the Blytt-Sernander sequence. The Isocardia clay reaches half-way into Sub-Boreal age, and is, according to Brøgger (1905, p. 124), related to the Older and Middle Tapes age. However, as revealed by low-lying borings of the present material, specifically the submarine ones, there occur F-assemblages which are of Sub-Atlantic age. A boring at Herøya, near Skien, with a surface 21.9 m below present sea level, seems to illustrate that F-assemblages of very recent origin occur in the area, with some difference, however, regarding the representation of *Nonion labradoricum* and *Elphidium incertum incertum*, mentioned on page 139. Consequently there exist sediments with zone F-faunas which are contemporaneous also with the *Scrobicularia clay*, the unit which in Brøgger's system succeeds the Isocardia clay. The few samples of Scrobicularia clay which have been micropaleontologically examined, did not, however, yield foraminiferal faunas of F-type but of G-type. This would probably indicate that the Isocardia clay, or clays closely related to it, were deposited also throughout Sub-Boreal and probably even in Sub-Atlantic time. The Scrobicularia clay would then have to be regarded as a shallow-water facies of the younger part of the Isocardia clay, or related sediments. Already Hessland (1943, p. 299, 300) called attention to the fact that *Scrobicularia plana* (Da Costa) lives in brackish shallow-water whereas *Glossus humanus* (Linné), the index form of the Isocardia clay, prefers clear and salty water of greater depth. He therefore suspected that the Scrobicularia clay was merely a shallow-water facies of the Isocardia clay. However, when Brøgger's papers and collections from the Late Quaternary of the Oslofjord area, kept in the Paleontological Museum of Oslo, are considered, it seems, in fact, that shells of *Scrobicularia plana* occur mainly in low-lying, i.e., young, deposits of the inner, northern Oslofjord area. *S. plana* was probably a late immigrant which did not appear until the inner fjord basin, as a result of the negative shift of the shoreline, was to some degree locked off from the outer basin and the circulation hampered enough to create ecological conditions fit for the species. If, however, by future investigations, *Scrobicularia plana* is found in Post Glacial deposits of the Oslofjord area at heights up to approximately 70 m above present-day sea level (p. 24), and frequent enough to characterize the deposit, the Scrobicularia clay would evidently have to be regarded as a mere shallow-water facies of the Isocardia clay, and through the whole range of the latter as being contemporaneous with it. As long as highlying occurrences of *Scrobicularia plana* are not ascertained, it seems safest to regard the Scrobicularia clay as a shallow-water facies only of a younger extension of the Isocardia clay.

The subzones of F, as mentioned on page 144, are most probably connected with certain depth zones which may well have been contemporaneous in different localities.

Zone G was recognized in samples of *Scrobicularia clay* (Feyling-Hanssen, 1954a, p. 124), which however, contained very few Foraminifera. A better example is given here by a sample from Tullinløkka in the low-lying centre of the city of Oslo (Paleont. Mus. coll.). It contained numerous valves of *Scrobicularia plana*, and the following Foraminifera were picked out of 100 g (dry weight) of this sample:

Species	Frequency	Percentage
Eggerella scabra	93	35.1
Ammonia batavus	65	24.6
Nonion depressulus asterotuberculatus	50	19.0
Ammoscalaria runia	23	8.7
Miliammina fusca	11	4.2
Elphidium incertum clavatum	7	2.6
Verneuilina media	6	2.3
Elphidium incertum incertum	3	1.1
Trochammina intermedia	2	0.8
Elphidium excavatum	2	0.8
Jadammina polystoma	1	0.4
Elphidium subarcticum	1	0.4
Total	264	100.0

A sample of Scrobicularia clay from Bestum, Oslo, collected by H. Rosendahl and submitted by him for radiocarbon dating, gave as result 2050 ± 150 years before present (Nydal, 1962, p. 168). The following Foraminifera were found in 120 g (dry weight) of the sample:

Ammonia batavus	55	specimens
Ammoscalaria runiana	30	–
Jadammina polystoma	15	–
Elphidium incertum incertum	9	–
Nonion depressulus asterotuberculatus	8	–
Eggerelle scabra	6	–
Miliammina fusca	6	–
Verneuilina media	1	–
Spiroplectammina biformis	1	–
Elphidium incertum clavatum	1	–
Total	132	specimens

Another sample from low-lying Scrobicularia clay in the city of Oslo, collected by Brøgger between the streets of Lakkegaten and Bekkegaten (Paleont. Mus. coll.), was radiologically dated at 980 ± 100 years before present (Nydal, 1960, p. 87; 1962, p. 161).

It contained *Mytilus edulis* and *Scrobicularia plana*, and the following few Foraminifera:

Elphidium excavatum	23	specimens
Ammonia batavus	17	–
Nonion depressulus asterotuberculatus	13	–
Eggerella scabra	10	–
Elphidium incertum clavatum	8	–
Elphidium incertum incertum	3	–
Total	74	specimens

These datings show that there occurs a Scrobicularia clay which is younger than estimated by Brøgger (Cp. present paper, p. 25). It is not restricted to the latest part of the Post Glacial Warm Interval, but occurs also among Sub-Atlantic deposits. It is here observed that Brøgger (1900–1901, p. 555, 556) mentioned the occurrence of very young clay with *Scrobicularia plana* in the river Göta älv at the Swedish west coast, even that this species was common in the living fauna at the mouth of that river.

Brøgger (l.c., p. 550) described the Scrobicularia clay mainly from low-lying deposits in the city of Oslo. He did not record it from the southern part of the Oslofjord area. The frequent occurrence of zone G, e.g., in Fredrikstad, illustrates therefore that this foraminiferal assemblage is not necessarily associated with Scrobicularia clay. The previously mentioned sample from Ringvoll brickworks in Bærum (p. 154) (Paleont. Mus. coll.), supposed to represent the Younger Arca clay but which contained as many constituents of the Isocardia clay among its enclosed molluscs, revealed the following foraminiferal fauna:

Species	Frequency	Percentage
Eggerella scabra	121	52.7
Elphidium incertum incertum	48	21.0
Elphidium incertum clavatum	24	10.4
Pullenia osloensis	10	4.4
Bulimina marginata	9	3.9
Ammonia batavus	6	2.6
Miliammina fusca	5	2.2
Ammoscalaria runiana	1	0.4
Haplophragmoides pusillum	1	0.4
Quinqueloculina seminulum	1	0.4
Lagena cf. *gracilis*	1	0.4
Lagena laevis	1	0.4
Cassidulina crassa	1	0.4
Nonionella turgida	1	0.4
Total	230	100.0

This assemblage indicates shallow water, and would be classified as zone G. Shells of the pelecypode *Pseudamussium septemradiatus* from this sample were radiologically dated at 8700 ± 200 years before present (Nydal, 1962, p. 169).

Again, it seems that zone G is not necessarily associated with the Scrobicularia clay, since no specimen of *Scrobicularia plana* was found in the sample from Ringvoll brickworks. Furthermore, if the radiocarbon dating is accepted, such assemblages may occur in sediments as old as the beginning of Atlantic time, probably even in deposits of Boreal age. If so, zone G may be regarded as the shallow-water facies not only of zone F but probably even of zone E, as illustrated in figure 31.

Outside the Oslofjord area foraminiferal assemblages similar to zone G were recognized in several borings in the valley of Namdalen. These deposits occurred as shallow-water facies of Holocene deposits (Feyling-Hanssen, 1959 b and 1961, reports to the Norwegian Geotechnical Institute).

Øyen's (i. a., 1915) system of shoreline stages was based upon the occurrence of molluscs in littoral deposits. Foraminifera assemblages from such deposits are hardly correlatable with units of the foraminiferal zonation in clay deposits, dealt with here.

The Ra ridge at Sarpsborg

Previous investigations. – The prominent ridge of unconsolidated material, the Ra, had been described in 1838 by Keilhau as a ridge running approximately parallel to the coast from Halden to Moss on the east side of the Oslofjord, damming a series of lakes. He considered it a shore formation. Kjerulf (Sars and Kjerulf, 1861) recognized this formation as being a marginal moraine and traced it also on the west side of the fjord, from Horten to Nevlunghavn, and plotted it in an accompanying map of 1859. He supposed that the ridge was built of unsorted moraine material, as also did Helland, (1876, 1894). L. Vogt (1881, 1892) recorded bedded sand and gravel in the Ra ridge at Bjørnstad at the southern end of Femsjø by Halden. Brøgger (1900–1901, p. 75) found, at Moss, that the Yoldia clay, which he considered to be contemporaneous with the Ra, could be traced on to the Ra ridge and found that the upper part of the Ra material extended over the clay and covered it. He explained this covering, at least in parts, as being the result of secondary wave washing from the moraine ridge. Brøgger regarded the Ra in southeastern Norway as a submarine formation. At Borregaard he found (l.c., p. 19) in excavations on the Ra in Sarpsborg in stony glacial clay, a large form of the bivalve *Macoma calcarea* (Chemnitz), which is typical of the Yoldia clay, and pointed to the fact that M. Sars had collected that species at Borregaard. Bjørlykke (1900 and 1905) studied the marginal moraines at Ås, Ski and Nordby, north of the Ra, and also the Ra ridge, at Horten and Moss. He concluded that these moraine ridges consisted of sand, gravel and stones, but that in addition they had generally a kernel of marine, fossil-bearing clay indicating that they were marine formations having been pushed up in front of an advancing ice front. Hansen (1910) arrived at the same conclusion after detailed study of the Ra ridge on the west side of the Oslofjord. A series of borings on the island of Jomfruland, east of Kragerø (Keilhau, 1842, p. 174), showed that this island, as far as it constitutes a part of the Ra ridge, is a clay bank with only a 0.5 m to 6.0 m thick coating of boulders, gravel and sand. Hansen (l.c.) found similar conditions at Larvik and Horten and concluded that the Ra came into existance in the following way: "The growing ice sheet, as it advanced upon the low country near the sea, ploughed its way, through the existing clay layers, pushing up ahead of it a wall of clay. From the glacier front, the melting water brought forward morainic detritus, especially during the thawing season, covering the clay wall with a mantle of stratified overwash gravel and sand." (l.c., p. 258). He emphasized this view 19 years later (Hansen, 1929), and a similar conclusion was reached by Johansson (1937) for Ledsjö-vallen, a part of the Central Swedish moraines in Västergötland. Holtedahl (1953, p. 648–655) summarizing the findings of marine fossils in the Ra ridge, called attention to a beautiful natural section in the Ra ridge at Åbufoss in Vestfold, where no traces of pressing or any kind of disturbance of the strata could be observed. He found it difficult to explain that formation by any pushing up of clay sediment ahead of an advancing ice front. As mentioned on page 22, the Ra was most probably formed during Younger Dryas time (Cp. De Geer, 1884, 1896; Fromm, 1938; Donner, 1957 – among others).

The micropaleontological investigation of the Ra cores from Borregaard (p. 105–115) confirms the consideration of the Ra being a submarine formation. Most samples contained numerous marine Foraminifera. Furthermore, the foraminiferal assemblages in the major part of the Ra samples had to be classified as subzone A_m. Even a clay sample from the remote elongated island of Jomfruland, which forms a part of the Ra ridge 50 km southwest of Sandefjord, contained the following typical A_m-fauna:

Species	Frequency	Percentage
Elphidium incertum clavatum	587	50.6
Cassidulina crassa	307	26.4
Nonion labradoricum	190	16.4
Cibicides lobatulus	26	2.2
Islandiella teretis	22	1.9
Virgulina loeblichi	8	0.7
Pyrgo williamsoni	6	0.5
Astrononion gallowayi	5	0.4
Elphidium incertum incertum	4	0.3
Quinqueloculina seminulum	3	0.3
Elphidium subarcticum	3	0.3
Lenticulina cf. *angulata*	1	0.1
Total	1162	100.1

Only towards the bottom of boring no. 13, on the distal slope of the Ra at Borregaard, did assemblages of A_I-type occur, whereas a boring immediately to the south of the Ra ridge at Moss contained faunas classified as subzone A_{II} (p. 104).

The A_{III}-samples usually contain richer foraminiferal populations than samples from the other subunits of zone A. Subzone A_{III} would therefore seem to reflect ecological conditions less severe than affected the subzones A_I and A_{II}. This may lead to the conclusion that the clay sediments of the foraminiferal subzone A_{III} at Valle and at Borregaard, i.e., in front of and within the Ra ridge, were originally deposited during a late part of the Allerød oscillation. The northernmost parts of these strata were then, at the beginning of Younger Dryas time, pushed a short way southwards and incorporated in the Ra ridge, or Ra *moraine* which would in that case have been the adequate descriptive term. Considered in that way, the Ra would represent the outer limit of a Younger Dryas age oscillatory ice front advance interrupting the general retreat which had, at an increased rate, taken place during the milder Allerød time. The ridge was formed at the front of an advancing ice sheet which invaded the already deposited clay sediments of subzone A_{III} and incorporated them in the moraine. Such a view would be compatible with that of Bjørlykke (1905) and Hansen (1910), if one excludes Hansen's view on the age of Ra. Subzone A_{II} would then be contemporaneous with the Ra formation, i.e., of Younger Dryas age, whereas A_I, according to its stratigraphical position below A_{III}, should probably be referable to the high-Arctic Older Dryas age which preceded the Allerød oscillation.

Unfortunately, these assumptions disagree with radiocarbon age determinations now at hand.

As mentioned above, the following carbon 14 datings were carried out by Nydal of the Laboratory for Radiological Dating, Trondheim, on shells of marine molluscs:

A sample of Yoldia clay from *Valle brickworks* collected by Brøgger in 1900, contained numerous valves of *Portlandia arctica*. It was submitted by O. Holtedahl, and dated at *9950 ± 300 years before present* (Holtedahl, 1960, p. 375; Nydal, 1960, p. 87). The content of Foraminifera in this sample places it in *subzone* A_{II}, as the following count will show:

Species	Frequency	Percentage
Elphidium incertum clavatum	171	90.0
Cassidulina crassa	7	3.7
Astrononion gallowayi	5	2.8
Nonion labradoricum	3	1.7
Elphidium incertum incertum	2	1.2
Virgulina schreibersiana	1	0.6
Total	189	100.0

Accordingly, if the dating is accepted, this A_{II} sample is of *Pre-Boreal age* rather than of Younger Dryas age.

Another sample of Yoldia clay from *Valle brickworks*, collected by Brøgger in 1899, contained large valves of *Macoma calcerea*. It was submitted by the present author, and dated at *10 700 ± 300 years before present* (Nydal, 1962, p. 170). The content of Foraminifera in this sample places it in *subzone* A_{III}, as demonstrated by the following count:

Species	Frequency	Percentage
Elphidium incertum clavatum	265	64.0
Cassidulina crassa	71	17.1
Virgulina schreibersiana	22	5.3
Nonion labradoricum	20	4.8
Astrononion gallowayi	12	2.9
Elphidium incertum incertum	12	2.9
Virgulina loeblichi	6	1.4
Islandiella teretis	3	0.7
Cibicides lobatulus	2	0.5
Quinqueloculina seminulum	1	0.2
Pyrgo williamsoni	1	0.2
Total	415	100.0

Accordingly, this A_m sample is of Younger Dryas age rather than of Allerød age.

In the Ra ridge, at Bøkeskogen in Larvik, on the west side of the Oslofjord, Øyen in 1920 collected a clay sample with shells of *Portlandia arctica* (Gray), *Ennucula tenuis* (Montagu), *Macoma calcarea* (Chemnitz), and *Saxicava* (*Hiatella*) *arctica* (Linné). It was submitted by the present author and dated at *11 000 ± 250 years before present* (Nydal, 1962, p. 170). The content of Foraminifera places, as would be expected, this sample also in *subzone* A_m. The following analysis illustrates this:

Species	Frequecny	Percentage
Elphidium incertum clavatum	288	68.7
Cassidulina crassa	54	12.8
Nonion labradoricum	47	11.2
Pyrgo williamsoni	10	2.4
Elphidium subarcticum	8	1.9
Virgulina loeblichi	3	0.7
Silicosigmoilina groenlandica	2	0.5
Elphidium incertum incertum	2	0.5
Cibicides lobatulus	2	0.5
Quinqueloculina seminulum	1	0.2
Astrononion gallowayi	1	0.2
Buccella frigida	1	0.2
Globigerina bulloides	1	0.2
Total	420	100.0

This A_m-sample from the Ra ridge itself at Larvik is thus of Early Younger Dryas age.

Finally, a sample of *Portlandia arctica* – shells from the Yoldia clay of Tønsberg brickworks at the city of Tønsberg on the west side of the Oslofjord, collected by Brøgger and Øyen and submitted by Rosendahl, was dated at *11 200 ± 200 years before present* (Nydal, 1962, p. 168). The clay which adhered to the shells was washed off and its content of Foraminifera examined with the following result:

Elphidium incertum clavatum	141	specimens
Cassidulina crassa	22	–
Virgulina schreibersiana	9	–
Virgulina loeblichi	4	–
Elphidium incertum incertum	2	–
Quinqueloculina stalkeri	1	–
Pyrgo williamsoni	1	–
Total	180	specimens

This sample, being older than the dated A_{III}-samples and having a faunal composition which is not in discordance with that of the lower part of zone A, is classified as subzone A_I. Subzone A_I would thus seem to be of very early Younger Dryas age or rather of Late Allerod age.

If these radiocarbon values are accepted (with regard to the validity of carbon 14 dates on shell material the reader is referred to discussions by Olson and Broecker, 1958; Olsson, 1961; Olsson and Blake, 1962), the following explanation of the faunal changes within zone A is suggested: During milder intervals in the Late Glacial climatic development increased melting of the land ice took place, and the water of the Oslofjord of that time was supplied with large quantities of cold melt-water which probably counteracted the improved hydrothermical conditions which would normally have been the result of an ameliorated climate. In addition the surplus of fresh melt-water reduced the salinity of the fjord water. These two factors may have hampered an expansion of the Foraminifera fauna which would otherwise have taken place. On the other hand, as discussed in the chapter on paleoenvironment (p. 66) an influx of fresh water seems normally to create a countercurrent of saltier water along the bottom. This saltier water would presumably exercise a favourable effect upon the foraminiferal benthos. If, however, a general melting occurred, and melt-water gushed into the fjord in enormous quantities turbulent mixing of the water masses is likely to have taken place. Decreased salinity created in this way may have affected even the benthos faunas. Furthermore the great load of sediment which must have been brought into the fjord by melt-water currents from the glaciated country impeded the phytoplankton production and with that the food supply for many of the Foraminifera (p. 69). Additionally, the increased sedimentation rate should, under these conditions, most probably produce deposits with a lower foraminiferal density than would otherwise be the case.

It is evident that the rapid Pre-Boreal ice recession from the Ra position must have considerably increased the fresh-water discharge into the fjord (p. 66). The rate of retrogression of the ice front during Allerod time is not known in this area. It was most probably more rapid than during the preceding Older Dryas time and certainly more rapid than during Younger Dryas time, when the ice front stagnated.

According to this view the more favourable ecological condition and the richer foraminiferal faunas occurred during the colder periods of this part of the Late Glacial, whereas the less favourable conditions and the poorer faunas occurred during ameliorated intervals. Phleger (1960) recorded observations from the Gulf of Mexico which may indicate that ecologically favourable environments there were lower populated by Foraminifera than less favourable ones. Many other investigations have given an opposite result (i.a., Remane, 1934), and it seems difficult to apply Phleger's view to environments and faunas of the Late Glacial Oslofjord.

Consequently, the Ra ridge, as far as indicated by the borings at Borregaard, is not to be considered as a push moraine. The A_m-deposits of which it consists appear to be contemporaneous with its formation, not older and later incorporated. The Ra ridge seems rather to represent accumulated sedimentation in front of and under the front of the, at least locally, floating and calving edge of the land ice. Johansson (1937), discussing the formation of the Central Swedish moraines, concluded that such stone- and gravel-mantled clay ridges cannot have been formed during stagnation of the ice front. But Holtedahl (1953) suggested that the Ra ridge may probably be regarded as the result of increased sedimentation near the ice margin. This will account for the stratified texture of the Ra deposits and also for the frequently occurring larger blocks in the sediment. The outer, or upper, mantle of coarse particles is ascribed to later wave washing.

Under a practically stagnant ice front with, as indicated by the high clay content of the deposit, moderate melt-water flow, an inflowing countercurrent of saltier water may even there have produced the comparatively favourable environment which was presumably required by the A_m-fauna. The A_u-deposits, which i.a., by Valle are superposed on A_m-layers, were, according to the present considerations, deposited during the ice recession from the Ra position. They will consequently be expected also in places north of the Ra, and, in fact, assemblages referable to this subzone have been recognized i.a., in the borings from Rakkestad. A_u-samples, as well as the other zone A-samples may contain shells of *Portlandia arctica* (Gray) and subzone A_u is thus a part of the Yoldia clay, which Brøgger (1900–1901) considered to be absent north of the Ra.

Future detailed micropaleontological investigation of the Ra ridge, with examination of samples from borings at many and widely separated localities, should most probably solve many a problem connected with it. The examination of the present borings from Borregaard could necessarily provide only limited and introductory information.

The area between the Ra ridge and the Ås-Ski ridges

Remarks on the borings

The margin of the land ice is assumed to have receded rapidly through the middle part of the Oslofjord area, from the moment it left the Ra position and until it again paused and deposited the Ås-Ski ridges (Brøgger, 1900–1901, p. 131; Holtedahl, 1953, p. 658). Clay with *Bathyarca glacialis* (Gray) as characteristic species was laid down on the fjord bottom of that time during this recession, in fact, the region between these two marginal formations is beyond others the region of the *Middle Arca clay*. The sample from Søreng in Eidsberg revealed the foraminiferal fauna of such a clay (p. 159).

As previously mentioned (p. 34) only few borings from this middle part of the Oslofjord area are represented in the material for the present investigation, and as a matter of fact, only eight are marked in this region on the map of the borings (fig.2). The deepest of these borings was 17 m deep, none of them reached bedrock. Four of the borings contained only shallow-water assemblages of Foraminifera, viz., an 11.8 m deep boring from Riser in Hobøl (B 12, procured by the Road Laboratory in Oslo) and a 7.3 m deep boring, no. 1, from Søndre Sandeelv in Sande (1191, also from the Road Laboratory), which contained exclusively zone G, and two other borings from Søndre Sandeelv, no. 2 and no. 3, which contained zone G and subzone F_{II}.

As the terrain surface at the boring from Riser was situated 55 m above present-day sea level, the presence of zone G there suggests that such assemblages already existed at least in Atlantic time, as mentioned on page 143. More interesting, however, is the occurrence of assemblages which seem difficult to classify other than as subzone A_{II} in the deeper parts of three of the other borings. Foraminiferal assemblages which, south of the Ra were associated with the Yoldia clay are evidently recognized also north of that ridge. Furthermore, assemblages classified as subzone B_{I} as well as subzone B_{II} occurred in this part of the Oslofjord area.

The boring from Holmestrand contained Late Glacial assemblages of A_{II}-type as well as of B_{I}-type. They interchanged, however, irregularly through the core with several repetitions. It is therefore assumed that the deposits of that boring have lost their original stratification by some later disturbance.

A boring from Askim, 32 km northeast of the city of Moss and at an altitude of 130 m, which was carried out by the Road Laboratory, Oslo, was sampled in a somewhat different manner than the other borings. The samples for micropaleontological examination were scraped or cut longitudinally from 80 cm long core fractions. Each sample thus represented nearly 1 m of the boring though it weighed not more than approximately 100 g in dry state. To compare foraminiferal faunas of such samples with faunas from ordinary samples is no easy matter. It is hardly possible at all, as faunal differences may be obscured or completely obliterated by intermingling of faunas, or rather faunal elements, over comparatively long stretches of time. The boring was only 10 m deep, and 8 samples were examined. All contained Foraminifera, 160 to 7600 per sample, but only 15 different species and subspecies were observed in total in the boring. According to expectation, since the locality is situated close to the position of the ancient ice front of the Ås–Ski substage, the samples yielded glacial assemblages with predominance of *Elphidium incertum clavatum* and a fair representation of *Cassidulina crassa*. Other species, except *Virgulina schreibersiana* and to some degree *Nonion labradoricum*, showed sparse and more or less accidental occurrence. Any distinct zonation of foraminiferal assemblages was not recognized.

Two of the borings from the middle part of the Oslofjord area are treated in some detail below, viz., those from Rakkestad.

Rakkestad

Boring no. 1 (341), Rakkestad is situated 20 km northeast of Sarpsborg and a little south of Rakkestad railway station. The terrain surface at the boring lies 103 m above present-day sea level. The boring, which was carried out by the Norsk Teknisk Byggekontroll, was 17 m deep and did not reach bedrock. 16 clay samples from this boring were micropaleontologically investigated, the uppermost sample was from 2.0 m below the surface, the lowest one from 17.0 m. All these samples were small, only half the weight of ordinary micropaleontologically examined core samples from the Oslofjord area, i.e., they weighed approximately 50 g each in dry state. The uppermost sample contained no Foraminifera and the next one, at 3.0 m depth, only two specimens of *Elphidium incertum clavatum*. Both samples belonged to the dry crust of the deposit. The sample at core level 8.0 m was also poorly populated, but the other ones contained from 150 to 2800 specimens per sample.

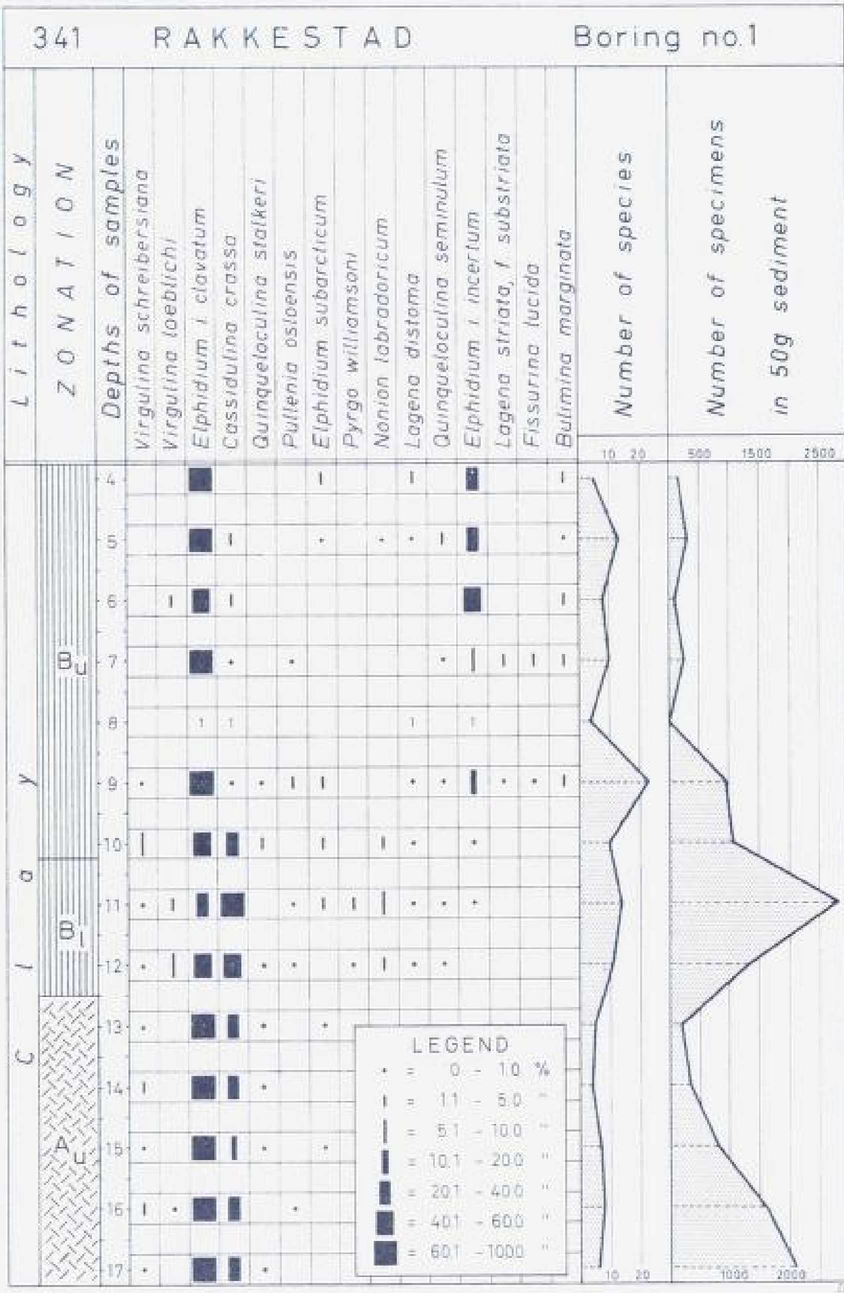


Fig. 32. Range chart for boring no. 1 at Rakkestad.

In total, 35 different species and subspecies were observed. *Elphidium i. clavatum* predominated in most samples and *Cassidulina crassa* was frequent in the lower half of the core. A vertical range chart for the boring is given in figure 32. Species which in no sample made more than 1.0 % of the fauna were precluded from the chart so that this comprises only the 15 most common species and subspecies.

In addition to the species listed on the range chart *Quinqueloculina arctica* occurred at 9.0 m depth, *Scutuloris* cf. *tegminis* ocurred at 17.0 m, 10.0 m and 5.0 m, *Triloculina trihedra* occurred at 17.0 m, *Lenticulina* (*R.*) cf. *angulosa* at 16.0 m, 15.0 m, 12.0 m, 11.0 m, and 9.0 m, *Dentalina drammenensis* at 16.0 m, *D. filiformis* at 16.0 m and 11.0 m, *Lagena clavata* at 9.0 m and 6.0 m, *Fissurina laevigata* at 9.0 m, *Parafissurina marginata* at 9.0 m, *Virgulina fusiformis* at 9.0 m and 5.0 m, *Bolivina pseudoplicata* also at 9.0 m and 5.0 m, *B. pseudopunctata* at 11.0 m, *Cassidulina laevigata laevigata* at 9.0 m and 5.0 m, *Cassidulina laevigata carinata* at 10.0 m, *Astrononion gallowayi* at 6.0 m, *Elphidium bartletti* at 9.0 m and at 7.0–5.0 m, *E. excavatum* at 9.0 m, *Buccella frigida* at 15.0 m, *Epistominella exigua* at 9.0 m, *Rosalina vilardeboana* at 7.0 m.

The foraminiferal assemblages of the lower part of the core, up to 13.0 m, are classified as *subzone* A_{II}. *Elphidium incertum clavatum* predominates, *Cassidulina crassa* is fairly frequent and the number of different species is low, at maximum 8, at minimum 4. The number of specimens per sample (50 g by this boring) decreases from approximately 2000 in the deepest samples to 400 at a depth of 13.0 m below surface. The samples at 12.0 m and 11.0 m depth contained assemblages which are classified as *subzone* B_I because *Virgulina loeblichi* and *Nonion labradoricum* were common in them. *Pyrgo williamsoni* also occurred. There were 11 species and subspecies in the lower one and 14 in the upper one of these two samples, and the number of specimens increased from 1250 at 12.0 m to 2800 at 11.0 m. *Cassidulina crassa* was very frequent, and this peculiarity persisted also in the sample from 10.0 m depth. *Nonion labradoricum* was also represented, accounting for 1.3 % of the fauna, but *Virgulina loeblichi* was absent, while *Virgulina schreibersiana*, instead, reached 9.5 %. Because of the two last species this particular sample is not referred to subzone B_I, although with some hesitation, as the high frequency of *C. crassa* may indicate closer relation to this subzone than to the next. From 10 m, upwards, a marked decrease in the frequency of *Cassidulina crassa* is observed, but simultaneously *Bulimina marginata* and *Elphidium incertum incertum* appear, the latter in considerable frequency. There is a culmination in the number of different species at 9.0 m depth; 23 species occurred in that sample, some of them, such as *Virgulina fusiformis*, *Elphidium excavatum*, and *Epistominella exigua*, not being usually met with in Late Glacial deposits of the area. Further upwards the samples were poorly populated, *Bulimina marginata* and *Elphidium i.incertum*, though, maintained their representation. The fossiliferous part of the boring from 10.0 m upwards is classified as upper part of zone B, i.e., *subzone* B_u. The assemblages of the upper samples, 7.0–4.0 m, are assumed to display a more typical development of this subzone than the assemblages at 10.0 m and 9.0 m. An example of the composition of a typical B_u-fauna is given below, the sample deriving from a depth of 7.0 m:

Species	Frequency	Percentage
Elphidium incertum clavatum	213	87.1
Elphidium incertum incertum	14	5.7
Bulimina marginata	5	2.0
Lagena striata f., *substriata*	3	1.2
Fissurina lucida	3	1.2
Quinqueloculina seminulum	2	0.8
Cassidulina crassa	2	0.8
Pullenia osloensis	1	0.4
Elphidium bartletti	1	0.4
Rosalina vilardeboana	1	0.4
Total	245	100.0

The whole sample was counted. It has the high content of *Elphidium i. calvatum* in common with subzone A_l and A_u but differs from them in the presence of *Bulimina marginata*, the common occurrence of *E. i. incertum* and the low content of *C. crassa*.

Boring no. 3 (B 09), at Klipper bridge, Rakkestad is situated 5 km north of the previous boring, at about the same height above sea level, 100.0 m. This boring, which was carried out by the Road Laboratory, Oslo, was 12 m deep and did not reach bedrock. Only 8 clay samples from this boring were available for micropaleontological examination, in dry state they weighed approximately 100 g each. The uppermost one, from 1.4 m below the surface, was weathered and contained no marine fossils, but the others, from 3.2 m depth to 11.6 m depth, contained from 240 to 20 000 foraminiferal specimens. As a total 31 different species, subspecies

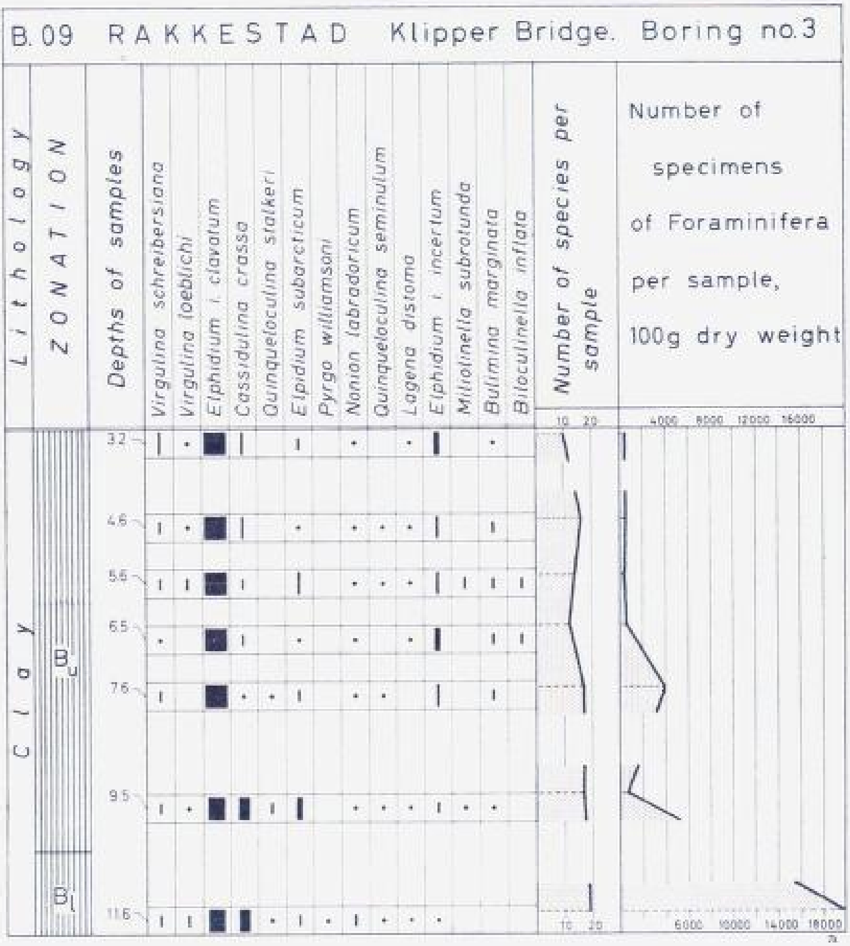


Fig. 33. Range chart for boring no. 3 at Rakkestad.

and forms of Foraminifera were observed in the samples. Also with this boring *Elphidium incertum clavatum* predominated and *Cassidulina crassa* was frequent in its lower part. The vertical distribution and relative frequency of the most common species are illustrated in the range chart of figure 33. With some exceptions species which at least in one sample exceeded 1 % of the fauna are inserted in the chart.

In addition the following species occurred: *Trochammina ochracea* at 6.5 m depth, *Lenticulina (R.)* cf. *angulata* at 11.6 m, 9.5 m, 7.6 m, and 4.6 m, *Lagena elongata* occurred in the three lowest samples, *Lagena* *mollis* only in the lowest, *L. striata*, forma *substriata* at 7.6 m, 6.5 m, and 5.6 m depth, *Fissurina lucida* at 7.6 m, 5.6 m, and 4.6 m, *Parafissurina lateralis* at 9.5 m and 7.6 m, *Globobulimina auriculata arctica* occurred in the lowest sample, *Robertinoides pumilum* also in the lowest sample, *Bolivina albatrossi* occurred at 7.6 m depth, *B. pseudoplicata* at 7.6 m, 6.5 m, and 4.6 m, *B. pseudopunctata* in the lowest sample, *Cassidulina laevigata laevigata* occurred at 7.6 m, *Pullenia osloensis* at 9.5 m and 4.6 m, *Astrononion gallowayi* at 11.6 m, *Cibicides lobatulus* also in the lowest sample, at 11.6 m depth, and *Buccella frigida* at 11.6 m and at 3.2 m below the surface.

The foraminiferal fauna of the lowest sample of this boring differed from those of the upper part of the boring by the much higher frequency of *Cassidulina crassa* and the much greater number of specimens. *Virgulina loeblichi* and *Nonion labradoricum* were not rare. The assemblage of this sample is classified as *subzone* B_l. The five upper samples contained a considerable number of *Elphidium incertum incertum*, and *Bulimina marginata* occurred in all of them. However, the number of foraminiferal specimens per sample was low, 267 as a maximum. This upper part of the core is referred to *subzone* B_u. The foraminiferal assemblage of the sample from 9.5 m depth correlates well with the sample from 10.0 m depth of boring no. 1, previously mentioned. *Cassidulina crassa* is frequent, *Elphidium subarcticum* quite so, and *Quinqueloculina stalkeri* not rare. As with the previous boring, this sample, at 9.5 m in boring no. 3, is with some hesitation placed in *subzone* B_u.

A fauna which could be referred to subzone A_u was not represented in boring no. 3, Klipper bridge, Rakkestad. This compares well with the results from boring no. 1. The border between A_u and B_l was in boring no. 1 situated at approximately 12.5 m depth; boring no. 3 was most probably not deep enough to reach into subzone A_u.

Interpretation

An explanation of the foraminiferal zonation of the two borings from Rakkestad is attempted below. The material is obviously insufficient to give a firm base for conclusions of general applicability for this middle part of the Oslofjord area. However, the foraminiferal pattern displayed by these two borings seems to indicate phenomena which most probably affected that part the Oslofjord area as a whole.

The comparatively rich assemblages, classified as subzone B_l, are, as mentioned on page 152, assumed to have lived under fairly favourable ecological conditions, probably as the retreating margin of the land ice paused at the Ås–Ski position. This stagnation in the ice recession was most probably caused by decreased air temperature which, in turn, may have cooled also the fjord water of that time. This cooling effect of the air upon the water was not necessarily greater than that which the melt-water exercised upon the fjord water during the preceding period of rapid recession. But still it prevented immigration of more thermophilous species to the area. Those species, however, which tolerated the temperature, were offered a possibility to expand their populations because the salinity became more normal and the load of minerogenic particles lessened as the melt-water pollution decreased. In addition, species which could bear the comparatively low temperature but not the lowered salinity and greater turbidity of the water during the preceding rapid recession, were now able to immigrate. The assemblages of subzone B_I are thus characterized by a considerable number of species, compared with that of subzone A_{II}, as well as by a comparatively large number of specimens per unit of sediment.

The A_{II}-faunas, as discussed on page 175, are assumed to have lived during the rapid recession of the land ice from the Ra to the Ås–Ski position. The climatic amelioration which induced the ice to recede, was counteracted in the fjord by the surplus of cold melt-water, and the ecological conditions additionally disparaged by increased turbidity and lowered salinity. The number of species was reduced, compared with the preceding subzone, and so was the number of specimens per unit sediment.

Subzone B_{II} in its major part is again characterized by low foraminiferal density. This is probably due to increased sedimentation rate during a period of renewed rapid melting of the land ice. It is assumed that the ice front during this facies of increased melting, receded from the Ås–Ski ridges to the Aker substage at the city of Oslo. Both the borings from Rakkestad show an increased number of species at the uppermost part of the subzone B_I or at the base of subzone B_{II}. *Bulimina marginata* appears and *Elphidium incertum incertum* becomes fairly frequent. *Cassidulina laevigata laevigata*, *Elphidium excavatum*, and *Epistominella exigua* are represented, and together with the two above mentioned species convey an element of amelioration to the fauna. As may be expected, the improved climate which again caused the ice margin to recede, at the beginning improved the ecological conditions for the foraminiferal benthos so that some species of Boreal character appeared in the assemblages. But soon thereafter the surplus of melt-water became large enough to prevail over the ameliorating effect of the rising temperature upon the water. The Boreal component of the fauna was therefore hampered in its expansion, as illustrated by the upper part of the two cores. Some of the species which attempted immigration at the beginning of the period of recession from the Ås–Ski ridges even seem to have disappeared again during later stages of that recession period. But most of them probably maintained low populations ready to flourish as soon as the environmental conditions improved.

Further investigation of the foraminiferal content of other borings from the area between the Ra and the Ås–Ski ridges will presumably show that the zonation and its indications are less simple, in detail, than the present study of the two borings from Rakkestad seems to illustrate.

Foraminiferal zonation in the northern part of the Oslofjord area

General trends

Numerous borings through Late Quaternary marine deposits were available for the present study from northern parts of the area, especially from the city of Oslo. They were situated at different heights in relation to present-day sea level, from 9.6 m below sea level, boring no. 5 in Storøysund at Fornebo, to 203.0 m above sea level, at Jessheim. The deepest boring in the northern part of the area reached 40.0 m below the surface, it was situated 2.4 m above sea level at Grønlandsleret in the city of Oslo.

The foraminiferal zonation described from the southern localities of the Oslofjord area is partly recognized in the borings from the northern part.

The shallow-water assemblages of *zone G* are developed in the same manner in and around the city of Oslo as they were e.g., in Sandefjord and Fredrikstad. Zone G was thicker in Bjørvika, an area of relatively high sedimentation rate near the mouth of the river Akerselva, than, for instance, at Fornebo. This zone was recognized up to approximately 50 m above present sea level, at Majorstuen, Oslo. An abundance of *Eggerelle scabra* and *Verneuilina media* and a simultaneous rich occurrence of *Nonion depressulus asterotuberculatus* is generally characteristic of the zone. *Virgulina fusiformis* and *Ammoscalaria runiana* are quite frequently found. As in the southern parts of the Oslofjord area *Nonion labradoricum* occurs frequently in the youngest part of zone G. This part is supposed to be of Sub-Atlantic age and was only found in the low-lying borings (Cp. p. 142).

Zone F is characterized by the same species and similar relative frequencies as zone F in the southern parts of the area. As with zone G, assemblages of zone F were recognized in localities up to approximately 50 m above sea level. However, since borings between 50 m above sea level and 80.0 m above sea level are lacking with the present material from the Oslo area, nothing is known about the presence of zone F in that height interval. The subdivision of this zone falls more naturally into two subzones in the northern part of the area than into three. The upper subzone, F_u, is characterized by frequent occurrence of *Virgulina fusiformis* together with *Ammonia batavus* and *Hyalinea balthica*, the lower, F_l, by frequent occurrence of *Cassidulina laevigata laevigata*. *Nonion labradoricum* is quite frequent in F_u-sediments situated near present-day sea level, especially in the upper part of the subzone.

Zone E is in the northern part of the area, as in the southern, characterized by almost equal frequency of *Elphidium incertum incertum* and *E. i. clavatum* and simultaneous fairly frequent occurrence of *Bulimina marginata* and *Cassidulina laevigata laevigata*. The borderline between zone E and zone F is not always sharp and with some borings it may be difficult to fix. In boring no. 1 (F 226) from Skøyen, Oslo, assemblages with E-composition seemed to intermingle with assemblages with F_l-composition in the lower half of the boring.

Zone D is very distinctly separated from the above-lying zone E and the under-lying zone C by its foraminiferal fauna. Zone D-assemblages are poorly populated and only few different species seem generally to belong to them. The dominant one is *Elphidium incertum clavatum*. *Cassidulina crassa* is frequent and *Quinqueloculina stalkeri* together with *Biloculinella inflata* and *Pullenia osloensis* are quite common in most samples of this zone. Examples of the species and their relative frequency within this zone are found in the range charts for boring no. 5 at Bekkelaget, boring no. 5 at Majorstuen, and boring no. 18 at Bryn. A count of a sample from boring no. 3 at the crossing of the roads Ulvenveien and Risløkkveien in Oslo is given here. The locality is situated 92.6 m above present-day sea level, and the sample was taken 12.1 m below the surface:

Species	Frequency	Percentage
Elphidium incertum clavatum	123	80.9
Cassidulina crassa	20	13.2
Quinqueloculina stalkeri	7	4.6
Biloculinella inflata	2	1.3
Total	152	100.0

The count represents the whole sample (100 g dry weight).

Another example is taken from boring no. 48, Grønlandsleret in the city of Oslo. The surface of this locality is situated 2.4 m above sea level, and the sample was taken 37.2 m below the surface:

Elphidium incertum clavatum	50	specimens
Cassidulina crassa	28	–
Pullenia osloensis	15	–
Quinqueloculina stalkeri	4	–
Biloculinella inflata	1	–
Lagena mollis	1	–
Fissurina cf. *fasciata*	1	–

This count also represents the entire content of Foraminifera extracted from the sample.

The assemblages are reminiscent of those belonging to subzone A_{II} in the southern parts of the Oslofjord area, but are even poorer. The dominant subspecies, *Elphidium incertum clavatum* is furthermore generally represented by smaller individuals in zone D than in zone A. An illustration of this is given in figure 34, where the diameter of 100 specimens of *E. i. clavatum* from zone D is compared with that of 100 specimens of the same subspecies from zone A by means of graphs.

Zone D is characteristic of the northern part of the Oslofjord area. It did not occur south of the marginal line of the Ås–Ski substage. It was not found in the borings at Ås (C 63) or Nesset (C 43) or Tohellinga (C 13). However, in the boring at Kolbotn (O 823), in the many borings in and around the city of Drammen, and in most of the other borings in the northern part of the Oslofjord area zone D was readily distinguished. Apart from Drammen, this zone increases in thickness towards north and northeast. With the high-lying borings immediately in front of the

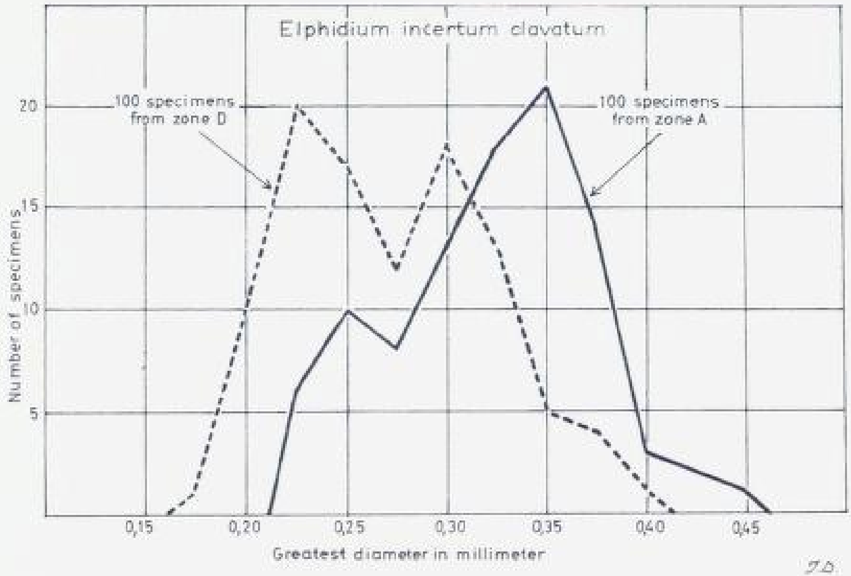


Fig. 34. Greatest diameter of 200 specimens of *Elphidium incertum clavatum*, 100 from zone A and 100 from zone D.

moraines of the Aker substage and with those north of these moraines, zone D is the only foraminiferal zone present.

With some of the lower-lying borings from the city of Oslo and at Fornebo there is a repeated occurrence of zone D-assemblages within zone E or in the lower part of subzone F_1. There are thus a lower and an upper zone D separated by indisputable thermophilous Post Glacial foraminiferal associations.

Zone C is easily distinguished from the above-lying zone D, by its much richer faunas. Being dominated by *Elphidium incertum clavatum* and usually containing numerous specimens of *Cassidulina crassa*, zone C, like zone D, has a Late Glacial character. It closely resembles subzone B_1, from the southern part of the area, by the frequent occurrence of *Virgulina loeblichi*. However, *Cassidulina laevigata carinata* has replaced *Nonion labradoricum* which, together with *V. loeblichi* characterized subzone B_1. *Pyrgo williamsoni* and *Pullenia osloensis* are usually common, in most samples also *Lagena mollis*, and *Bulimina marginata* may occur. As an example of a zone C-assemblage is here presented the count of a sample from 20 m depth in boring no. 5 at Majorstuen, Oslo:

Species	Frequency	Percentage
Elphidium incertum clavatum	211	44.5
Cassidulina crassa	56	11.8
Pullenia osloensis	56	11.8
Virgulina loeblichi	38	8.0
Quinqueloculina stalkeri	27	5.7
Cassidulina laevigata carinata	24	5.1
Biloculinella inflata	14	3.0
Quinqueloculina seminulum	8	1.7
Elphidium incertum incertum	8	1.7
Lagena striata, forma *substriata*	5	1.1
Hauerinella inconstans	4	0.8
Pyrgo williamsoni	4	0.8
Elphidium subarcticum	4	0.8
Miliolinella cf. *subrotunda*	3	0.6
Lagena mollis	3	0.6
Fissurina lucida	2	0.4
Nonion labradoricum	2	0.4
Lenticulina cf. *angulata*	1	0.2
Bulimina marginata	1	0.2
Virgulina fusiformis	1	0.2
Virgulina schreibersiana	1	0.2
Cibicides lobatulus	1	0.2
Total	474	99.8

This count represented the whole foraminiferal content of a 100 g dry sediment. Most zone C samples were richer in Foraminifera. Many of them also showed higher percentage of *Cassidulina l. carinata*. Other examples are found in the above-mentioned range charts.

The southernmost locality in which zone C-assemblages occurred was Nesset, 21 km south of Oslo centre, the northernmost Brobekkveien (O 1-41), close to the borings of project F 107 on figure 35. Assemblages of this composition were not observed north of the moraines of the Aker substage, at least not in typical development. Northeast of these moraines a previously mentioned sample of Mytilus clay from Strømmen, Skedsmo, which was radiologically dated at 9500 ± 200 years before present, contained the following Foraminifera:

Species	Frequency	Percentage
Elphidium incertum clavatum	119	50.2
Cibicides lobatulus	54	22.8
Elphidium subarcticum	47	19.9
Buccella frigida	8	3.4
Nonion depressulus asterotuberculatus	5	2.1
Cassidulina crassa	2	0.8
Pullenia osloensis	1	0.4
Protelphidium orbiculare	1	0.4
Total	237	100.0

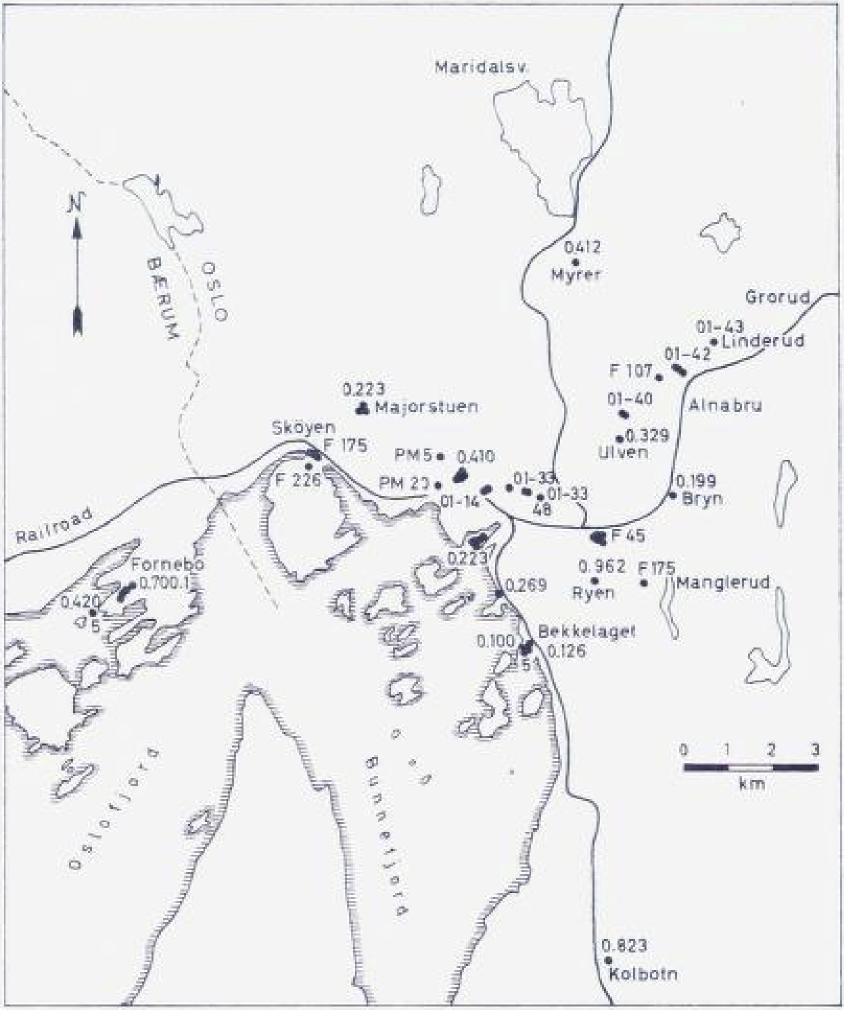


Fig. 35. Position of borings in and around the city of Oslo.

This locality was situated 147 m above sea level and the fauna may be regarded as a shallow-water assemblage corresponding to zone C. Another dubious zone C occurrence was noted at Naddum bridge, 140 m above sea level. Otherwise, assemblages of this zone were not traced in localities at greater elevation than 130 m. Zone C was the deepest unit of the foraminiferal zonation in most of the borings from the city of Oslo and the neighbouring regions on both sides of the fjord. Its thickness did usually not exceed 3 m.

Subzone B_{II} seems to be represented in a few borings in the northern part of the Oslofjord area, viz., boring no. 1 (O 823) at Kolbotn, situated 96.8 m above sea level on the east side of the Bunnefjord, boring no. 2 (O 962) at Ryen, 129.3 m above sea level northeast of Bekkelaget in Oslo, boring no. 1 (F 175) at Manglerud, 130.0 m above sea level, Oslo, and two borings at Fornebo, no. F 1 (O 700) of Storøymyr, 0.7 m above present-day sea level, and no. 5 (O 420) in Storøysund. The surface of the latter boring was situated 9.6 m below present-day sea level. In all these five borings subzone B_{II} was situated below assemblages of zone C-composition and represented the deepest fossiliferous part of the borings.

The assemblages from the higher-lying borings fit well into subzone B_{II} as described from the borings in Rakkestad. The faunas from the deepest part of the above-mentioned borings from Fornebo, however, were much richer and would, if they occurred as separate samples, without any doubt be classified as Post Glacial.

The deepest sample of boring F 1, Storøymyr, 20.38 m below the surface, thus yielded the following fauna:

Species	Frequency	Percentage
Bulimina marginata	100	30.5
Elphidium incertum clavatum	95	28.4
Virgulina fusiformis	35	10.1
Cassidulina crassa	33	9.8
Elphidium incertum incertum	11	3.3
Virgulina loeblichi	10	3.0
Pullenia osloensis	7	2.1
Pyrgo williamsoni	5	1.5
Cassidulina laevigata carinata	5	1.5
Quinqueloculina stalkeri	3	0.9
Nonion barleeanum	3	0.9
Nonion labradoricum	3	0.9
Elphidium subarcticum	3	0.9
Biloculinella inflata	2	0.6
Epistominella exigua	2	0.6
Ammonia batavus	2	0.6
Hyalinea balthica	2	0.6
Silicosigmoilina groenlandica	1	0.3
Quinqueloculina horrida	1	0.3
Quinqueloculina seminulum	1	0.3
Miliolinella cf. *subrotunda*	1	0.3
Lagena mollis	1	0.3
Lagena striata, forma *typica*	1	0.3

Globobulimina turgida	1	0.3
Virgulina skagerakensis	1	0.3
Fissurina lucida	1	0.3
Parafissurina lateralis, forma *carinata*	1	0.3
Nonionella turgida	1	0.3
Cibicides pseudoungerianus	1	0.3
Elphidium macellum	1	0.3
Total	334	100.1

This sample thus contained 30 species, subspecies and forms. The count represents 2/9 of the foraminiferal content, the total content of foraminiferal specimens in the sample (dry weight 100 g) was 1500. The sample above this, at 20.0 m depth of the same boring, contained 36 different species, subspecies, and forms of Foraminifera, but fewer specimens, approximately 1100.

The general trend of the foraminiferal zonation of the Holocene in the northern parts of the Oslofjord area, from the marginal ridges of the Ås–Ski substage northwards, is illustrated in the simplified range chart of figure 36, in which the range and the average frequency of 21 selected species and subspecies is visualized. This range chart is to be substituted in the place of the simplified distribution chart published by the present author in 1958 (fig. 6 of that paper). Low-lying localities with occurrence of Recent (Sub-Atlantic) deposits are not considered in the present simplified range chart. With such borings there are usually a frequent occurrence of *Nonion labradoricum* in the upper part of zone F and in the lowest part of zone G, and *Elphidium incertum incertum* has almost disappeared in these strata. In the highest-lying borings, on the other hand, the Post Glacial sequence is lacking. These borings are also omitted in the present chart.

On the following pages is given a brief review of the borings from the northern part of the Oslofjord area. Many units in the foraminiferal zonation, well-known from the southern parts of the area, are recognized in the northern ones. Hence, to avoid repetition description in detail is given only for a few borings.

Review of the borings in the northern part of the area

Årungen, Ås (*C 63*). Årungen is a narrow lakelet between the marginal ridges of the Ås–Ski substage. The water level is 32.6 m above sea level. Two borings in the bottom of this lakelet were carried out by the Road

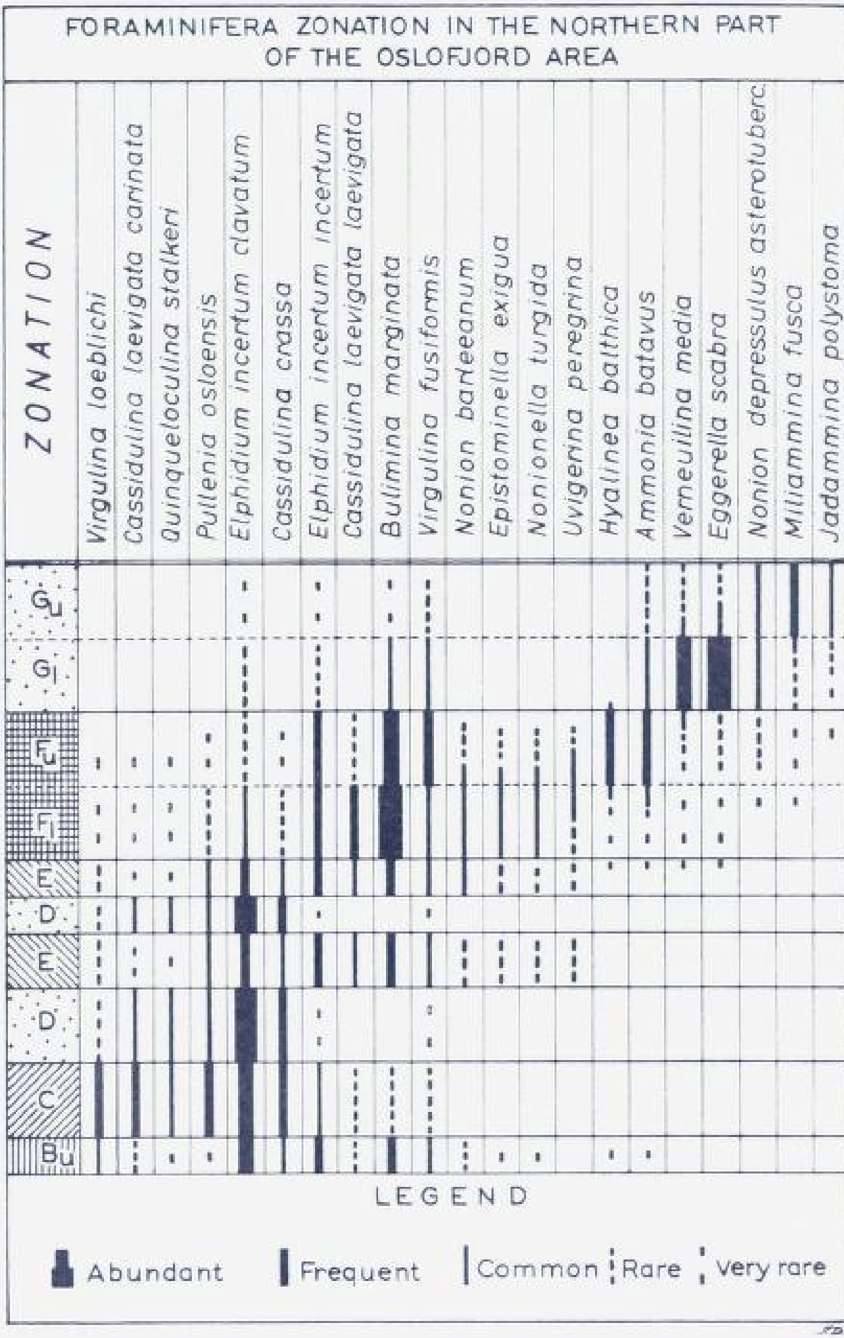


Fig. 36. Simplified range chart for the northern part of the Oslofjord area, illustrating the zonation by the average range and frequency of 21 selected species of Foraminifera.

Laboratory, boring no. 1, at 6 m depth, was 13.5 m long, boring no. 2, at 1.6 m depth, was 13.0 m long. Neither of them reached bedrock.

Boring no. 1 revealed fresh-water deposits, with numerous Thecamoebina of the species *Difflugia oblonga* and *Pontigulasia compressa*, from the top of the boring down to 4.6 m below the surface (i. e., below the bottom of the lakelet). Plant remains were richly represented in this part of the boring. Below 4.6 m and to the bottom of the boring marine deposits with rich foraminiferal assemblages of typical zone F-composition occurred.

Boring no. 2 showed lacustrine deposits from the top of the boring down to 3.2 m, below this marine deposits with Foraminifera occurred. However, with this boring zone G-assemblages were met with at the top of the marine sequence, from 3.2 m down to 4.7 m. The rest of the boring, from 4.7 m to the bottom, comprised typical zone F-assemblages.

Provided the sediments are in situ, the micropaleontological zonation in these two borings may render another indication of the contemporaneity of zone G and F. Notwithstanding that the present position of the water level of Årungen does not necessarily indicate the height of the water level at the time when the marine conditions in the basin changed to lacustrine, the water was evidently shallow enough for zone G to develop at the place of boring no. 2, whereas at the 4.4 m deeper locality of boring no. 1 this zone could not develop. The boundary between lacustrine and marine deposits must be contemporaneous in the two borings, and consequently zone G-assemblages replaced the fresh-water biota at boring no. 2 at the same time as zone F-assemblages populated the bottom at boring no. 1.

It must be mentioned that neither *Hyalinea balthica* nor *Höglundina elegans* occurred in the investigated deposits. *Nonion labradoricum* occurred quite frequently in zone F and so did *Cassidulina crassa*. Frequent occurrence of *Cassidulina laevigata laevigata* in zone F made these assemblages resemble subzone F_1.

Nesset in Nordby (C 43). Boring no. 297, carried out by the Road Laboratory of the Norwegian Road Administration, was situated at the southwest side of the pond Søndre Pollevann. The boring was 9.7 m deep and its surface situated approximately 2 m above present-day sea level. The foraminiferal zones C, E, F and G were present in the boring. This is the southernmost of the investigated localities in which zone C was recognized. More or less decalcinated specimens occurred in the upper part of the boring.

Tohellinga, Nesset (*C 13*). This locality is situated on the southwest side of the lakelet Pollen, just northeast of the previous locality. The terrain surface at the boring, which was carried out by the Road Laboratory, was situated c. 7 m above present-day sea level, and the boring was 10.0 m deep. The Post Glacial zones E, F and G were present.

Naddum bridge (*O 708*) in Høland is situated 45 km east-south-east of the centre of Oslo. Samples from one boring, no. 2, carried out by the Norwegian Geotechnical Institute, were investigated micropaleontologically. The surface at the boring lay 140 m above sea level, and the boring was 19.3 m deep. Foraminifera occurred from 8 m below the surface to the bottom of the boring. All fossiliferous samples contained Late Glacial assemblages, from 8.0 m to approximately 16.0 m referable to zone D, from 16.6 m *Elphidium incertum incertum* was quite frequent, indicating a possible amelioration of climate. Below 17.0 m the faunas were again unmistakably glacial.

Drammen, to the west of the inner part of the Oslofjord. Fourteen borings from this town were investigated micropaleontologically, nine of them by Risdal (1962). All the borings were situated close to present-day sea level, two of them below. The borings ranged in depth from 15 m to 37 m.

The majority of the clay samples from these borings contained foraminiferal assemblages referable to zone D, this zone being about 20 m thick in most of the borings. In boring no. 20 (O 88) it attained 27 m thickness. Zone C was not recognized in any of the borings from Drammen, neither was subzone B_u. None of the borings reached bedrock, and this may explain the lack of the deepest, or oldest, zones. If, on the other hand, the succession revealed by the investigated borings in Drammen is the normal one, the Late Glacial conditions there would very much resemble those found in localities north of the moraines of the Aker substage, where no foraminiferal zones older than D were found. Again, this would lead to considerations about the age of the Svelvik ridge, the conspicuous glacifluvial ridge at the mouth of the Dramsfjord. Already Brøgger (1900–1901, p. 132–141), who described this ridge in details, called attention to the possible existence of long valley glaciers at the time of its formation (questioned by Holtedahl, 1953, p. 658), not an almost continuous ice front as when the Ra ridge was formed. Such a configuration of the land ice margin, well-known from many other parts of the country, probably even with isolated plateau glaciers in separated highlands, would complicate the later combination and correlation of marginal formations. However, the present material is not fit for an investigation of this problem. Additional borings in the front of, i.e., at the south side of, the Svelvik ridge would be needed for such an undertaking.

Post Glacial parts of the foraminiferal zonation occurred in six of the borings from Drammen, viz., zone E in two of them, the zones E, F and G in four.

Kolbotn (*O 823*). One boring, no. 1, carried out by the Norwegian Geotechnical Institute, was examined. The surface at the boring was situated 96.8 m above sea level, and the boring was 14.0 m deep. The sediment consisted of clay, some silt and sand occurred with the clay in the deepest samples. Zone E-assemblages occurred in the upper part of the boring down to 6.0 m. There were few specimens of *Bulimina marginata* in the upper part of the zone, many in the lower. The shallow-water indicator *Elphidium excavatum* was frequent, especially in the upper part of the zone. In addition *Verneuilina media* and *Eggerella scabra* occurred. In other respects zone E was typically developed.

Zone D occurred at 7–8 m below the surface. Abrupt variation in shear strength allows one to locate the border between zone D and zone E at 6 m. At 10 m assemblages readily referable to zone C occurred. The large spacing between samples in that part of the boring makes it impossible to fix accurately the borders between zone C and zone D and between zone C and the underlying unit. At 12.2 m and 13.3 m below the surface there occurred assemblages which were classified as subzone B_{II}. *Cassidulina crassa* was very frequent, and *Quinqueloculina seminulum*, *Pyrgo williamsoni*, *Biloculinella inflata*, and *Cassidulina laevigata carinata* common.

Bekkelaget O 100; O 126, Oslo, is situated 5 km southeast ot the centre of the city, at the fjord. Core samples from several borings were available from this locality in connection with geotechnical investigation of a land slide which occurred there in 1953 (Eide, 1955; Feyling-Hanssen, 1954 b). Samples from eight of these borings were examined micropaleontologically. The Late Glacial zones C and D were present in all of the borings, and so was the Post Glacial zone E. Zone F occurred in six of them and zone G in two of them.

The foraminiferal range chart for boring no. 5 (O 100.2) is given in figure 37. The terrain surface at this boring was situated 8.6 m above present-day sea level, and the boring was 11.6 m deep. Nine samples were analyzed, the uppermost taken 2.2 m below the surface, the deepest

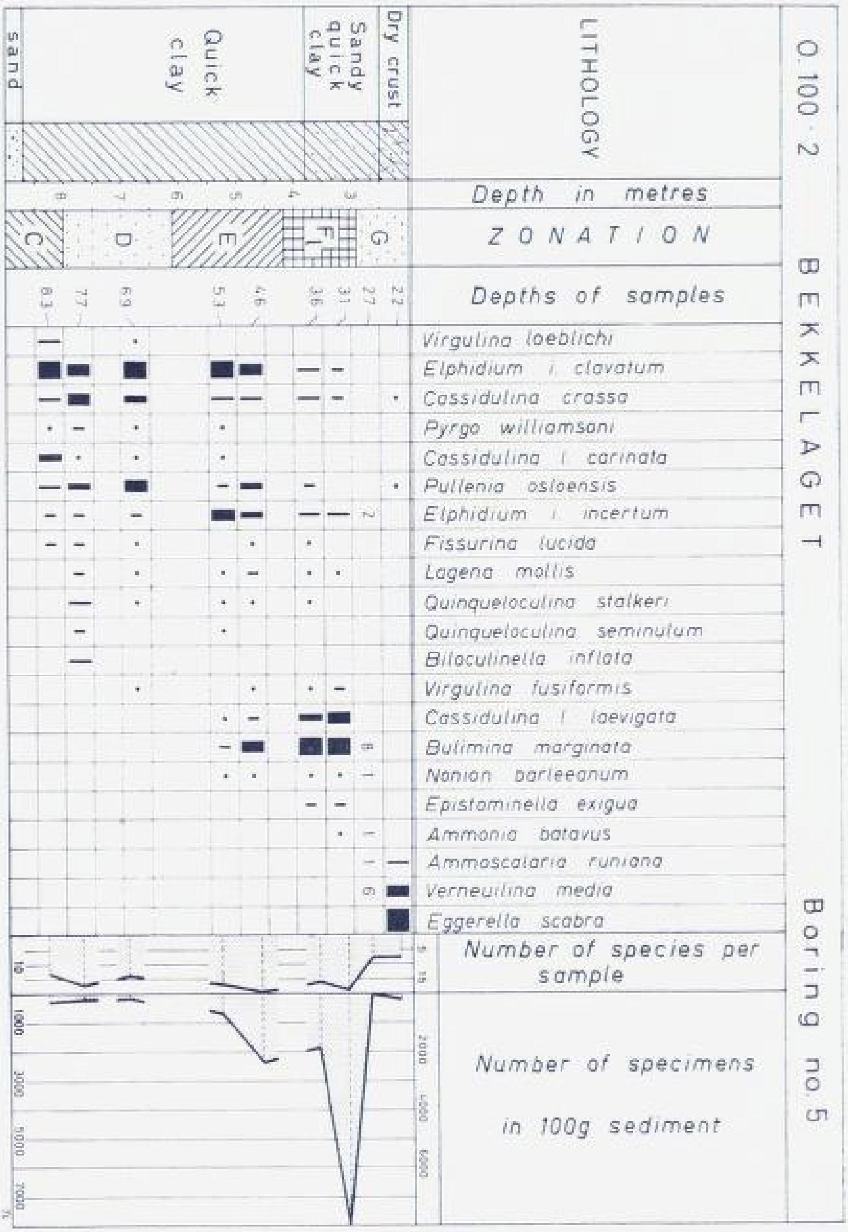


Fig. 37. Range chart for boring no. 5 at Bekkelaget, Oslo.

one at 8.3 m. The spacing of the samples was thus quite large, e.g., there was no sample taken between 5.3 m and 6.9 m. The lowest sample from zone G was poorly populated, the number of specimens of each species was plotted directly in the chart for that sample, symbols were not used.

In addition to the species inserted in the chart, the following ones occurred in the investigated samples: *Lenticulina* (*Robulus*) cf. *gibba* and *Astrononion gallowayi* at 8.3 m, *Cibicides pseudoungerianus* at 8.3 m, 4.6 m, and 3.1 m, *Cibicides lobatulus* at 8.3, 7.7, 5.3 and 4.6 m, *Lagena distoma*, *Robertinoides pumilum*, and *Rosalina vilardeboana* at 7.7 m, *Lenticulina* (*Robulus*) cf. *angulata* at 7.7 m and 6.9 m, *Nonion labradoricum* at 7.7, 6.9 and 5.3 m, *Virgulina schreibersiana* at 6.9 m, *Lenticulina* (*Robulus*) *convergens* at 5.3 m, *Lagena laevis* at 5.3, 4.6 and 3.6 m, *Lagena hispidula*, *Oolina hexagona*, *Oolina lineato-punctata*, and *Bolivina pseudoplicata* at 4.6 m, *Lagena striata*, forma *substriata* at 4.6, 3.6 and 3.1 m, *Fissurina castanea* and *Globobulimina turgida* at 3.6 and 3.1 m, *Lagena striata*, forma *typica*, *Lagena distoma*, and *Nonionella turgida* at 3.1 m, *Uvigerina peregrina* at 2.7 m, and *Miliammina fusca* and *Jadammina polystoma* at 2.2 m depth.

Fornebo (*O 420* and *O 700*). This locality is situated at the west side of the innermost basin of the Oslofjord. Clay samples from seven borings, carried out by the Norwegian Geotechnical Institute, were examined. Figure 38 gives the position of these borings. Six of them are situated on the bog of Storøymyr, the surface of no. 5 was at 2.6 m above sea level, the surface of the others 0.7–0.8 m above sea level. One boring, no. 5 of project O 420.2, was taken in the bottom of the sound Storøysund between the peninsula of Storøy and the island of Torvøy. The surface of this boring was situated 9.6 m below sea level. The length of the borings ranged from 8.8 m to 20.5 m; all of which reached bedrock. The sediment consisted mainly of soft clay. Some sand and gravel occurred at the bedrock and silty and even gravelly clay occurred with the upper zone C of boring no. 5 (O 420) in Storøysund. The result of the micropaleontological examination is illustrated in the profile of figure 39.

As previously mentioned (p. 72) decalcination phenomena occurred in the top layers of the borings of Storøymyr. The fossils were corroded or dissolved to such a degree that with four of these borings it was impossible to classify the upper parts of the cores by the aid of the foraminiferal faunas. Only in boring F 1 were certain zone G-assemblages discernible. Boring no. 3 contained in its upper part some badly preserved faunas which are probably referable to zone G. In the submarine boring, no. 5,

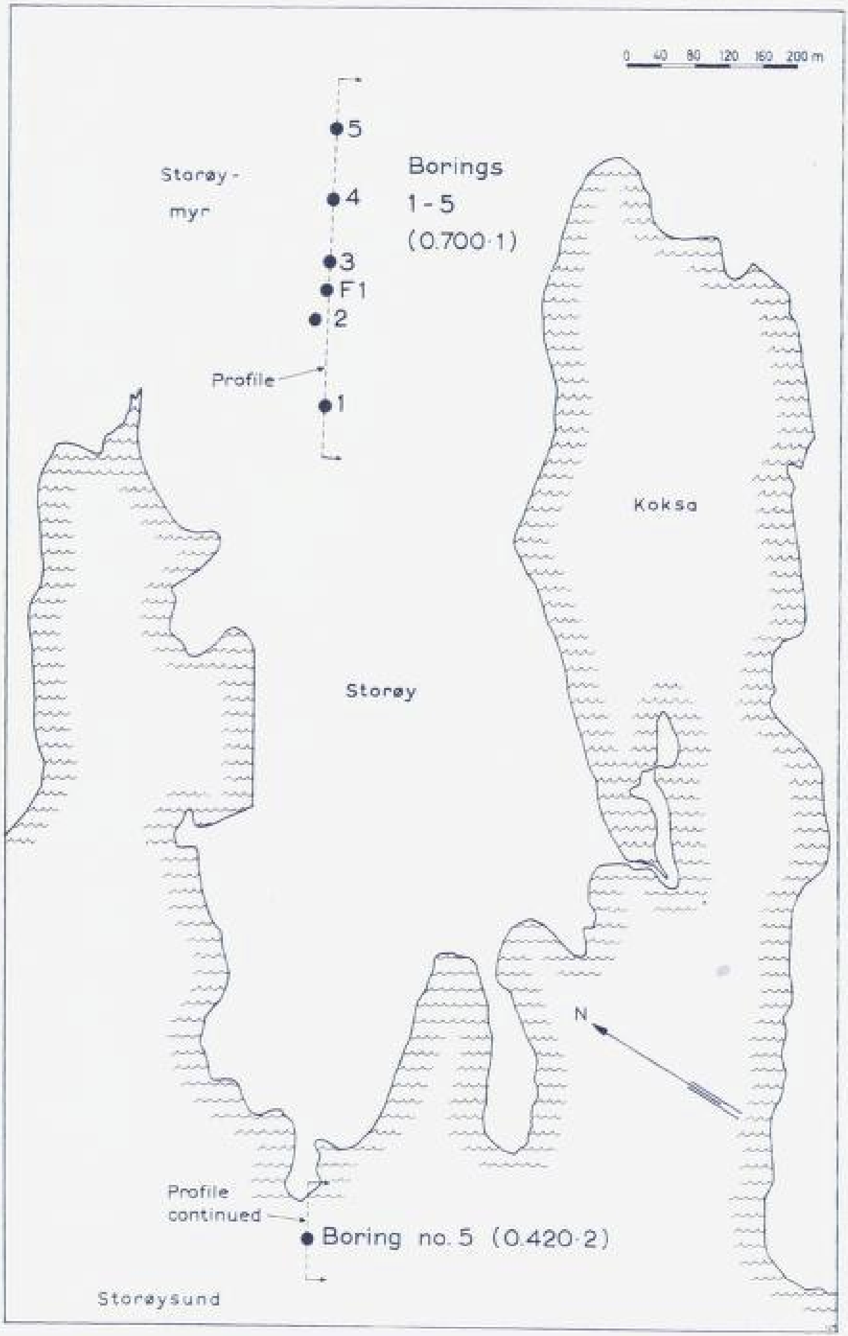


Fig. 38. Position of the investigated borings at Fornebo, near Oslo.

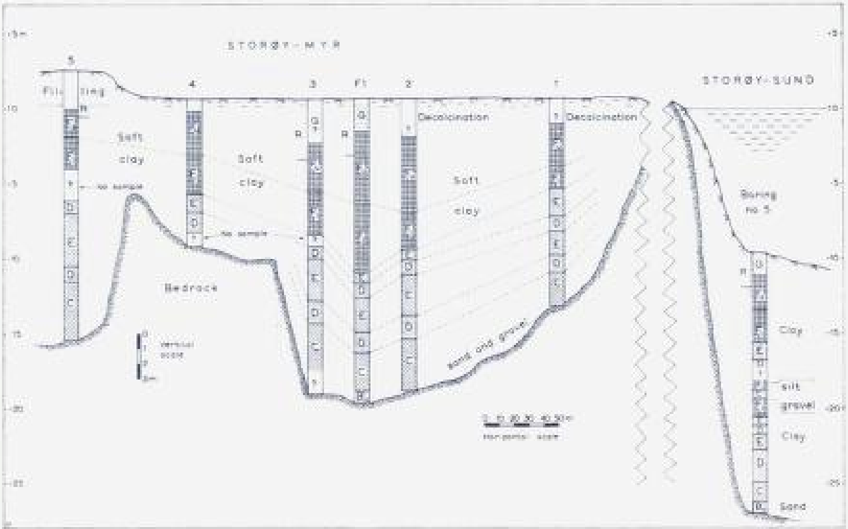


Fig. 39. The foraminiferal zonation in the borings at Fornebo. The assumed Recent part of the cores is indicated with an R.

in Storøysund zone G was developed in the two upper samples. Otherwise subzone F_u was present in the upper parts of all the cores. In the borings number 5, 3 and F 1 of Storøymyr and also in boring no. 5 in Storøysund *Nonion labradoricum* occurred frequently in the upper samples down to levels which are marked with a short horizontal line at the borings mentioned. Above these lines the cores are supposed to be of Recent, i.e., Sub-Atlantic, age, indicated by "R" in the profile of figure 39.

In five of the borings from Storøymyr zone D occurred twice. As usual, the assemblages of this zone were distinctly different from the assemblages of the neighbouring zones. There occur transitional faunal compositions between zone E and subzone F_l, but not between zone E and zone D or between zone D and zone C. Any general difference between the upper and lower zone D was not observed. The thickness of the upper zone D was approximately 1 m whereas that of the lower was 1.0–1.5 m.

As an example of zone D-faunas from these borings the count of sample (O 700.1–122) from 16.2 m depth of boring no. F 1 is given here:

Species	Frequency	Percentage
Elphidium incertum clavatum	228	75.0
Cassidulina crassa	53	17.4
Pullenia osloensis	5	1.6
Biloculinella inflata	4	1.3
Quinqueloculina stalkeri	3	1.0
Pyrgo williamsoni	2	0.7
Fissurina lucida	2	0.7
Cassidulina laevigata carinata	2	0.7
Elphidium incertum incertum	2	0.7
Silicosigmoilina groenlandica	1	0.3
Lenticulina cf. *angulata*	1	0.3
Fissurina marginata	1	0.3
Elphidium subarcticum	1	0.3
Total	305	100.3

In five of the borings from Storøymyr rich assemblages referable to zone C occurred under the lower zone D. *Virgulina loeblichi* and *Cassidulina laevigata carinata* were frequently found. *Cassidulina crassa,* however, was quite rare. The count of the sample from 19.2 m depth in boring no. F 1, is presented below as an example of such a zone C-assemblage:

Species	Frequency	Percentage
Elphidium incertum clavatum	214	34.5
Virgulina loeblichi	107	17.2
Cassidulina laevigata carinata	97	16.6
Pullenia osloensis	88	14.2
Lagena mollis	22	3.6
Biloculinella inflata	15	2.4
Lagena striata, forma *substriata*	14	2.3
Lagena laevis	12	1.9
Quinqueloculina seminulum	6	1.0
Cassidulina crassa	6	1.0
Nonion labradoricum	6	1.0
Quinqueloculina stalkeri	4	0.6
Pyrgo williamsoni	3	0.5
Cassidulina laevigata laevigata	3	0.5
Elphidium incertum incertum	3	0.5
Elphidium subarcticum	3	0.5
Silicosigmoilina groenlandica	2	0.3
Miliolinella cf. *subrotunda*	2	0.3
Lenticulina cf. *angulata*	2	0.3
Lenticulina cf. *gibba*	2	0.3
Cibicides lobatulus	2	0.3
Cibicides pseudoungerianus	2	0.3
Lagena distoma	1	0.1

Pandaglandulina sp.	1	0.1
Robertinoides normani	1	0.1
Robertinoides pumilum	1	0.1
Buccella frigida	1	0.1
Total	620	100.6

In all zone C-samples from these borings there occurred some sand within the clay.

Below zone C rich faunas tentatively classified as subzone B_u occurred. A count of one of the samples was presented on page 190. This subzone B_u was recognized also in boring no. 5 in Storøysund.

This latter boring revealed repeated occurrence not only of zone D but also of zone C. This may probably be ascribed to a submarine slide which has brought sandy zone C-deposits down on top of F_l-layers.

Skøyen, Oslo (*F 175 and 226*). This locality is situated at the junction between the Bygdøy peninsula and the mainland, on a clay flat at the northeast end of Hengsåsen. The surface lies 2.0 m above sea level. Four borings, carried out by the Norwegian Geotechnical Institute, were examined.

Boring no. 2 (F 175) was 23.2 m deep. It contained zone G down to 6.7 m below the surface. From 6.7 m to 11.3 m subzone F_u occurred and down to 16.4 m subzone F_l. Zone E occupied 2.9 m of the core, from 16.4 m to 19.3 m, underlain by a 1.9 m thick zone D. From 21.2 m to 22.0 m zone E reappeared, and the deepest part of the boring, from 22.0 m to 23.2 m, again contained zone D. Zone C did not occur in this boring. Boring no. 1, which was 11.9 m deep, did not penetrate below zone F, and this was also the case with boring E, which was 11.7 m deep.

Boring no. 1 (F 226) was 27.0 m deep and reached bedrock. This boring was more densely sampled than the others in the present investigation, 70 samples being examined. A discontinuity occurred at 5.2 m depth, G- and F-layers being present above this depth and again zone G below. This disturbance may have been caused by excavations in connection with road building close to the boring locality. The boundary between zone G and zone F was situated 8.0 m below the ground surface. Two parts of zone F were readily discernible, viz., subzone F_u down to 10.4 m. F_l down to 12 m. *Nonion labradoricum* was abundant in samples from the lower part of zone G and the upper part of subzone F_u down to approximately 9 m below the surface. Zone E occurred from 12.0 m to 15.2 m. The assemblages in the lowest part of this interval were much like those of subzone F_1. The boundary between zone E and zone D, at 15.2 m, was very distinct. The lower border of this zone D, lay 15.8 m below the surface. From 15.8 m to 20.7 m again rich Post Glacial assemblages occurred varying in composition between zone E and subzone F_1. At 20.7 m again a remarkably sharp boundary between zone E above, and zone D, below, occurred. Finally, at 24.3 m depth there was a very distinct border between zone D and zone C, the latter zone being traced down to 26.0 m. No specimens of Foraminifera were found between this level and the bedrock at 27.0 m, but two valves of juvenile pelecypods occurred. The lower zone D of this boring was 3.6 m thick and thus considerably thicker than the corresponding layer in the borings at Fornebo.

Bjørvika (O 223). Bjørvika is a bay in the eastern harbour of Oslo. The Norwegian Geotechnical Institute carried out borings in the bottom of the bay in 1955 in connection with a planned filling of the inner part of the bay. The bay was 3–8 m deep at the borings. The sediment consisted of an upper, 3–4 m thick layer of mud underlain by clay to great depths. None of the borings reached bedrock. According to soundings, however, the depth to bedrock ranged from 20 to 60 m.

Samples from five borings were examined:

Boring no. 1 taken at 7 m water depth, penetrated 14 m of sediment. Shallow-water assemblages, classified as zone G occurred down to 5.4 m below the sea bottom, where it was underlain by zone F to 10.0 m. Zone E was not represented, zone F was directly underlain by zone D, which occupied the lower part of the boring.

Boring no. 2, taken at 3.5 m water depth, reached 25.5 m below the bottom. Zone G was 10 m thick in this boring. Zone F was only 4 m thick, and zone E 2.5 m thick, from 14.0 m to 16.5 m below the sea bottom. Below the latter unit there was a nearly 6 m thick layer of zone D. Again, in the deepest part of the boring, from 22.5 to 25.5 m, zone E-associations reappeared, one sample contained even a zone F-fauna. This boring almost reached bedrock.

Boring no. 4, taken at 6.1 m water depth also reached 25.5 m below the sea bottom. As in the previous boring zone G was 10 m thick, zone F 5.5 m, from core level 10.0 m to 15.5 m. Zone E was 9 m thick, extending from 15.5 to 24.5 m. A zone D-association was found only in the deepest sample of the boring, at 25 m below the sea bottom.

Boring no. 5, taken at 7.1 m water depth, reached only 11 m below the sea bottom. In consequence it comprised only zone G and the uppermost part of zone F.

Finally, boring no. 6, taken at 4.4 m water depth, reached 19.8 m below the sea bottom. Zone G was 8 m thick, zone F 7.5 m. As in boring no. 1, zone E was not represented, zone F was underlain directly by zone D.

In all the examined borings from this locality *Nonion labradoricum* flourished in their upper parts. In boring no. 5, to mention one example, faunas with remarkably rich occurrence of this species occurred a core levels between 12 m and 14 m. *Ammoscalaria pseudospiralis* was common in zone G at Bjørvika.

Grønlandsleret and Akerselva, Oslo (*O 1–33*). Boring no. 48 at the low and extensive clay-flat of Grønlandsleret penetrated 40 m and was thus the deepest among the micropaleontologically examined borings from the northern part of the Oslofjord area. It did not reach bedrock. The sediment consisted of a somewhat silty clay.

The upper 2.5 m of the boring consisted of filling. This extended to 5.0 m depth because zone E-assemblages occurred at 4.2 m and 4.9 m most probably representing foreign clay material placed there by human activity. From 5 m to 11 m zone G occurred. In the lower part of this *Nonion labradoricum* was frequently found from 9 m depth. It disappeared again at 12 m, i.e., in the uppermost part of subzone F_u. Subzone F_l ranged from 13.5 m to 20.5 m. The underlying zone E was 9.5 m thick, from 20.5 m to 30.0 m, i.e., considerably thicker than at Skøyen and Fornebo. A 2.5 m thick layer with zone D-assemblages occurred from 30.0 to 32.5 m. At 33.2 m zone F was again represented and at 33.8 m zone E. Three samples from the lowest part of the boring, at 32.2 m, 32.8 m, and 39.9 m, again contained typical zone D-assemblages. Wood particles and plant remains occurred at a number of levels in this particular boring. Some samples from zone E, especially at 21.2 m and at 25.2 m contained shallow-water species in considerable frequency, *Eggerella scabra*, *Nonion depressulus asterotuberculatus*, *Ammonia batavus*, and *Elphidium excavatum*. This may possibly indicate that slides had taken place within the clays penetrated by boring no. 48.

Boring no. 31, situated at the river Akerselva, was 19.2 m deep. The ground surface at the boring lay 3.2 m above sea level, and the sediment consisted of a somewhat silty clay. The foraminiferal zones from C to G were present in complete succession. However, a repeated zone D-occurrence was not recognized. This was probably due to the sampling interval, which was too large at the levels where a second zone D would be expected. *Nonion labradoricum* appeared at 8.9 m depth, and was frequent at 8.4 m. It disappeared again in the lower part of zone G at 6.5 m.

Other borings in low-lying parts of the city of Oslo exhibited foraminiferal succession similar to the borings from Grønlandsleret and Akerselva. A 13 m deep boring at *Nationaltheateret* comprised only zone F. The terrain surface was situated there 7.0 m above sea level. There were no samples above 5 m depth. *Nonion labradoricum* occurred at 6.0 m and 6.5 m, but was not especially frequent.

Borings at Pilestredet, 14–16 m above sea level, did not reveal any late flourishing of *Nonion labradoricum*, neither did they reveal any repeated occurrence of zone D. Young sediments or shallow-water sediments (subzone F_u and zone G) were not represented in borings 7 and 10 of project O 411. This was also the case with boring no. 5 (Paleontological Museum's collection) further up in Pilestredet, 29.0 m above sea level.

At Konows gate in the valley of Lodalen in Oslo, six borings were carried out by the Norwegian Geotechnical Institute in connection with a slide which occurred there in 1954 (Sevaldson, 1956). These borings were dealt with by the present writer in a paper of 1957.

Majorstuen O 283. This locality is an almost horizontal plain situated 47–49 m above present-day sea level in the city of Oslo. Subsurface investigations undertaken by the Norwegian Geotechnical Institute, revealed filling of 0.5 to 1.5 m thickness at the top of the deposits. This was underlain by a firm dry crust down to 2.5–3.5 m. Below the dry crust silty or even sandy clay occurred down to 6–8 m depth, and below these layers the sediment consisted of clay down to a 0.5 to 1.0 m thick layer of sandy or gravelly clay resting upon the rock floor. Bedrock was situated 20 to 33 m below the surface.

Sampling was undertaken in three boreholes nos. 1, 4 and 5, none of which reached bedrock. Boring no. 1, which was 18.8 m deep and boring no. 4 which was 20.3 m deep, comprised both the foraminiferal zones D, F and G. Zone E was not recognized. In boring no. 5, however, the zones C, D, E, F and G occurred (Cp. Feyling-Hanssen, 1957).

The range chart of boring no. 5 is given in figure 40 of the present paper. In addition to the species entered in the chart, the following occurred in that boring: *Lagena striata*, forma *typica* at 22.2 m, 12.1 m, and 8.6 m, *Oolina lineato-punctata* at 22.2 m and 3.4 m, *Hauerinella inconstans* in the three zone C samples and at 10.7 m, *Robertinoides normani* in the two lowest samples and at 12.1 m and at 9.6 m, *Dentalina ittai* at 22.2 m, *Lenticulina (Robulus)* cf. *gibba* at 22.2 m and 11.1 m, *L.* (*R*) *limbosus chiriguanoi* at 22.2 and 8.6 m, *Robertinoides pumilum* at 21.7 m, *Triloculina trihedra* at 16.6 m, *Alveolophragmium crassimargo* at 13.6 m and 12.6 m, *Amphicoryna scalaris*, forma *compacta* at 13.3 m, *Dentalina drammenensis* and *Uvigerina peregrina* at 11.7 m, *Oolina hexagona* at 11.7 m and 8.1 m, *Lagena setigera* at 11.7, 11.1 and 8.1 m, *Globobulimina turgida* at 10.7 m, *Lagena distoma* at 10.2, 8.1, 5.1, and 3.4 m, *Cibicides pseudoungerianus* at 9.6 and 9.2 m, *Dentalina advena* at 9.2 m, *Triloculina tricarinata* at 9.2 and 8.6 m, *Saccammina sphaerica* at 8.6 and 7.1 m, *Fissurina laevigata* at 5.1 m, *Laryngosigma hyalascidia* and *Patellina corrugata* at 3.4 m.

Zone C and D are well developed. Zone F is readily subdivided into a lower subzone with *Cassidulina laevigata laevigata* commonly represented and an upper one in which *Virgulina fusiformis* was frequent. Zone G is a distinct shallow-water biofacies of subzone F_{II}. The water evidently became to shallow for *Bulimina marginata* to thrive there, *Eggerella scabra*, *Ammonia batavus*, and *Nonion depressulus asterotuberculatus* flourished instead, and so did *Elphidium excavatum* towards the top of the marine sequence.

Bryn (O 199). Samples from one boring, carried out by the Norwegian Geotechnical Institute on the west bank of the rivulet Loelva (Alna) where this is crossed by the highroad of Tvetenveien, were available. The bank is located at 80.0 m above sea level and close to the track of the main railroad (Hovedbanen). The boring was 19.7 m deep and was assumed to reach bedrock. The sediment consisted of quick clay with scattered particles of silt, sand and granules. The upper 3.5 m of the sediment was transformed into a dry crust. 18 samples were investigated micropaleontologically, the uppermost one from 8.2 m depth, the deepest one from 19.2 m. All of them contained Foraminifera, but three of them, at 10.2, 10.7, and 11.2 m contained very few. The result of the investigation is given in the range chart of figure 41. In addition to the species inserted in the chart, a few specimens of the following were observed in the boring:

Elphidiella arctica at 19.2 m, *Hauerinella inconstans* at 19.2 m and 18.4 m, *Fissurina laevigata* at 19.2 and 17.2 m, *Rosalina vilardeboana* at 19.2 and 9.2 m, *Lagena striata*, forma *substriata* at 19.2, 18.4, 17.2, 16.2, and 13.2 m, *Virgulina fusiformis* at 19.2, 18.4, 9.2, and 8.7 m, *Triloculina oblonga* and *Buccella frigida* at 18.4 m, *Oolina lineato-punctata* at 18.4 and 17.2 m, *Robertinoides normani* at 18.4 and 16.2 m, *Lagena laevis* at 18.4, 17.7, 16.2 and 14.2 m, *Parafissurina lateralis*, forma *simplex* at 18.4, 16.2 and 11.7 m, *Lagena distoma* at 18.4, 16.2, 14.2, and 11.2 m, *Lenticulina (Robulus) limbosus chiriguanoi* and *Robertinoides pumilum* at 17.7 m,

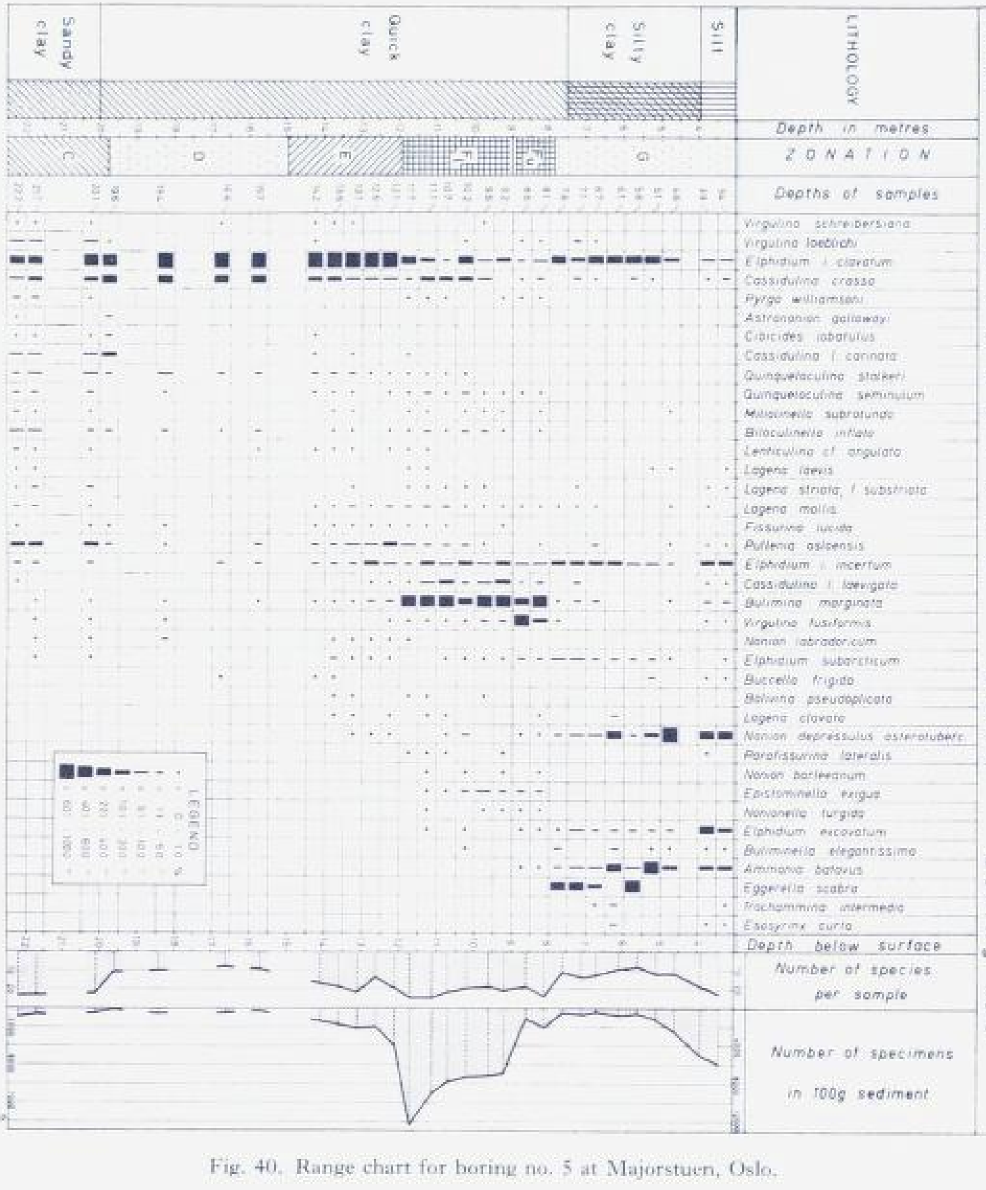


Fig. 40. Range chart for boring no. 5 at Majorstuen, Oslo.

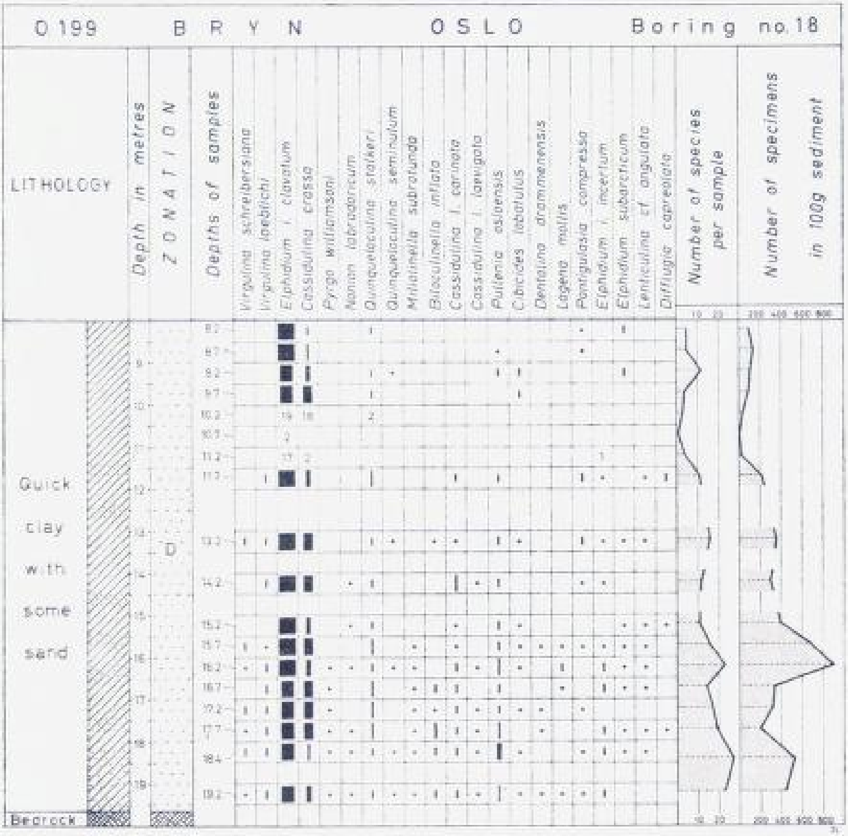


Fig. 41. Range chart for boring no. 18 at Bryn, Oslo.

Lagena elongata at 16.7 m, *Fissurina lucida* at 15.7, 13.2 and 11.7 m, *Triloculina trihedra* at 15.2 and 9.2 m, *Textularia earlandi* and *Guttulina dawsoni* at 9.2 m.

The foraminiferal associations of the investigated part of the boring reflect Late Glacial conditions. In the chart they are all referred to zone D. However, the deeper ones, from core level 15.7 m downwards would probably as easily be referred to zone C. *Virgulina loeblichi* occurred in all these samples, accounting for 1–5 % of the faunas, and *Cassidulina laevigata carinata* and *Pullenia osloensis* were quite common. On the other hand, however, the faunal difference between the two parts of the boring is not as distinct as is usually the case between zone D and zone C. It is not known whether Post Glacial deposits were represented in the uppermost part of the boring, above 8 m. Such deposits may have existed even above the present terrain surface and may have been carried away by later erosion by the Loelva.

Other high-lying borings in the northern part of the Oslofjord area contained foraminiferal faunas which can be referred almost exclusively to the Late Glacial zone D. This was the case with nearly all the borings in the Grorud valley comprising the borings along Brobekkveien and Ulvenveien (project numbers F 107, O 329), at Linderud (O 1–42) and Veitvedt (O 1–43), located at heights from 99 m to 153 m above sea level.

An exception was *boring no. 3* (*project O 1–40*) at the junction of the roads Brobekkveien and Risløkkveien, situated 92.6 m above sea level. In the upper half of this boring layers with shallow-water deposits containing *Bulimina marginata*, *Elphidium incertum incertum*, *E. excavatum*, and *Verneuilina media* in addition to *Elphidium incertum clavatum* and *Cassidulina crassa*, were interbedded between zone D-layers. These layers showed some similarity with the fauna of a sample from Havnens brickworks 100 m above sea level in Oslo, collected immediately above the 9100 years old sample from that locality, described on page 163 of the present paper. If zone E is considered to represent the first Post Glacial deposits immediately succeeding the Late Glacial ones, these levels at 93 m to 100 m are probably not far from the position of the shoreline at the time of the transition from Late Glacial to Post Glacial marine-climatic condition.

In the 21.8 m deep *boring no.* 2 (*O 962*) *at Ryen* and the 14.6 m deep *boring no. 1* (*F 175*) *at Manglerud*, both situated approximately 130 m above sea level, foraminiferal associations referable to the Late Glacial subzone B_{II} occurred below zone C layers. Above this zone D was developed as in the other high-lying borings.

At *Myrer* (*O 412*) close to the moraine at the southern end of the lake Maridalsvann, samples from a 24 m deep boring, carried out by the Norwegian Geotechnical Institute, were available. The surface was situated 174 m above sea level, and all the fossiliferous samples were referable to zone D. This zone was at least 21 m thick at this place. The uppermost part of the core consisted of 1 m of mould and peat underlain by stratified unfossiliferous clay.

At *Strømmen* (*O 394*), approximately 130 m above sea level and north-east of the moraines of the Aker substage, samples from at 18.5 m deep boring were examined. The dry crust was almost 5 m thick. In the two uppermost samples at 2.2 m and 2.7 m depth, no Foraminifera were observed. One specimen of *Elphidium incertum clavatum* occurred at 4.1 m and three at 9.6 m. The sample at 4.9 m was again barren. At 5.5 m there were found 27 specimens of *E. i. clavatum*, 4 of *E. subarcticum*, 2 of *E. i. incertum* and 1 of *Cibicides lobatulus*. Samples were lacking between 5.5 m and 7.8 m, but between 8 m and 11 m the samples contained between 1000 and 10000 specimens each, *Elphidium i. clavatum* accounting for 99 % of the faunas. From 11.5 m to the deepest sample at 18.5 m few if any Foraminifera occurred. The fossiliferous part of the b*o*ring was referred to zone D.

A 15 m deep boring at *Roiri, Lørenskog*, 180 m above sea level, carried out by the Geological survey of Norway (NGU), consisted entirely of zone D. The dried samples weighed 115 g each and contained 28 to 166 specimens. At 6 m below the surface 25 *Elphidium incertum clavatum*, 1 *Cassidulina crassa*, 1 *Quinqueloculina stalkeri*, and 1 *Nonionella turgida* occurred. Only *E. i. clavatum* and *C. crassa* occurred in the other samples. A 10 m deep boring from *Jessheim*, 203 m above sea level, yielded poorly populated samples with *Elphidium i. clavatum* and one small *Quinqueloculina*. P. Holmsen collected a clay sample from Borgen in Ullensaker, 160–170 m above sea level, 30 km northeast of Oslo and not far from the previous locality. This sample contained 134 specimens of *E. i. clavatum* and 1 worn specimen of a *Globigerina*, probably *bulloides* (Cp. Feyling-Hanssen, 1954 c). These and a few other samples from the district of Romerike were dealt with by the present writer in a paper of 1959 a. In that paper he also recorded the foraminiferal content of samples from two borings near the lake *Storsjøen* in Odal. The surface at these borings is situated 133 m above present-day sea level, and the following Foraminifera were observed: 41 specimens of *Elphidium i. clavatum*, 3 *Cassidulina crassa*, 3 *Nonion labradoricum*, 2 *Pyrgo williamsoni*, 1 *Quinqueloculina seminulum*, 1 *Nonionella turgida*, 1 *Elphidium i. incertum*, and 1 *Cibicides lobatulus*. The sediment was assumed to have been deposited at the end of Late Glacial time. The locality is the northernmost one in which marine Foraminifera have hitherto been observed in the area under consideration.

Two samples from Sørkedalen, north of Majorstuen in Oslo, contained foraminiferal associations referable to zone D. In one of the samples, collected by the writer at Bakk in Sørkedalen, 160 m above sea level, *Elphidium i. clavatum* and *Cassidulina crassa* occurred in abundance and in addition the following species were observed: *Quinqueloculina stalkeri*, *Elphidium subarcticum*, *Elphidium i. incertum*, *Quinquloculina seminulum*, *Lagena mollis*, *Lagena striata*, forma *substriata*, *Fissurina lucida*, *Bulimina marginata*, and *Cibicides bertheloti*.

A surface sample of clay from Fetsund near the northern end of the lake Øyern, contained no Foraminifera, whereas a sample from Sundvollen, approximately 70 m above sea level, near the lake Tyrifjorden, contained one specimen of *Elphidium i. clavatum* and one of *Cassidulina crassa*. A sample from Eidsvoll, at the southern end of Mjøsa, was barren, and so was a sample of blue clay from Feiring at the west side of the southern end of Mjøsa. A sample of clay from Kongsberg, collected by the Norwegian Geotechnical Institute below sandy layers, contained one specimen of *Islandiella norcrossi*.

Rosendahl collected a fossiliferous sample from an 8 m long clay lense in the moraine at Grefsen school, south of Maridalsvann. The sample contained *Elphidium i. clavatum* in abundance, *Cassidulina crassa* was frequent, and *Quinqueloculina stalkeri* common.

A sample of Portlandia clay collected by Øyen near the marine limit in Skådalen, Oslo, and labelled "Villa Yoldia" contained:

Species	Frequency	Percentage
Elphidium incertum clavatum	305	63.3
Elphidium subarcticum	154	32.0
Pateoris hauerinoides	8	1.6
Virgulina schreibersiana	8	1.6
Cassidulina crassa	6	1.2
Difflugia capreolata	1	0.2
Total	482	99.9

Interpretation of the zonation in the northern part of the area

The units of the foraminiferal zonation in the northern part of the Oslofjord area seem to reflect partly Late Glacial partly Post Glacial marine-climatic conditions. To the latter group belong the zones E, F and G. They are of the same character as the corresponding zones in the other parts of the area, and the interpretation already suggested for these zones there, would seem to be applicable also in the northern region. The units in this part of the area correspond with those in the southern part, and the correlation with Brøgger's mollusc zones appears to be identical with that attempted for the southern part of the area.

However, zone E constitutes an exception in that its older part is probably younger in the northern area than in the southern. According to the previous interpretation zone E contains the first thermophilous faunas which succeeded the Arctic and Sub-Arctic faunas of the Late Glacial Oslofjord, within the depth intervals accessible with the present material. During the northward retreat of the glacier fronts through the area, the marine environment was transformed from an Arctic or Sub-Arctic into temperate, and this transformation had to occur earlier in the southern parts of the fjord than in the north. The corresponding climatically induced faunal migration took place from south to north, so that zone E-faunas were probably well established in the southern parts of the fjord when zone D-faunas still populated the northern parts of it.

Within the Late Glacial group belong subzone B_{u}, zone C and zone D.

The assemblages classified as *subzone* B_{u} occurred also in the borings at Rakkestad, in the middle part of the Oslofjord area, and were assumed to originate from the time when the margin of the land ice receded from the ridges of the Ås–Ski substage to the position now marked by the moraines of the Aker substage. The climatic amelioration which caused the ice margin to recede, was in the marine environment counteracted by surplus of cold and turbid melt-water which was the result of the increased temperature. The Boreal component which appeared in the faunas as a result of this amerlioration was hampered in its expansion by the subsequent increased influence of this melt-water (Cp. p. 183).

As the ice margin approached the position of the Aker substage (Cp. fig. 2) the retrogression ceased and was replaced by an interval of stagnation or minor oscillations. Whatever the cause for this stagnation might have been – lowered air temperature probably played an important role – it resulted in decreased melt-water influx into the fjord. The hampering influence of the cold and turbid melt-water upon the foraminiferal benthos became less effective. Consequently the Boreal elements in the fauna were for a limited span of time given an opportunity to expand before the lowered air temperature, which probably brought about the glacial stagnation, could affect the water of the fjord bottom. Provided the B_{u}-fauna, detected in the deepest part of boring no. F1 (O 700) and no. 5 (O 420) at Fornebo, is autochthonous and belongs to the succession dealt with in the present paper, this fauna may constitute an illustration of such a development. Its composition approaches those met with in Post Glacial assemblages of the area.

However, these conditions were soon followed by a drop in the water temperature caused by the assumed deteriorated climate of the Aker substage. The temperate elements of the foraminiferal fauna were suppressed and the assemblages of zone C established. Zone C is thus assumed to be contemporaneous with the Aker substage within the depths represented in the material investigated. It would, in a way, be equivalent to subzone B_I, which corresponds to the stagnation of the Ås–Ski substage and to subzone A_{III}, corresponding to the Ra substage. In many of the borings zone C was associated with clay layers carrying sand grains and granules. These may have been brought into the sediment by ice-rafting from calving glaciers of the more or less stagnant margin of the glaciation.

On the other hand, the presence of coarse-grained particles may indicate that zone C is simply a bio-facies associated with a certain, probably relatively shallow, depth zone. This is difficult to envisage, however, firstly because zone C is overlain by zone D, and in some cases underlain by subzone B_{II}, which shows no particular relation to shallow water, secondly because zone C correlates with the Aker substage, which would be approximately contemporaneous with the highest Late Quaternary position of the sea level, the uppermost marine limit, 221 m, in the Oslofjord area (Cp. Isachsen, 1941; Gjessing and Fjellang, 1956). The highest-lying localities at which zone C was recognized were situated approximately 130 m above present-day sea level. If zone C is still associated with the above-mentioned interval of glacial stagnation, this may indicate that zone C would not develop in water shallower than 90–70 m (220–200 m – 130 m = 90–70 m). Or it may well be that the investigated borings did not reveal zone C at greater heights.

Zone D is assumed to have succeeded zone C as the interval of glacial stagnation was followed by rapid retreat. Large amounts of cold and turbid melt-water issued anew into the fjord and changed the fairly favourable ecological conditions in the inner ramifications of the fjord into unfavourable ones resulting in low populations. Not only is the number of specimens per unit of sediment small, which could have been explained by an increased sedimentation rate, but there is a distinct decrease also in the number of different species from zone C to zone D. In addition, the specimens are smaller in zone D than in the other units of the foraminiferal zonation. The unfavourable effects of the turbid melt-water which probably entered the fjord mainly as underflow, were felt especially in the narrow inner ramifications of the fjord and in the shallow waters over the flats of Romerike northeast of Oslo. It seems reasonable to assume that both decreased salinity and decreased transparancy with consequent deterioration of food supply occurred in these parts of the ancient fjord. The environment probably remained unfavourable as long as cold and turbid melt-water in sufficient quantity entered the fjord, which could have occurred even when the glacier fronts had retreated up into the valleys or melted away as dead-ice. The general climate of the area was already Post Glacial, and Post Glacial foraminiferal faunas had probably populated other parts of the ancient Oslofjord for some time. Therefore, as soon as the melt-water ceased to affect the waters of the inner ramifications of the fjord, the Post Glacial faunas could almost immediately immigrate and occupy these parts of the fjord. This may explain the very sharp boundary between zone D and zone E in the northern parts of the area.

The upper zone D which occurred in some of the lower-lying borings was not distinguished from the ordinary zone D otherwise than by its position. It was interlayered in the lower part of the Post Glacial sequence, between zone E or subzone F_1 layers. At an early stage of the present investigation such repeated occurrence of zone D was ascribed to disturbed stratification, and it was thought to indicate that slides had taken place. However, as an upper, usually thin but very distinct, bed with zone D-assemblages appeared in borings situated a considerable distance from each other, it was considered to represent the normal zonation of sediments in the northern part of the Oslofjord area, at least in localities at a moderate height above present-day sea level.

Thus, within the lower part of the Post Glacial sedimentary sequence, probably within the earlier half of the Post Glacial Warm Interval (Hypsithermal Interval, Altithermal) the well-established, rich foraminiferal faunas of zone E or subzone F_1 withdrew from some parts of the northern Oslofjord area and were replaced by the poor faunas of zone D, an interpretation of which was attempted above.

A well-founded explanation of this problem must be left to future work.

Distribution of arenaceous tests in the borings

Increase of areanaceous specimens towards the top of the borings and the scarcity or absence of such tests in deeper parts is a general and regional trend with the present material from the Late Quaternary of the Oslofjord area. It may be that this represents the original distribution, or it may have been caused by secondary processes, to a larger or lesser degree.

It is known from Green's (1960, p. 57) investigation of the ecology of Foraminifera from the central Arctic basin that 85 % of the normal benthonic fauna there consisted of hyaline forms, 14 % were porcellaneous. Arenaceous Foraminifera were not present at all in most of his samples. Loeblich and Tappan (1953, p. 9) recorded 74 species from the Barrow area, Alaska, only 14 of which were agglutinated. As the deeper samples from many of the borings from the Oslofjord area are of Late Glacial age, deposited under Arctic or Sub-Arctic conditions, any considerable amount of arenaceous forms would not be expected in them, according to the above observations. On the other hand, however, arenaceous forms are known to be frequently represented in Recent samples from the Siberian side of the Arctic (Stschedrina, 1950).

If arenaceous forms accounted for a greater part of the Late Glacial fauna of the Oslofjord than indicated by the tests preserved in the core samples, a decimation of such tests may have taken place during consolidation of the sediments. Some arenaceous forms, e. g., of the genus *Reophax*, are known to be very fragile. It is also possible that the protoplasma in some species plays an important role in the maintaining of the arenaceous test wall. The protoplasma is known to form an exterior coating, as well as an internal filling, of the test in some species. When such forms die and the protoplasma vanish, the test may be so weakened that it is apt to collapse by any extra mechanical stress. The total absence, for example, of *Rhabdammina* in Late Quaternary samples from the Oslofjord area may be explained in this way. Recent faunas from the Gullmarfjord as well as from the Oslofjord usually contain specimens of this and other fragile arenaceous genera.

Phleger (1960, p. 37, 38) found that thin-walled arenaceous forms, and some tectinous forms too, appeared to disintegrate after drying. Larger arenaceous species appeared to be injured or destroyed by the drying process.

Possible crushing of tests during the laboratory treatment of the samples was mentioned on page 43.

The predominance of arenaceous specimens of e.g., *Ammoscalaria runiana*, *Eggerella scabra*, *Spiroplectammina biformis*, and *Miliammina fusca* in zone G is primarily explained by the shallowing of the water which took place during the Holocene negative shift of the shoreline. Such arenaceous forms are known to be frequent in Recent assemblages from shallow water in the Oslofjord as well as in the Gullmarfjord. The submarine borings of the present investigation, e.g., the borings in Bjørvika, Oslo, the boring in Storøysund at Fornebo, the northernmost of the borings at Slagenstangen, and the submarine cores in the city of Fredrikstad, exhibit characteristic predominance of arenaceous tests in their upper parts. They were all from shallow water.

With some cores, however, it was obvious that the predominance of arenaceous tests was not original, but had been caused by secondary solution of calcarous tests, as described on page 73 of the present paper.

Systematic part

In this section the microfossils dealt with on the previous pages are treated systematically. Thanks to the comparatively extensive literature on Recent Foraminifera it was in most cases possible to recognize previously described species. During the identification work the present author has benefited from an inspiring correspondence with Drs. E. Boltovskoy, A. Dinesen, A. R. Loeblich, A. Nørvang, R. Todd, and J. H. van Voorthuysen, who all supplied specimens from their collections, for the purpose of comparison. 180 species, subspecies, and forms of Foraminifera were recognized. Two of the species, *Dentalina drammenensis* and *Dentalina trondheimensis*, were described as new. In addition 4 species of Thecamoebina occurred.

The species of Foraminifera were arranged in accordance with the classification proposed by Pokorný (1958, German edition by K. Diebel), with a number of alterations and additions of minor importance. Concerning the problems of classification of the class *Rhizopoda* the reader is referred to the comprehensive papers of Cushman (1928, and 4th edition 1955), Glaessner (1945, and 2nd edition 1948), and Pokorný (1958). Recent discussions are by Loeblich and Tappan (1961 b), who proposed a well-founded suprageneric classification of the *Rhizopoda*, by Glaessner (1963), and by Reiss (1963 b).

23 families, belonging to 7 superfamilies, are represented in the present material, viz.: Superfamily *Astrorhizoidea* with the families *Saccamminidae* (3 genera and 3 species, *Astrorhizidae* (1 genus and 1 species), *Reophacidae* (1 genus and 3 species), and *Ammodiscidae* (2 genera and 2 species).

Superfamily *Lituoloidea* containing the families *Lituolidae* (5 genera, 9 species), *Textulariidae* (3 genera, 6 species), *Trochamminidae* (2 genera, 4 species), and *Verneuilinidae* (4 genera, 4 species).

Superfamily *Milioloidea* with families *Nubeculariidae* (Syn. *Ophthalmidiidae*, 2 genera, 3 species), and *Miliolidae* (8 genera, 22 species).

Superfamily *Nodosarioidea* with families *Nodosariidae* (7 genera, 34 species) and *Polymorphinidae* (6 genera, 8 species).

Superfamily *Buliminoidea* with the families *Buliminidae* (10 genera, 32 species), *Cassidulinidae* (3 genera, 5 species), and *Nonionidae* (4 genera, 11 species).

Superfamily *Spirillinoidea* with the family *Spirillinidae* (1 genus, 1 species).

Superfamily *Rotalioidea* with the families *Discorbidae* (7 genera, 10 species), *Ceratobuliminidae* (1 genus, 1 species), *Epistominidae* (1 genus, 1 species), *Robertinidae* (1 genus, 2 species), *Orbulinidae* (1 genus, 1 species), *Elphidiidae* (3 genera, 7 species), and *Rotaliidae* (2 genera, 2 species).

In accordance with Recommendation 29 A (International Code of Zoological Nomenclature, adopted by the XV International Congress of Zoology, 1961, p. 29) the termination – OIDEA was adopted here for the names of superfamilies. Author and date were cited with the supraspecific taxonomic units on the following pages. These authors were usually not entered in the list of references cited unless reference to their publications was made in other connection, e.g., in connection with the presentation of a species. For a more comprehensive literature list, the reader is referred to the abovementioned papers by Cushman, Glaessner, Loeblich and Tappan, and Pokorný.

The systematic presentation of each species, subspecies, or form, is followed by some dimensions of specimens of the present material. The *occurrence* in the Late Quaternary of the Oslofjord area is recorded, and under *remarks* characters of systematic value are in many cases discussed. For stratigraphically significant species records of their occurrence in Quaternary deposits outside the Oslofjord area are also given, usually limited to Scandinavian countries. The general distribution in Recent waters is also given for these species.

The majority of the species in the present material were photographed. In a few instances Recent specimens from the author's collections from Spitsbergen and the Oslofjord were illustrated, for comparison or as substitutes. The catalogue designation P.M.O., used in the descriptive and illustrative sections of this study refers to the Paleontological Museum of the University of Oslo, in which the type material is kept.

THECAMOEBINA

Four species of this group were recognized in the Late Quaternary deposits of the Oslofjord area. These species are:

Difflugia capreolata Penard
Plate 1, figures 1–3

Diffluga oblonga Ehrenberg
Plate 1, figures 4, 5

Pontigulasia compressa (Carter)
Plate 1, figures 6, 7

Centropyxis arenatus (Cushman)
Plate 1, figures 8–10

They occurred in some samples from the Post Glacial zone G (Sandefjord and Årungen) and also in samples from the youngest Late Glacial zone D (Bryn, Oslo). Single specimens have also been observed in other assemblages.

Most Thecamoebina live in very shallow fresh water, or in brackish water, while very few genera live in the ocean (Cp. Todd and Bronnimann, 1957). The occurrences in the present Late Quaternary clay deposits are in good agreement with the general ecology of this group. Sediments with zone G-assemblages were very often deposited in shallow water of low salinity, and zone D-sediments were deposited in fjord water which must have been considerably diluted by fresh melt-water. The top samples from boring no. 2, Årungen (C 63) carried exclusively Thecamoebina and plant remains, thus representing the final fresh-water facies of the sediment there. Their scattered occurrence in samples also from other zones may be explained by fresh-water species having been carried out into the sea by streams. There exists, of course, the possibility that specimens of Thecamoebina may have entered a sample in the water spray during the washing process in the laboratory. The distinct concentration of Thecamoebina just in zone G and, to a lesser extent, in zone D, however, would reduce this possibility.

No classification of the Thecamoebina is attempted. Loeblich and Tappan (1961 b, p. 267) placed forms "With a test or rigid external membrane, and with definite aperture for extrusion of the lobose pseudopodia" in the order *Arcellinida* Kent, 1880, regarding the order *Thecamoebida* Delage and Hérouard, 1896, as a junior synonym. Pokorný (1958,

p. 87) considered this group to be insufficiently known and their distinction from the Foraminifera still uncertain. He applied to them the informal term Thekamöben (Thekamoebines).

FORAMINIFERA

Superfamily ASTRORHIZOIDEA Glaessner, 1945
Family **SACCAMMINIDAE** Brady, 1884
Subfamily **Psammosphaerinae** Eimer and Fickert, 1899
Genus Psammosphaera Schulze, 1875
Psammosphaera fusca Schulze

1875. *Psammosphaera fusca* Schulze, p. 113, pl. 2, fig. 8.
1894. *Psammosphaera fusca* Schulze – Goës, p. 14, pl. 3, fig. 19.
1918. *Psammosphaera fusca* F. E. Schulze – Cushman, p. 34, pl. 13, figs. 1–6; pl. 14, figs. 1–3.
1947. *Psammosphaera fusca* Schulze – Höglund, p. 46, pl. 4, figs. 9–14.
1948. *Psammosphaera fusca* F. E. Schulze – Cushman, p. 8, pl. 1, figs. 2, 3.

Occurrence. – A small specimen of this species, greatest diameter 0.30 mm, occurred in a zone G sample from Fredrikstad, obviously a shallow-water deposit. *P. fusca* seems to be extraordinary rare in the Late Quaternary of the Oslofjord area. This may, at least partly, be due to loss of specimens during the washing of the samples in the laboratory. Loosely cemented arenaceous tests, especially when not secondarily filled with foreign material, e.g., pyrite, may be broken and destroyed if the spray of water which is directed upon the sample is too strong.

Remarks. – The Recent geographical distribution of this species is very wide. There are numerous records from the Arctic (Cushman). It was originally described from Haugesund, on the west coast of Norway, at a depth of approximately 250 m (Schulze). Todd and Bronnimann (1957) figured a specimen from the eastern Gulf of Paria, and Heron-Allen and Earland (1922 and 1932a) figured very roughly and irregularly formed specimens from the Falkland Islands area and from the Antarctic "Terra Nova" expedition. Cushman recorded specimens with diameter up to 4.00 mm. It lives in the present Oslofjord, where it has been collected at depths between 60 and 200 m (Christiansen, 1958, p. 37).

Subfamily **Saccammininae** Brady, 1884
Genus Saccammina Carpenter, 1869
Saccammina sphaerica Brady

1869. *Saccammina sphaerica* M. Sars, p. 248 (nomen nudum).
1871. *Saccammina sphaerica* Brady, p. 183.
1872. *Saccammina sphaerica* G. O. Sars, p. 250.
1894. *Saccammina sphaerica* M. Sars – Goës, p. 13, pl. 3, figs. 16–18.
1918. *Saccamina sphaerica* G. O. Sars – Cushman, p. 44, pl. 16, figs. 4, 5; pl. 19, figs. 2–5.
1947. *Saccammina sphaerica* G. O. Sars – Höglund, p. 50, pl. 4, figs. 15–17.
1948. *Saccammina sphaerica* M. Sars – Cushman, p. 10, pl. 1, fig. 4.
1961a. *Saccammina sphaerica* Brady – Loeblich and Tappan, p. 79.

A specimen from zone D, Bryn, Oslo, had a diameter of 0.32 mm.

Occurrence. – This species is rare in the Late Quaternary of the Oslofjord area. Very few specimens were observed in samples from zone F and G from the city of Oslo. It was also recorded in a zone F sample from Valle, near Sarpsborg (Feyling-Hanssen, 1954 a, p. 125).

Remarks. – *S. sphaerica* seems to be recorded from all great ocean basins (Cushman, 1918). Höglund (1947, p. 51) dredged it in the Skagerrak off the Swedish west coast at depths of from 200 to 700 m. It was, however, rare in the Koster Channel, and he did not find it in the Gullmarfjord. Christiansen (1958, p. 39) found it in numerous dredge samples from the Drøbaksund, Oslofjord, at depths between 60 and 210 m. It was also found there by Kiær (1900, p. 13).

The diameter of specimens treated by Cushman (1918, 1948) varied between 1.00 and 3.50 mm. In Höglund's material the specimens varied between 0.35 and 2.00 mm in diameter. A small specimen was figured by Todd and Bronnimann (1957, pl. 1, fig. 16) from the Gulf of Paria.

Genus Proteonina Williamson, 1858
Proteonina fusiformis Williamson
Plate 1, figure 11

1858. *Proteonina fusiformis* Williamson, p. 1, pl. 1, fig. 1.
1884. *Reophax fusiformis* (Williamson) – Brady, p. 290, pl. 30, figs. 7–11.
1939. *Proteonina fusiformis* Willamson – Cushman and McCulloch, p. 41.
1947. *Proteonina fusiformis* Williamson – Höglund, p. 52, pl. 4, fig. 21; text figs. 20, 21.
1948. *Proteonina fusiformis* Williamson – Cushman, p. 11, pl. 1, fig. 6.
1955b. *Reophax fusiformis* (Williamson) – Loeblich and Tappan, p. 7.
1958. *Proteonina fusiformis* Williamson – Christiansen, p. 40.

Length of a specimen from the Post Glacial zone G at Glemmen Church, Fredrikstad, 0.70 mm, breadth 0.35 mm. Length of a specimen from zone F, upper part, of the same locality, 0.46 mm, breadth 0.23 mm, and another specimen in the same sample measured: length 0.45 mm, breadth 0.19 mm.

Occurrence. – This species seems to be rare in the Late Quaternary of the Oslofjord area. It occurred in boring no. 22, core level 4.2 m, at Valle by Sarpsborg, in the Post Glacial zone G; it was found also in boring no. 3, at core levels 3.7 and 6.2 m, at Glemmen Church, Fredrikstad, in zone G and in subzone F_{II}. In the northern part of the area *P. fusiformis* occurred in boring no. 48, Grønlandsleret, Oslo, at core level 9.2 m and 9.9 m, zone G, and core level 18.2 m, subzone F_I.

Remarks. – *P. fusiformis* was originally recorded from various stations about the British Isles (Williamson, 1858; Brady, 1884). It was later found living at many Arctic localities, and occasionally also on the western side of the Atlantic. On the Swedish west coast Höglund (1947, p. 53) found it in great abundance at depths between 15 and 40 m in the Gullmarfjord, and in the Skagerrak it occurred frequently at depths ranging from 66 to 700 m. *P. fusiformis* is one of the most common Foraminifera in the Drøbaksund, Oslofjord, to-day (Christiansen, 1958, p. 40). The salinity of the fjord water at this locality, and at depths corresponding to the frequent occurrence of this species, varies between 25 and 34 ‰.

Williamson (l.c., p. 1) erected the genus *Proteonina* for arenaceous, free, irregular, fusiform, or compressed, single-chambered forms. In his discussion of the type species of *P. fusiformis* (subsequent designation by Rhumbler, 1904, p. 244) Rhumbler stated not to have found any internal septa in this form. Loeblich and Tappan (1955 b, p. 7, 8) re-examined specimens of *P. fusiformis* from Williamson's Skye material, and found that Williamson's figured specimen was a three-chambered form. They therefore suppressed the name *Proteonina* as a synonym of the genus *Reophax* Montfort, 1808. In consequence of this also Pokorný (German edition by Diebel, 1958, p. 171) and Barker (1960, p. 62) listed *Proteonina* as a synonym of *Reophax*. Barnard (1959, p. 134) found, however, that there may be some justification for the retention of the genus, and Christiansen (l.c., p. 41) who studied many thousand specimens of *P. fusiformis* from the Drøbaksund in aniseed oil, found that some of them were incompletely divided in the apical part by constrictions of the wall, but none of them could be assigned to the genus *Reophax*. Accordingly he allowed all his specimens to pass under the old designation. My few specimens from the Late Quaternary are all single-chambered.

Family **ASTRORHIZIDAE** Brady, 1881
Genus Crithionina Goës, 1894
Crithionina pisum Goës

1896. *Crithionina pisum* Goës, p. 24, pl. 2, figs. 1, 2.
1909. *Crithionina pisum* Goës – Heron-Allen and Earland, p. 410, pl. 34, fig. 6.
1947. *Crithionina pisum* Goës – Höglund, p. 35, pl. 2, figs. 1, 2; pl. 25, figs. 8–14, 31; text fig. 7.

Occurrence. – This species was found only three times in the Late Quaternary of the Oslofjord area, viz., one specimen in a Post Glacial sample from zone G at Glemmen Church, Fredrikstad, one in a zone G sample from boring no. 2 at Lodalen, Oslo, and one in a zone G sample from boring no. 7 in the same locality.

Remarks. – The wall of this globular species is very loosely cemented. Thus, all the three specimens were broken before the writer could measure them. This very loose texture is also, most probably, one reason for the scarcity of this species in the washed samples from the Late Quaternary deposits. Christiansen (1958, p. 29) found *C. pisum* on muddy bottom in the deepest part of the Drøbaksund, Oslofjord, approx. 200 m, and Höglund (1947, p. 39) found it in the Skagerrak, only at stations deeper than 200 m.

The diameter of the specimens treated by Höglund (p. 36) varied between 1 and 3 mm.

Family **REOPHACIDAE** Cushman, 1910
Genus Reophax Montfort, 1808
Reophax atlantica (Cushman)

1944. *Proteonina atlantica* Cushman, p. 5, pl. 1, fig. 4.
1952a. *Proteonina atlantica* Cushman – F. Parker, p. 393, pl. 1, fig. 2.
1960. *Reophax atlantica* (Cushman) – Barker, p. 62, pl. 30, fig. 5.

A single specimen, probably belonging to this species, occurred in a zone G-assemblage of boring no. 2, profile C in Fredrikstad. Its length was 0.35 mm, breadth 0.22 mm.

Remark. - This species was originally described from shallow water off the New England coast. Brady's record of *Reophax difflugiformis*, referred by Barker (1960), was from the Faroe Channel in the North Atlantic.

Reophax pilulifera Brady
Plate 1, figure 16

1884. *Reophax pilulifera* Brady, p. 292, pl. 30, figs. 18–20.
1910. *Reophax pilulifera* H. B. Brady – Cushman, p. 85, text figs. 117, 118.
1947. *Reophax subfusiformis* Earland – Höglund (part.), p. 82, pl. 9, fig. 3.
1953. *Reophax pilulifera* Brady – Loeblich and Tappan, p. 23, pl. 2, fig. 6.

Length of hypotype of figure 16, 2.03 mm, breadth 0.70 mm. The initial chamber is broken off this specimen, complete its length would have been 2.30 mm.

Occurrence. – Single specimens of this species were found in Post Glacial sediments, zone E, F, G, i.a., in the city of Oslo, Lodalen, boring no. 2, and also in Drammen and Fredrikstad.

Remarks. – The sutures of this species are so deeply constricted between the chambers that the chambers very easily break off from each other. Separated chambers are quite often found in the samples. Specimens secondarily filled with pyrite are often met with.

Höglund (l.c., p. 86) is of the opinion that *R. pilulifera* is only an extreme variant, "Extreme Variant No. 2" of *R. subfusiformis*. Christiansen (1958, p. 53), who examined nearly a thousand specimens of this form from the Drøbaksund, Oslofjord, arrived at the same conclusion. In my material from the Post Glacial of the Oslofjord area, the specimens are certainly few compared with the Recent material from Drøbak, the two forms appear as distinctly different species. *R. pilulifera* is characterized by its globular chambers and in being much more constricted between the chambers than *R. subfusiformis*. Considering the numerous text figures and photographs of *R. subfusiformis* given by Höglund (p. 84, pl. 26, 27), I find it very difficult to pick out even a single typical *R. pilulifera*.

Reophax subfusiformis Earland
Plate 1, figures 12–15

1933. *Reophax subfusiformis* Earland, p. 74, pl. 2, figs. 16–19.
1947. *Reophax subfusiformis* Earland – Höglund, p. 82, pl. 9, figs. 1, 2, 4; pl. 26, figs. 1–36; pl. 27, figs. 1–19; text figs. 43–50.
1958. *Reophax subfusiformis* Earland – Christiansen, p. 52.

Length of hypotype of figure 12, 1.30 mm, breadth, 0.49 mm. Length of the hypotype of figure 13, 1.70 mm, breadth 0.62 mm. Figures 14 and 15 show broken specimens.

Occurrence. This species seems usually to be rare in the Late Quaternary of the Oslofjord area, a fact which, at least to some extent, may be due to the fragile character of the species. It is very easily broken, even on the specimen on figure 13, the apertual end had broken off.

R. subfusiformis occurred quite frequently in a sample of Isocardia clay, zone F, from Årum clay pit at Sarpsborg (Feyling-Hanssen, 1954 a, p. 125), it was quite frequent in zone G of boring no. 527 at Slagenstangen, and one specimen occurred in a zone G sample from boring no. 2, profile B, core level 11.5 m, in Fredrikstad.

Remarks. – Christiansen (l.c.) found living specimens of this species in the Oslofjord, Drøbak area, on mud or sandy mud bottom at depths between 40 and 210 m.

F. L. Parker (1952 a, p. 395) regards *R. subfusiformis* as synonymous with *R. curtus* Cushman (1920, pt.3, p.8), a view which is also held by Loeblich and Tappan (1953, p.22, 23). *R. curtus*, in its typical form, was described as three chambered and as having an apertual end without a definite neck. From figures given by Cushman (1920, pl. 2, figs. 2, 3; 1948, pl. 2, figs. 13, 14) it seems also evident that *R. curtus* is a shorter and thicker form than *R. subfusiformis*. Even though F. L. Parker (l.c.) noted that *R. curtus* may have a definite neck, but that this may be broken, it is here preferred, at the present state of knowledge about these two forms, to regard them as different species.

Family **AMMODISCIDAE** Reuss, 1862
Subfamily **Rzehakininae** Cushman, 1933
Genus Silicosigmoilina Cushman and Church, 1929
Silicosigmoilina groenlandica (Cushman)
Plate 1, figures 17–19

1933. *Quinqueloculina fusca* Brady, var. *groenlandica* Cushman, p. 2, pl. 1, fig. 4.
1948. *Quinqueloculina groenlandica* Cushman – Cushman, p. 34, pl. 3, fig. 18.
1953. *Silicosigmoilina groenlandica* (Cushman) – Loeblich and Tappan, p. 38, pl. 4, figs. 7–9.

Length of the specimen of figure 17, 0.29 mm, breadth 0.14 mm. Length of specimen of figure 18, 0.30 mm, breadth 0.15 mm. Length of the specimen of figure 19, 0.27 mm, breadth 0.12 mm. An unfigured specimen from subzone B_I of a boring from Herøya had a length of 0.65 mm.

Occurrence. – This species was rare in the Late Quaternary of the Oslofjord area, it occurred in Pleistocene strata as well as in Holocene.

Remarks. – The specimens of *S. groenlandica* from the Late Quaternary of the Oslofjord area are often small. In the material treated by Loeblich and Tappan (l.c.) specimens of this species ranged from 0.29 to 0.70 mm in length, and one of their figured specimens was even 0.75 mm long. The length of Quaternary specimens from the Oslofjord area did usually not exceed 0.30 mm. Specimens from zone C in borings at Fornebo were, however, longer. Most of the present specimens were very finely arenaceous, the wall surface appeared almost porcellaneous. They were insoluble in acid.

Miliammina fusca (Brady)
Plate 2, figures 1, 2

1870. *Quinqueloculina fusca* Brady, p. 286, pl. 11, fig. 2.
1929. *Quinqueloculina fusca* H. B. Brady – Cushman, Bull. 104, pt. 6, p. 23, pl. 1, fig. 4.
1936. *Miliammina fusca* (Brady) – Rhumbler, p. 209.
1938. *Quinqueloculina fusca* H. B. Brady – Bartenstein, p. 391, text fig. 11.
1952. *Miliammina fusca* (H. B. Brady) – Parker, a, p. 404, pl. 3, figs. 15, 16; b, p. 452, pl. 2, fig. 6.
1957. *Miliammina fusca* (Brady) – Todd and Bronnimann, p. 26, pl. 3, fig. 1.

Length of hypotype of figure 1, 0.54 mm, greatest breadth 0.24 mm. Length of hypotype of figure 2, 0.35 mm, greatest breadth 0.16 mm. Other specimens ranged from 0.40 mm to 0.24 mm in length.

Occurrence. – This species occurred mainly in shallow-water facies of marine Holocene deposits of the Oslofjord area, and was especially frequent in sediments deposited in more or less stagnant water of reduced salinity. The figured specimens are from the upper part of the Post Glacial zone G of boring no. 1 in Sandefjord. Unfigured specimens occurred at the transition between zone G and zone F of the same boring. *Miliammina fusca* was quite commonly met with in zone G-assemblages from the northern as well as from the southern part of the investigated area. It was rare in zone F, and occurred only accidentally in zone E. It was not observed in Pleistocene deposits and not in zone B, the youngest Holocene unit.

Remarks. – This species is close to *Miliammina oblonga* Heron-Allen and Earland (1930 a), which was renamed *Miliammina earlandi* Loeblich and Tappan (1955 b, p. 12, 13, pl. 1, figs. 15, 16), but differs from it in having a thinner wall, a rougher surface and in being more coarsely arenaceous. *M. oblonga* sometimes has its aperture on a somewhat produced neck with a recurved collar. Neither a neck nor a collar has been observed with the present specimens of *M. fusca*. Brady's figure (Brady, 1870, pl. 11, fig. 2) shows a lip or collar, but it is not mentioned in his description. A tooth was present in most of the writer's, more than 100, specimens, very often small, but readily distinguishable. Brady's figure (l.c., pl. 11) shows no tooth. Bartenstein (1938, p. 391, fig. 11 c) figured a specimen without a tooth, from the Jade Bay on the north coast of western Germany. Boltovskoy (1954 a, p. 123, pl. 1, fig. 12 c) recorded a specimen, also without a tooth, from the Gulf of San Jorge on the east coast of southern South America. Several other authors have, however, noted the presence of an apertural tooth with their specimens, e.g. Goës (1894, p. 110, pl. 19, fig. 848 g) who figured a specimen from the Baltic Sea, with a distinct tooth, and the specimens figured by Parker (1952 a, p. 404, pl. 3, fig. 15; 1952 b, p. 452, pl. 2, fig. 6 a) from Buzzards Bay and the Gulf of Maine on the east coast of northern North America, are furnished with an apertural tooth. The same is true of specimens figured by Phleger (1954 p. 642, pl. 2, fig. 23), from Mississippi Sound, by Todd and Bronnimann (1957, p. 26, pl. 3, fig. 1 b), from the Gulf of Paria, and by Parker and Athearn (1959, p. 340, pl. 50, fig. 11), from Poponesset Bay, Massachusetts.

Several of the author's specimens were studied in aniseed oil to make internal structures visible. A planispiral chamber arrangement in early stages was not detected (Cp. also Loeblich and Tappan, 1955 b, p. 13).

The maximum length of *M. fusca* is approximately 0.50 mm. The 1 mm long, round specimen from a Late Pleistocene deposit in Bohuslän, on the Swedish west coast, figured by Hessland (1943, pl. 1, fig. 4), does not belong to this species.

Miliammina fusca is a marsh form (Miller, 1953, p. 51; Lankford, 1959, p. 2079; Parker and Athearn, 1959, p. 340) occurring in temperate waters of the eastern as well as of the western Atlantic. The marsh fauna is characterized by poorly cemented arenaceous species which have a world-wide distribution (Lankford, l.c., p. 2077). Water depths usually less than 0.3 m, and salinity less than 20 ‰. *M. fusca* is, thus, common especially under brackish-water conditions, but, as stated by Phleger and Walton (1950, p. 280) and Parker (1952 b, p. 436, 452), it apparently has a certain ability to exist also in water of higher salinity, 25–32 ‰. Lankford (l.c.) in the Mississippi delta found it also in interdistributary bay environment, water depths down to 2 m, salinity from less than 1 ‰ to 10 ‰, temperature ranging from 0° C to 38° C. It occurred even in fluvial marine environment, water depths 1 to 10 m, salinity from less than 1 ‰ to 32 ‰, water temperature ranging from 8 to 29° C.

From the eastern Gulf of Paria, Trinidad, Todd and Bronnimann (1957, p. 8) recorded *M. fusca* as occurring abundantly in the tidal zone and near shore zone, to a depth of about 4 m. It was rare in the offshore zone, to a depth of about 35 m. (Cp. also Closs, 1963, p. 27).

M. fusca was also recorded from the Indo-Pacific (Cushman, 1929, p. 24). Hada (1936, 1937) and Takayanagi (1955) recorded it from Japan. It has not been observed in Arctic environment. Cushman's record of *Quinqueloculina fusca* in "Arctic Foraminifera" (1948, p. 33) was transferred to *Quinqueloculina stalkeri* Loeblich and Tappan by Loeblich and Tappan (1953, p. 40).

Superfamily LITUOLOIDEA Lamarck, 1809

Family **LITUOLIDAE** Lamarck, 1809

Genus Adercotryma Loeblich and Tappan, 1952

Adercotryma glomeratum (Brady)

Plate 2, figures 3, 4

1878. *Lituola glomerata* Brady, p. 433, pl. 20, fig. 1.
1884. *Haplophragmium glomeratum* (Brady) – Brady, p. 309, pl. 34, figs. 15–18.
1894. *Haplophragmium glomeratum* (Brady) – Goës, p. 23, pl. 5, figs. 134–139.
1920. *Haplophragmoides glomeratum* (H. B. Brady) – Cushman, Bull. 104, p. 47, pl. 9, fig. 6.
1947. *Haplophragmoides glomeratum* (Brady) – Höglund, p. 135, pl. 10, figs. 3, 4; text fig. 112.
1948. *Haplophragmoides glomeratum* (H. B. Brady) – Cushman, p. 28, pl. 2, fig. 16.
1952.b *Haplophragmoides glomeratum* (H. B. Brady) – Phleger, p. 85, pl. 13, fig. 10.
1953. *Adercotryma glomeratum* (Brady) – Loeblich and Tappan, p. 26, pl. 8, figs. 1–4.
1958. *Adercotryma glomeratum* (Brady) – Christiansen, p. 60.

The figured specimen is a Recent one from a dredged sample taken by the author in the Oslofjord, just north of the Biological Station at Drøbak, at a depth of 70–80 m. Its greatest diameter is 0.32 mm, its thickness 0.30 mm. A Post Glacial specimen from the upper part of zone F of boring no. 22 at Valle by Sarpsborg had a greatest diameter of 0.16 mm and a thickness of 0.17 mm.

Occurrence. – Several specimens of this species occurred in very young zone G-assemblages of boring no. 527 at Slagenstangen, one specimen in subzone F_{II} at Valle, and three specimens in zone G of boring no. 48, Grønlandsleret, Oslo. It occurred also in the Late Glacial zone C of boring no. 1 (F 175) at Manglerud, Oslo. It seems to be rare in the Late Quaternary of the Oslofjord area.

Remarks. – This species is a frequent inhabitant of the Oslofjord today. Kiær (1900, p. 5–11) and Christiansen (1958, p. 60) found it at many places on both hard and soft bottom. It was common also in the Gullmarfjord but less so in the Kattegat and Skagerrak. *A. glomeratum* is widely distributed in Arctic waters as well as in temperate, and is also recorded from the Antarctic (Pearcey, 1914, p. 1008).

Genus Haplophragmoides Cushman, 1910

Haplophragmoides bradyi (Robertson)

1887. *Trochammina robertsoni* Brady, p. 893.
1891. *Trochammina bradyi* Robertson, p. 388.
1942. *Haplophragmoides bradyi* (Robertson) – Nørvang, p. 6, fig. 1.
1947. *Haplophragmoides bradyi* (Robertson) – Höglund, p. 134, pl. 10, fig. 1; text fig. 111.
1951. *Haplophragmoides bradyi* (Robertson) – F. L. Parker, p. 3, pl. 1, fig. 10.
1958. *Haplophragmoides bradyi* (Robertson) – Christiansen, p. 58.

One specimen referable to this species occurred in subzone F_{II} of boring no. 2, profile B, Fredrikstad. Its greatest diameter was 0.22 mm, thickness 0.14 mm. Another specimen occurred in the 8700 years old zone G-assemblage from Ringvoll brickwork, Bærum (Cp. p. 168). It occurs in the Oslofjord of the present-day.

Haplophragmoides pusillum Höglund

1947. *Haplophragmoides pusillum* Höglund, p. 140, pl. 10, fig. 2; text fig. 113.
1958. *Haplophragmoides pusillum* Höglund – Christiansen, p. 59.

One specimen of this very small and coarsely agglutinated species occurred in zone G of boring no. 2, profile C in Fredrikstad. Its greatest diameter was 0.19 mm, its thickness 0.11 mm. Another specimen occurred in zone G of boring no. 2, profile B, also in Fredrikstad. It lives in the present Oslofjord.

Genus Alveolophragmium Stschedrina, 1936
Alveolophragmium crassimargo (Norman)
Plate 2, figures 5–8

1892. *Haplophragmium crassimargo* Norman, p. 17.
1894. *Haplophragmium canariense* d'Orbigny – Goës (part.), p. 20, pl. 5, figs. 92–96 (not d'Orbigny).
1943. *Haplophragmoides canariensis* (d'Orbigny) – Hessland, pl. 1, fig. 1 (not d'Orbigny).
1947. *Labrospira crassimargo* (Norman) – Höglund, p. 141, pl. 11, fig. 1; text figs. 121–125.
1953. *Alveolophragmium crassimargo* (Norman) – Loeblich and Tappan, p. 29, pl. 3, figs. 1–3.
1958. *Cribrostomoides crassimargo* (Norman) – Christiansen, p. 61.
1960. *Alveolophragmium crassimargo* (Norman) – Barker, p. 72, pl. 35, fig. 4.

Greatest diameter of the hypotype of figure 5 and 6, 0.89 mm, thickness 0.51 mm. Greatest diameter of hypotype of figure 7 and 8, 0.87 mm, thickness 0.46 mm. The figured specimens are from a Recent bottom sample from the Wijdefjord in Spitsbergen, which the writer collected at a depth of 8 m. Specimens from the Late Quaternary of the Oslofjord area varied in diameter from 1.08 mm (a specimen from zone D of Majorstuen, Oslo) to 0.59 mm (a specimen from zone F, Lodalen, Oslo). Höglund (1947, p. 141) found specimens in the Gullmarfjord, Swedish west coast, with diameter up to 1.25 mm, and Loeblich and Tappan (1953, p. 30) recorded Arctic specimens with diameter up to 2.65 mm.

Occurrence. – This species was found in the Late Glacial zones C and D and in the Post Glacial zones E, F, and G of the Late Quaternary in the Oslofjord area. One specimen, diameter 0.81 mm, thickness 0.32 mm, occurred in zone E of boring no. 48 at Grønlandsleret, Oslo; another specimen occurred in zone F of the same boring. In a boring at Pilestredet 48 b, Oslo, it occurred in zone F and also in the Late Glacial zone D. In boring no. 2, Lodalen, also Oslo, there occurred 15 specimens in one zone F sample, the diameter varied from 0.59 to 0.92 mm. The species occurred also in zone G of boring no. 3 in the same locality. At boring no. 5, Majorstuen, Oslo (Sørkedalsveien 8), single specimens occurred in the lowest part of zone E and upper part of zone D. A specimen from zone D had a diameter of 1.08 mm, thickness 0.70 mm; another specimen of this zone had diameter 0.95 mm, thickness 0.57 mm. It was quite frequent in zone C of a boring at Manglerud (F 175), Oslo. In the southern part of the Oslofjord region *A. crassimargo* occurred in zone F in boring no. 22 at Valle, and in zone G in Fredrikstad.

Remarks. – *A. crassimargo* is common in the Oslofjord to-day. It was frequent in a dredge sample taken by the present author in 1949 north of the Biological Station at Drøbak at a depth of 70–80 m. Christiansen (1958, p. 61) found it in the Drøbak area of the Oslofjord below 50–70 m. Höglund (1947, p. 141) found it evenly spread in the entire Gullmarfjord, though not at the shallowest stations. Its maximum frequency there was found at depths between 55 and 80 m. In the Skagerrak he found it at depths between 66 and 300 m.

It was represented in two of the bottom samples from Spitsbergen, sparingly in a sample from the van Keulenfjord, 8 m depth, quite frequently in a sample from Wijdefjord, also 8 m. It occurred also in two of the author's bottom samples from Northeast Greenland, sparingly in a sample from Myggbukta, 10 m depth, and very frequently in a sandy sample from Revet, at the junction of the Tyrolerfjord and the Copelandfjord on the west side of Clavering Island, at a depth of 30 m. Goës (1894, p. 21) gave many Arctic records of the species, both from Spitsbergen and Greenland. And Loeblich and Tappan (1953, p. 31) found it at 35 Alaskan, Canadian and Greenland stations at depths varying between 13 and 223 m, the shallowest records being from Northeast Greenland. It was also recorded from the Sea of Okhotsk, the Kara Sea, the Sea of Japan, the coast of Finnmark, and the Gulf of St. Lawrence (Loeblich and Tappan, l.c.). F. L. Parker (1952 a, p. 401) recorded it from New Hampshire and the Long Island Sound – Buzzards Bay area (1952 b, p. 451) on the northern east coast of the United States of America. She assumed that the area immediately south of Cape Cod is close to the southern limit of occurrence of this species on the North American east coast.

Hessland (1943, p. 159, 262) found 16 specimens of this species in a Late Glacial sample from Kläppen, North Bohuslän, on the Swedish west coast.

Alveolophragmium nitidum (Goës)

1896. *Haplophragmium nitidum* Goës, p. 30, pl. 3, figs. 8, 9.
1947. *Labrospira nitida* (Goës) – Höglund, p. 145, pl. 11, fig. 5; text fig. 127.
1959. *Alveolophragmium nitidum* (Goës) – Boltovskoy, p. 40, pl. 1, fig. 3.

A specimen of this thick-walled species occurred in subzone F_u of boring no. 2, profile C, Fredrikstad. Its greatest diameter was 0.21 mm, thickness 0.14 mm. A specimen in subzone F_u of boring no. 5, profile B, Fredrikstad, had a greatest diameter of only 0.19 mm.

Genus Recurvoides Earland, 1934

Recurvoides trochamminiforme Höglund

1947. *Recurvoides trochamminiforme* Höglund, p. 149, pl. 11, figs. 7, 8; pl. 30, fig. 23, text fig. 120.
1958. *Recurvoides trochamminiforme* Höglund – Christiansen, p. 62.

Greatest diameter of a specimen from boring no. 48, Grønlandsleret, Oslo, 0.22 mm, thickness 0.14 mm. A specimen from Glemmen Church, Fredrikstad, measured: diameter 0.19 mm, thickness 0.11 mm.

Occurrence. – This species was observed only in zone G of Post Glacial deposits in the Oslofjord area, viz. 1 specimen in boring no. 3 of Glemmen Church, Fredrikstad, 1 in boring no. 2, profile B, Fredrikstad and 10, 5, and 2 specimens in three samples from zone G in boring no. 48, Grønlandsleret in the city of Oslo.

Remarks. – Christiansen (1958, p. 62) found living specimens of this species in the Drøbaksund of the Oslofjord at depths between 10–20 and 210 m, only in small numbers. It was common in the Gullmarfjord, but less so in the Skagerrak and the Kattegat (Höglund, 1947, p. 149). The diameter of Höglund's specimens varied between 0.11 and 0.35 mm.

Recurvoides turbinatus (Brady)

1881. *Haplophragmium turbinatum* Brady, p. 50.
1884. *Haplophragmium turbinatum* Brady – Brady, p. 312, fig. 9.
1952a. *Recurvoides turbinatus* (Brady) – F. Parker, p. 402, pl. 2, figs. 23, 24.
1953. *Recurvoides turbinatus* (Brady) – Loeblich and Tappan, p. 27, pl. 2, fig. 11.

Four specimens of this species occurred in the Holocene zone C of boring no. 1 at Kolbotn (O 823). One of them had a greatest diameter of

0.21 mm, thickness 0.13 mm. Another one had a greatest diameter of 0.23 mm.

This species was not recorded by Christiansen (1958) in the Recent fauna of the Drøbaksund in the Oslofjord, nor by Höglund from the Gullmarfjord.

Genus Ammoscalaria Höglund, 1947

Ammoscalaria pseudospiralis (Williamson)

Plate 2, figures 9–12

1858. *Proteonina pseudospiralis* Williamson, p. 2, pl. 1, figs. 2, 3.

1884. *Haplophragmium pseudospirale* (Williamson) – Brady, p. 302, pl. 33, figs. 1–4.

1920. *Ammobaculites pseudospirale* (Williamson) – Cushman, Bull. 104, pt. 2, p. 62, pl. 12, fig. 4 (after Williamson).

1947. *Ammoscalaria pseudospiralis* (Williamson) – Höglund, p. 159, pl. 31, fig. 1.

1953. *Ammoscalaria pseudospiralis* (Williamson) – Parker, Phleger, and Peirson, p. 6, pl. 1, figs. 29, 35.

1958. *Ammoscalaria pseudospiralis* (Williamson) – Christiansen, p. 63.

1959. *Ammoscalaria pseudospiralis* (Williamson) – Lankford, p. 2078, 2083, pl. 1, figs. 5–7.

1961. *Ammoscalaria pseudospiralis* (Williamson) – Boltovskoy, p. 253, pl. 1, fig. 2.

Only broken specimens of this species were found. Therefore, no exact dimensions can be given. The largest figured fragment from boring no. 2, Bjørvika, Oslo (figure 9), had a length of 1,32 mm, breadth 0.70 mm, thickness 0.27 mm. A Recent specimen from a bottom sample taken by the author in the Oslofjord, just north of the Biological Station at Drøbak, depth 70–80 m (figure 12) had a length of 1.51 mm, breadth 0.76 mm, thickness 0.30 mm. This specimen also was not quite complete, a part of the apertural end being broken off. From the Swedish west coast Höglund (1947, p. 160) recorded specimens with length up to 2.0 mm, breadth up to 0.8 mm, thickness up to 0.3 mm.

Occurrence. – This species was quite common in the Post Glacial zone G of the borings no. 2, 4, 5, and 6 at Bjørvika (O 223) in the city of Oslo, and in zone G of boring no. 527 at Slagenstangen.

Remarks. – This species occurred quite frequently together with *Ammoscalaria tenuimargo* (Brady), in a Recent bottom sample from the Oslofjord, taken by the author just north of the Biological Station at Drøbak at a depth of 70–80 m. Christiansen (1958, p. 63) found *A. pseudospiralis*, also living specimens, in the Drøbaksund at depths between 10–20 m and 200 m, in greatest quantities on mud bottom in the deepest part of the area. Kiær (1900, p. 44) found it in the outer part of the Oslofjord. Höglund (1947, p. 160) found it in considerable quantities on sandy bottom at depths between 20 and 50 m in the Gullmarfjord on the Swedish west coast. It was also quite common in the Kattegat, but occurred only at two shallow stations in the Skagerrak.

It was once obtained from the Davies Strait, West Greenland, 62° 6′ N. lat., by the Valorons Expedition (Ellinger, 1914, p. 762).

Nørvang (1945, p. 4) referred to a record of this species (recorded as *Haplophragmium calcareum*) from Iceland (Terquem and Terquem, 1886, p. 332, pl. 11, fig. 11), and summarized its Recent distribution as follows: "This species seems to be limited to rather shallow water off the coasts of northern Europe. Along the Norwegian coast it has been found north of Hankø, near Stavanger, Kristiansand and Bergen. It is further found off the coast of Bohuslän, Sweden. From the British Isles it is recorded from several localities, mostly from the west coast of Scotland and Ireland and from the Irish Sea. Main distribution: Boreal? Vertical range: From 20 to about 700 m." Later *A. pseudospiralis* was recorded from San Antonio Bay, South-west Texas (Parker, Phleger, and Peirson, 1953, p. 6), from the Central Texas coast (Phleger, 1956, p. 112), from east Mississippi delta (Lankford, 1959, p. 2083), where it occurred in sound environment, and from off the coast of Brazil (Boltovskoy, 1961, p. 253).

The amount of cement in the wall of the Post Glacial specimens of *A. pseudospiralis* from the borings in Oslo is relatively slightly smaller than in the wall of the author's Recent specimens from the Drøbaksund of the Oslofjord. The sutures are usually readily discernible on the Post Glacial specimens, whereas on most of the Recent specimens they are invisible. The cement is insoluble in hydrochloric acid.

The very compressed species *A. tenuimargo* which is common in the Oslofjord of the present-day, was not observed in Late Quaternary deposits.

Ammoscalaria runiana (Heron-Allen and Earland)

Plate 3, figure 1

1916b. *Haplophragmium runianum* Heron-Allen and Earland, p. 224, pl. 40, figs. 15–18.
1920. *Haplophragmoides runianum* (Heron-Allen and Earland) – Cushman, Bull. 104. pt. 2. p. 48, pl. 10, figs. 1, 2.
1947. *Ammoscalaria runiana* (Heron-Allen and Earland) – Höglund, p. 162, pl. 9, figs. 23, 24.
1954a. *Ammoscalaria runiana* (Heron-Allen and Earland) – Feyling-Hanssen, p. 125.
1958. *Ammoscalaria runiana* (Heron-Allen and Earland) – Christiansen, p. 63.

A specimen from boring no. 5, Sandefjord, core level 5.4 m, had a greatest diameter of 0.32 mm and a thickness of 0.11 mm.

Occurrence. – This species was represented in zone G of Post Glacial samples, i.a., from borings at Sandefjord, Fredrikstad and Valle. Single specimens, mostly, occurred also in the upper part of zone F in borings in Fredrikstad. 8 specimens occurred also in a sample from Stein clay pit at Sandefjord (Feyling-Hanssen, 1954 a, p. 125).

Remarks. – *Ammoscalaria runiana* is a shallow-water form, recorded from the west coast of Scotland and from the Plymouth district by Heron-Allen and Earland (1916 b, p. 224). Höglund (1947, p. 162) found it in the Gullmarfjord, Swedish west coast, at depths from 7 to 33 m. Christiansen (1958, p. 63) obtained it from the Drøbaksund of the Oslofjord down to 42 m, besides a few dead tests at 170 m. The cement of the test of this species is insoluble in hydrochloric acid.

Family **TEXTULARIIDAE** Ehrenberg, 1839
Genus Spiroplectammina Cushman, 1927
Spiroplectammina biformis (Parker and Jones)
Plate 3, figures 2, 3

1865. *Textularia agglutinans* d'Orbigny, var. *biformis* Parker and Jones, p. 370, pl. 15, figs. 23, 24.
1884. *Spiroplecta biformis* (Parker and Jones) – Brady, p. 376, pl. 45, figs. 25–27.
1894. *Spiroplecta biformis* (Parker and Jones) – Goës, p. 38, pl. 7, figs. 308–312.
1932. *Spiroplectammina biformis* (Parker and Jones) – Lacroix, p. 5, fig. 1.
1932a. *Spiroplectammina biformis* (Parker and Jones) – Heron-Allen and Earland, p. 347, pl. 8, figs. 27–31.
1947. *Spiroplectammina biformis* (Parker and Jones) – Höglund, p. 163, pl. 12, fig. 1; text figs. 140, 141.
1948. *Spiroplectammina biformis* (Parker and Jones) – Cushman, p. 30, pl. 3, figs. 7, 8.
1952b. *Spiroplectammina biformis* (Parker and Jones) – Phleger, p. 86, pl. 13, figs. 29, 30.
1953. *Spiroplectammina biformis* (Parker and Jones) – Loeblich and Tappan, p. 34, pl. 4, figs. 1–6.

Length of hypotype of figures 2 and 3, 0.38 mm, breadth 0.16 mm, thickness 0.09 mm. Other specimens range in length from 0.19 mm to 0.36 mm.

Occurrence. – This species occurred in a limited number in zone G-assemblages in the Post Glacial of the Oslofjord area. A single specimen was observed in zone E of boring no. 48, Grønlandsleret in the city of Oslo.

Remarks. – Pokorný (1958, p. 193) registers *Spiroplectammina* as a synonym of *Bolivinopsis* Yakovlev, 1891, but mentions the possibility of their being two different genera. Some of the present specimens are quite narrow, approaching the form of *Morulaeplecta bulbosa* Höglund. The cement of the test of the author's specimens of *S. biformis* was insoluble in hydrochloric acid.

Christiansen (1958, p. 64) found this species in the Drøbaksund of the Oslofjord on mud bottom at depths between 30 and 149 m. It was recorded from the Swedish west coast, in the Gullmarfjord (Höglund, 1947, p. 164) most commonly between 16.5 and 22 m. In Skagerrak Höglund found it down to 242 m. Kiær (1900, p. 31) recorded *S. biformis* from the Dramsfjord, a westerly branch of the Oslofjord.

Spiroplectammina biformis is widely distributed in Arctic and Sub-Arctic waters. On the western side of the Atlantic it is very rare south of Cape Cod, on the eastern side it is recorded as far south as the British Isles. It is reported as rare in the Antarctic (Phleger 1952 b, p. 86).

Genus Morulaeplecta Höglund, 1947

Morulaeplecta bulbosa Höglund

1947. *Morulaeplecta bulbosa* Höglund, p. 165, pl. 12, fig. 2; text fig. 142.

One specimen of this species was observed in a sample from zone G of boring no. 2, profile C, Fredrikstad. Its length was 0.29 mm, breadth 0.13 mm, thickness 0.10 mm.

Remarks. – Höglund found this species regularly at depths between 20 m and 50 m in the Gullmarfjord.

Genus Textularia Defrance, 1824

Textularia bocki Höglund

Plate 3, figures 6, 7

1894. *Textularia agglutinans* d'Orbigny – Goës (not *Textularia agglutinans* d'Orbigny, 1839), p. 35, pl. 7, figs. 281–284, 294–296.
1947. *Textularia bocki* Höglund, p. 171, pl. 12, figs. 5–7; text figs. 152, 153.
1954a. *Textularia bocki* Höglund – Feyling-Hanssen, p. 126.
1958. *Textularia bocki* Höglund – Christiansen, p. 65.

Length of hypotype of figures 6 and 7, 0.64 mm, breadth 0.35 mm, thickness 0.27 mm.

Occurrence. – This species occurred, in limited number in the Post Glacial zone F of the Oslofjord area, especially in subzone F_{III} and the lower part of subzone F_{II}, e.g., Sandefjord, Fredrikstad. A single specimen occurred at the transition between zone F and zone G of boring no. 3, Glemmen Church, Fredrikstad. *T. bocki* was observed also in a sample of Isocardia clay from Årum clay pit near Sarpsborg (Feyling-Hanssen, 1954 a, p. 126).

Remarks. – *Textularia bocki* differs from *T. sagittula* in being less compressed, having higher chambers, and having sharpened edges instead of being strongly keeled. Furthermore there is a distinct difference in the initial part of the two species. In the Gullmarfjord, on the Swedish west coast, Höglund (1947, p. 172) found specimens of *T. bocki* with length up to 1.12 mm. It occurred there in greatest abundance at depths between 30 and 45 m. In the Skagerrak he found it between 29 and 305 m. Christiansen (1958, p. 65) found this species in six bottom samples from the Drøbaksund of the Oslofjord, at 150 m 24 individuals were found, in the other samples it was very sparse.

Textularia contorta Höglund

1947. *Textularia contorta* Höglund, p. 182, pl. 13, fig. 4; text fig. 158.

A single specimen of this small and twisted species occurred in zone G of boring no. 2, profile C, Fredrikstad. Its length was 0.19 mm, breadth 0.12 mm, thickness 0.09 mm.

Textularia aff. earlandi Phleger
Plate 3, figure 8

1947. *Textularia tenuissima* Earland – Höglund (not *Textularia tenuissima* Earland, 1933, not *Textularia tenuissima* Häusler, 1881), p. 176, pl. 13, fig. 1; text figs. 154, 155, 161.
1952b. *Textularia earlandi* Parker, (footnote) (not *Textularia earlandi* Phleger, 1952, b) p. 458, pl. 2, figs. 4, 5.
1954. *Textularia earlandi* Parker – Parker (not *Textularia earlandi* Phleger, 1952, b), p. 490, pl. 2, fig. 12.
1955. *Textularia* cf. *T. earlandi* Parker – Walton, p. 1015, pl. 100, fig. 5.
1958. *Textularia earlandi* Parker – Arnal (not *Textularia earlandi* Phleger, 1952, b) p. 41, pl. 9, figs. 1–3.
1958. *Textularia earlandi* Phleger – Christiansen (not *Textularia earlandi* Phleger, 1952 b), p. 65.
1959. *Textularia earlandi* Parker – Lankford (not *Textularia earlandi* Phleger, 1952, b) p. 2078, pl. 1, fig. 10.
1959. *Textularia earlandi* Parker – Boltovskoy (not *Textularia earlandi* Phleger, 1952 b), p. 42, pl. 2, figs. 8, 9.

Test small, elongate, $2\frac{1}{2}$ to 5 times as long as broad, straight, slowly tapering towards the bluntly pointed initial end, greatest breadth at the apertural end, oval in section, periphery margin rounded, lobulate, apical end with a very small spiral, the rest of the test biserially arranged; chambers 3–4 in the spiral part, up to 30, or more, in the biserial part, gradually increasing in size as added, becoming slightly inflated; sutures distinct, depressed, more or less at right angles to the long axis of the test; wall arenaceous, relatively thin, composed of a single layer of angular mineral grains, surface rough; aperture a semicircular opening at the inner margin of the last-formed chamber; colour ferruginous.

Length of the specimen of figure 8, 0.28 mm, breadth 0.09 mm, thickness 0.06 mm.

Occurrence. – This species was found only once in the Late Quaternary of the Oslofjord area, viz., one single specimen from the Post Glacial zone G in boring no. 2, profile B, Fredrikstad (O 313), at core level 11.4 m.

Remarks. – There is some doubt that the *Textularia earlandi* from the Post Glacial of Fredrikstad is identical with *Textularia earlandi* Phleger (= *Textularia tenuissima* Earland), the latter, presumably, is an Arctic form, probably with bipolar distribution. I have compared my Post Glacial specimen with several specimens of *T. earlandi* from bottom samples which I collected from shallow water (8, 8, 15, 15, 8, 20, and 10 m) in Spitsbergen and Northeast Greenland. Two of them are figured on plate 3, figures 9 and 10; length of the specimen of figure 9, 0.49 mm, breadth 0.16 mm; length of the specimen of figure 10, 0.50 mm, breadth 0.13 mm. They all agree very well with the description and figures of *Textularia tenuissima* Earland (= *T. earlandi* Phleger) given by Earland (1933, p. 95) in his paper on Foraminifera from South Georgia. They also agree completely with the figures given by Phleger (1952, b, p. 86, pl. 13, figs. 22, 23) for specimens from the Canadian and Greenland Arctic. They are relatively large, their surface is smoothly finished, and their colour is light grey, "often silvery", to cite Earland (l.c., p. 96).

They do, however, not agree in all respects with the specimen from zone G of the boring at Fredrikstad. This specimen is considerably smaller than my Recent specimens from the Arctic, its length being only 0.28 mm. Furthermore its surface is rough instead of smoothly finished, and its colour is strongly ferruginous instead of light grey.

The differences, pointed out here, are the same as those mentioned by Earland (1933, p. 96) between his South Georgian *Textularia tenuissima* Earland (= *T. earlandi* Phleger) and the Mediterranean form described by Lacroix (1932, p. 8) as *Textularia elegans* Lacroix. However, Earland (l.c., p. 97) regarded these differences as being of minor importance when compared with the numerous points of agreement, and consequently considered his South Georgian form as conspecific with the Mediterranean *T. elegans*. As, however, the specific name *elegans* appeared to be preoccupied for an entirely different *Textularia*, *Plecanium elegans* Hantken, 1868, he proposed the new name *Textularia tenuissima* Earland. On account of homonymy with *Textularia tenuissima* Häusler, 1881, Phleger in turn (1952 b, p. 86) published the new name *Textularia earlandi* for Earland's species.

In doing so, Phleger, referred to a manuscript by F.L. Parker. Later in the year of 1952 F. L. Parker (1952 b, p. 458) tentatively referred a form from Buzzards Bay and Gardiners Bay to Earland's species, and in a footnote proposed the new name *Textularia earlandi* for Earland's species. The specimens described and figured by F. L. Parker (l. c.) are, however, more like the present writer's Post Glacial form than Earland's cold-water species. This is obviously also the case with her *T. earlandi* from the northeastern Gulf of Mexico (Parker, 1954, p. 490, pl. 2, fig. 12).

The figure of a specimen from the Mississippi delta, referred to *T. earlandi* Parker (Lankford, 1959, pl. 1, fig. 10) seems to fit well the external characters of my Post Glacial form from Fredrikstad, and such is also the case with specimens from the coast of Brazil (Boltovskoy, 1959, p. 42, pl. 2, figs. 8, 9). Höglund (1947, p. 176) made an extremely detailed study of a large number of specimens which he with some hesitation referred to *T. tenuissima* Earland (= *T. earlandi* Phleger). The present author's Post Glacial specimen agrees in all respects with the descriptions, comments, and figures given by Höglund (and by Closs, 1963, p. 39).

Considering these records, I assume that we are dealing with two different species: one inhabiting warm and temperate waters, the Post Glacial specimen from zone G of Fredrikstad belongs to this, and one cold-water species which is the true *Textularia earlandi* Phleger. As Höglund (l.c., p. 178) states, a direct comparison between *Textularia tenuissima* Earland, *T. elegans* Lacroix, *T. parvula* Cushman (1922, Bull. 104, pt. 3, p. 11, pl. 6, figs. 1, 2) and the Swedish form is extremely desirable. Being equipped with only a single individual of what I think is the warm-water form I do not feel ready to undertake the final separation.

Textularia earlandi Phleger
Plate 3, figures 9, 10

1933. *Textularia tenuissima* Earland, p. 95, pl. 3, figs. 21–30.
1952b. *Textularia earlandi* Phleger, p. 86, pl. 13, figs. 22, 23.

A specimen of this species which occurred in the Pleistocene subzone A_1 in boring no. 13, Borregaard, Sarpsborg, had a length of 0.50 mm, breadth 0.19 mm, thickness 0.11 mm. A broken specimen occurred in the Holocene zone D of boring no. 18 at Bryn, Oslo. The two figured specimens are Recent ones from Spitsbergen. (Cp. remarks under *Textularia* aff. *earlandi* on page 237).

Textularia sagittula Defrance
Plate 3, figures 4, 5

1824. *Textularia sagittula* Defrance, p. 177.
1884. *Textularia sagittula* Defrance – Brady, p. 361, pl. 42, figs. 17, 18.
1894. *Textularia sagittula* Defrance var. *cuniformis* Goës, p. 36, pl. 7, figs. 288–290.
1894. *Textularia Williamsoni* Goës, p. 36, pl. 7, figs. 285–287.
1900. *Textularia agglutinans* d'Orbigny – Kiær (part. not *Textularia agglutinans* d'Orbigny, 1839), p. 10, 30.
1916a. *Spiroplecta Wrighti* Silvestri – Heron-Allen and Earland, p. 42, pl. 6, figs. 7–10.
1947. *Textularia sagittula* Defrance – Höglund, p. 167, pl. 12, figs. 3, 4; text figs. 143–146.
1954a. *Textularia sagittula* Defrance – Feyling-Hanssen, p. 126.
1958. *Textularia sagittula* Defrance – Christiansen, p. 64.
1958. *Textularia sagittula* Defrance – Van Voorthuysen, p. 5, pl. 1, fig. 2.

Length of hypotype of fig. 5, 0.96 mm, breadth 0.57 mm, thickness 0.29 mm. Length of hypotype of figure 4, 0.52 mm, breadth 0.40 mm, thickness 0.20 mm.

Occurrence. – This species seems to be rare in the Late Quaternary of the Oslofjord area. It was found only in the outer fjord region, the southernmost parts of the area, and exclusively in deposits belonging to the Post Glacial zone F. Thus one specimen occurred in the upper and one in the middle part of zone F of boring no. 22 at Valle. A few specimens occurred in the upper part of zone F in boring no. 2, profile B, as well as in the upper and middle part of boring no. 28, profile A, in Fredrikstad, and single specimens in upper and middle part of the same zone in boring no. 5 in Sandefjord. One specimen was found in a sample of

Isocardia clay (zone F) from the old Årum clay pit, close to Sarpsborg (Feyling-Hanssen, 1954 a, p. 126).

Remarks. - The microspheric form of this species is the most common among my few specimens from the Post Glacial of the outer fjord region.

Christiansen (1958, p. 64) found *T. sagittula* in the Drøbaksund of the Oslofjord at depths between 25 and 155 m, most abundant at 25 m on a place where the bottom mud was mixed with sand and gravel. It was absent in the deepest mud area of the sound. Kiær (1900, p. 10, 30) collected it close to Hankø in the outer Oslofjord (Cf. Christiansen l.c.). On the Swedish west coast Höglund (1947, p. 168) found it in the Gullmarfjord at depths between 32 and 109 m, a few specimens also in the Skagerrak. Brady (1884, p. 361) regarded *T. sagittula* as a cosmopolitan species usually occurring in shallow water of temperate seas.

Family **TROCHAMMINIDAE** Schwager, 1877
Genus Trochammina Parker and Jones, 1859
Trochammina adaperta Rhumbler

1938. *Trochammina squamata* Parker and Jones, v. *adaperta* Rhumbler, p. 184, figs. 21-26.
1947. *Trochammina adaperta* Rhumbler - Höglund, p. 204, pl. 15, fig. 1; text fig. 185.

A single specimen referable to this species occurred in zone G of boring no. 2, profile C, Fredrikstad. Its greatest diameter measured 0.22 mm, thickness 0.07 mm.

Christiansen (1958, p. 69) found this species in the Recent fauna of the Drøbaksund, Oslofjord.

Trochammina intermedia Rhumbler

1938. *Trochammina squamata* Parker and Jones, v. *intermedia* Rhumbler, p. 186, fig. 27.
1947. *Trochammina intermedia* Rhumbler - Höglund, p. 206, pl. 16, fig. 1; text fig. 188.

A few specimens which are in accordance with the descriptions given by Rhumbler and Höglund occurred. The greatest diameter of a specimen from boring no. 2, profile B, Fredrikstad, was 0.27 mm, thickness 0.11 mm.

Occurrence. - This species was rare, it occurred only in the younger parts of the Late Quaternary sequence in the Oslofjord area. Three specimens were found in zone G and one in a zone F-sample from boring no. 5 in Sandefjord and one in zone G samples from boring no. 2, profile B and C, in Fredrikstad. Single specimens occurred in zone G also of other borings of the area. A few specimens were present in zone F of boring no. 5 at Majorstuen, Oslo.

Remarks. – Rhumbler (1938) described this form from shallow water off Heligoland, and Höglund (1947) found one single specimen at a core sampler station on the Danish side of the Skagerrak, at a depth of 66 m. It was not recorded by Christiansen (1958) from the Drobaksund of the Oslofjord.

Trochammina ochracea (Williamson)

Plate 3, figures 11, 12

1858. *Rotalia ochracea* Williamson, p. 55, pl. 4, fig. 112; pl. 5, fig. 113.

1938. *Trochammina ochracea ochracea* (Williamson) – Rhumbler, p. 190 (with exhaustive synonymy).

1947. *Trochammina ochracea* (Williamson) – Höglund, p. 211, pl. 16, fig. 2; text fig. 190.

1949. *Trochammina ochracea* (Williamson) – Cushman, p. 17, pl. 3, fig. 1.

1952a. *Trochammina ochracea* (Williamson) – F. L. Parker, p. 409 (under *T. squamata* and related species), pl. 4, figs. 13, 14.

A few specimens of this small, watch-glass-shaped species occurred in the Late Quaternary of the Oslofjord area.

Greatest diameter of the hypotype of figures 11 and 12 was 0.21 mm, thickness 0.05 mm.

Occurrence. – One specimen of this species occurred in a Late Glacial deposit at Klipper bridge, Rakkestad, probably belonging to subzone B_u. Another specimen occurred at the transition between zone G and subzone F_u in a boring from Onsøy. It occurred also in zone G of boring no. 2, profile C, Fredrikstad.

Remarks. – This species differs from *T. intermedia* in being smaller, thinner, with a more acute periphery, and in having 7 or more chambers per whorl instead of 5. Höglund (1947) found one specimen in the Gullmarfjord on the Swedish west coast. On the Danish side of the Skagerrak he found it at depths varying between 66 and 305 m. F. L. Parker (1952 a) recorded it from the Portsmouth area, New Hampshire; it is also found in the Arctic.

Genus Jadammina Bartenstein and Brand, 1938
Jadammina polystoma Bartenstein and Brand
Plate 3, figures 13–15

1938. *Jadammina polystoma* Bartenstein and Brand, p. 381, text figs. 1–3.
1959. *Jadammina polystoma* Bartenstein and Brand – F. L. Parker and Athearn, p. 341, pl. 50, figs. 21, 22, 27.
1959. *Jadammina polystoma* Bartenstein and Brand – Shepard and Lankford, p. 2062 (listed).

Several specimens of this trochoid but extremely low-spired form occurred in the present material. Its tectinous wall carries a variable, usually very small, amount of agglutinated mineral grains, and is often hollow between the septae, also externally.

Greatest diameter of hypotype of figure 13, 0.46 mm, thickness 0.14 mm. Greatest diameter of hypotype of figure 14, 0.42 mm, thickness 0.13 mm. Greatest diameter of hypotype of figure 15, 0.38 mm, thickness 0.13 mm.

Occurrence. – This species occurred only in the Post Glacial zone G of the Late Quaternary sequence in the Oslofjord area, usually in the upper part of this zone, together with *Miliammina fusca*.

Remarks. – *Jadammina polystoma* seems to inhabit brackish shallow-water environment. It was described from the Jade Bay on the German North Sea coast in sea water much diluted by fresh water. Hofker (1922) described *Haplophragmoides trullisata* (Brady) from the Zuider Sea, the Netherlands, and Bartenstein and Brand referred also this form to *J. polystoma*. F. L. Parker and W. D. Athearn (1959) found *J. polystoma* in the marshes of Poponesset Bay, Massachusetts, and observed that its frequency increased with increasingly marine condition. At one station, no. 8, *J. polystoma* occurred in the inner end of a long, narrow high-water marsh in a shallow pool, isolated except at high tide and not flushed by every tide. The temperature varied between 0.2° C (Feb.) to 30° C (Aug.), and the salinity between 26.5 and 45.2 ‰, the salinity only reaching this high value at one time of sampling, its maximum otherwise being 35.8 ‰.

Shepard and Lankford (1959) found *J. polystoma* among marsh forms in the Mississippi Delta.

Family **VERNEUILINIDAE** Cushman, 1927
Subfamily **Verneuilininae** Cushman, 1911
Genus Verneuilina d'Orbigny, 1840
Verneuilina media Höglund
Plate 4, figures 1–3

1894. *Verneuilina polystropha* (Reuss) – Goës (part.), p. 32 (not *Bulimina polystropha* Reuss, 1846).
1947. *Verneuilina media* Höglund, p. 184, pl. 13, figs. 7–10; pl. 30, fig. 21.

Length of hypotype of figure 1, 0.43 mm, breadth 0.25 mm. Length of hypotype of figure 2, 0.33 mm, breadth 0.21 mm. Length of hypotype of figure 3, 0.43 mm, breadth 0.22 mm.

Occurrence. – This small species was found only in Post Glacial deposits of the Oslofjord area, primarily in zone G but also in upper part of zone F. It is one of the characteristic species of the zone G – assemblage in the southern as well as in the northern part of the Oslofjord area.

Remarks. – This species has some resemblance with small specimens of *Eggerella scabra* (Williamson). It differs from *E. scabra* in being smaller, being triserial throughout, in having only slightly inflated chambers, a rough exterior and indistinct sutures. The cement of the test is insoluble in hydrochloric acid.

Christiansen (1958, p. 66) found *V. media*, living and dead specimens, in the Drøbaksund of the Oslofjord, at depths between 10–20 m and 211 m. Höglund (1947) found it to be very frequent in the Skagerrak between 150 m and 250 m. In the Gullmarfjord it occurred in greatest frequency between 34 and 67 m. Höglund did not observe it at stations with depths less than 22 m.

Subfamily **Valvulininae** Berthelin, 1880
Genus Valvulina d'Orbigny, 1826
Valvulina fusca (Williamson)

1858. *Rotalina fusca* Williamson, p. 55, pl. 5, figs. 114, 115.
1884. *Valvulina fusca* (Williamson) – Brady, p. 392, pl. 49, figs. 13, 14.
1947. *Valvulina fusca* (Williamson) – Höglund, p. 190, pl. 14, fig. 2; text figs. 173–176.
1954a. *Valvulina fusca* (Williamson) – Feyling-Hanssen, p. 127.

This species was recorded by Feyling-Hanssen (1954 a) from a sample of *Scrobicularia* clay (zone G) from the city of Oslo.

Genus Eggerella Cushman, 1933

Eggerella scabra (Williamson)

Plate 4, figures 4–6

1858. *Bulimina scabra* Williamson, p. 65, pl. 5, figs. 136, 137 (*B. arenacea* on explanation of plate).
1865. *Verneuilina polystropha* (Reuss) – M. Sars, p. 91.
1894. *Verneuilina polystropha* (Reuss) – Goës (part.) (not *Bulimina polystropha* Reuss), p. 32, pl. 7, figs. 247–255.
1900. *Verneuilina polystropha* (Reuss) – Kiær (not *Bulimina polystropha* Reuss), p. 5–8, 10, 11, 32.
1922. *Verneuilina scabra* (Williamson) – Cushman, Bull. 104, pt. 3, p. 55.
1936. *Verneuilina scabra* (Williamson) – Rhumbler, p. 236, figs. 234–246.
1937b. *Eggerella scabra* (Williamson) – Cushman, p. 50, pl. 5, figs. 10, 11.
1947. *Eggerella scabra* (Williamson) – Höglund, p. 191, pl. 13, figs. 12–14; text figs. 162–165.
1949. *Eggerella scabra* (Williamson) – Cushman, p. 7, pl. 1, figs. 6.
1954a. *Eggerella scabra* (Williamson) – Feyling-Hanssen, p. 126.
1958. *Eggerella scabra* (Williamson) – Christiansen, p. 68.

Length of hypotype of figure 4, 0.76 mm, breadth 0.30 mm. Length of hypotype of figure 5, 0.64 mm, breadth 0.32 mm. Length of hypotype of figure 6, 0.65 mm, breadth 0.29 mm. Unfigured specimens from boring no. 2 and no. 4 in Bjørvika, Oslo, varied in length from 0.35 mm to 0.82 mm.

Occurrence. – This species is usually dominant in samples from zone G of the Oslofjord area, most of such samples containing hundred of specimens. It occurs accidentally in deposits belonging to the Post Glacial zones F and E.

Remarks. – Kiær (1900, p. 6, 7) recorded Recent specimens of this species in the Drøbaksund of the Oslofjord at depths between 10 and 20 m. Christiansen (1958, p. 68) found it to be common in the Drøbaksund at depths between 10 m and 70 m. The present author caught it there between 70 and 80 m. Höglund (1947, p. 192) found *E. scabra* to be one of the most abundant species in the Gullmarfjord, on the Swedish west coast, thousands of specimens occurring in each core sample between 15 and 20 m. It was seldom met with there in water deeper than 60 m. At many of the shallowest stations, less than 20 m, it numerically dominated the foraminiferal fauna. In the Skagerrak Höglund found it down to 204 m. That author (1947, p. 193) made the following observation about the wall structure of *E. scabra*: "The wall structure varies quite considerably according to the depth of the localities. At the very shallowest stations the test is quite fine and smooth, and the arrangement of chambers very regular, but the deeper one goes, the coarser and less regular the test, which results in this species, at a hasty glance, being readily confused with *Verneuilina media*".

M. Sars (1865, p. 91) found this species in Post Glacial deposits at Ørlandet and at Steinkjer in the Trondheimsfjord area, and recorded it as living along the south and west coast of Norway as far north as Lofoten. Nordgaard (1913, p. 4) recorded *V. polystropha* from the Hardangerfjord on the Norwegian west coast. Terquem and Terquem (1886, p. 337) recorded *Bulimina scabra* from Iceland, but Nørvang (1945, p. 5) stated that the distribution of *Verneuilina scabra* is: "Around the British Isles, in the Gulf of St. Lawrence and off the coast of New England". Cushman (1949, p. 8) found *E. scabra* to be rare among Recent Belgian Foraminifera. Its main habitat seems to be shallow waters of Boreal and Lusitanian regions.

The cement of the test of *E. scabra* is insoluble in acid.

Eggerella advena Cushman seems to be very closely related to *E. scabra*.

Genus Liebusella Cushman, 1933

Liebusella goësi Höglund

Plate 4, figure 7

1894. *Bigenerina digitata* d'Orbigny – Goës (not *Bigenerina digitata* d'Orbigny, 1826), p. 38, pl. 7, figs. 324–343.

1947. *Liebusella goësi* Höglund, p. 194, pl. 14, figs. 4–8; text figs. 177–179.

1958. *Liebusella goësi* Höglund – Christiansen, p. 68.

Very few specimens of this large form occurred in the present material.

Length of hypotype of figure 7, 1.38 mm, breadth 0.41 mm. Unfigured specimens from the same boring, boring no. 2, Lodalen, Oslo, at core level 13.2 m, measured: Length 1.46 mm, breadth 0.40 mm; length 1.35 mm, breadth 0.38 mm; length 1.19 mm, breadth 0.43 mm. A specimen from boring no. 48, core level 16.2 m, Grønlandsleret, Oslo, had a length of 1.51 mm, breadth 0.40 mm.

Occurrence. – This species seems to be rare in the Late Quaternary of the Oslofjord area, it occurred only in Post Glacial deposits, viz., in zone E and F in two borings in Oslo, being somewhat more frequent in E than in F, and in subzone F_u of a boring in Fredrikstad.

Remarks. – Christiansen (1958) found *L. goësi* to be common in the

Recent Foraminifera fauna in the Drøbaksund of the Oslofjord, at depths between 15 and 211 m, on almost every kind of bottom. He found it in greatest abundance between 80 and 100 m. Höglund found it to be common in the Gullmarfjord below 30 m. Nørvang (1942, p. 8) recorded *Bigenerina cylindrica* Cushman from off Bergen on the Norwegian west coast, a form which Höglund considered to be identical with *L. goësi*.

Superfamily MILIOLOIDEA Ehrenberg, 1839
Family **NUBECULARIIDAE** Jones, 1875
Subfamily **Cyclogyrinae** Loeblich and Tappan, 1961 b
Genus Cyclogyra Wood, 1842
Cyclogyra foliacea (Philippi)
Plate 4, figure 8

1844. *Orbis foliaceus* Philippi, p. 147, pl. 24, fig. 26.
1862. *Cornuspira foliacea* (Philippi) – Carpenter, Parker, and Jones, p. 68, pl. 5, fig. 16.
1865. *Cornuspira foliacea* (Philippi) – Parker and Jones, p. 408, pl. 15, fig. 33.
1894. *Cornuspira foliacea* (Philippi) – Goës, p. 106, pl. 18, fig. 834.
1929. *Cornuspira foliacea* (Philippi) – Cushman, p. 79, pl. 20, figs. 3–5.
1931. *Cornuspiroides foliaceus* (Philippi) – Wiesner, p. 61.
1943. *Cornuspiroides foliaceum* (Philippi) – Hessland, p. 347, pl. 1, fig. 12.
1945. *Cornuspira foliacea* (Philippi) – Nørvang, p. 14.
1948. *Cornuspira foliacea* (Philippi) – Cushman, p. 40, pl. 4, figs. 9, 10.
1960. *Cornuspiroides foliaceus* (Philippi) – Barker, p. 22, pl. 11, figs. 5, 6.

Greatest diameter of hypotype of figure 8, 0.51 mm. Greatest diameter of unfigured specimen from boring no. 5 at Sandefjord, 0.54 mm.

Occurrence. – This species seems to be very rare in the Late Quaternary of the Oslofjord area. One specimen was found in the lowest part of zone F in Sandefjord, another specimen occurred in the lower part of zone F of boring 1 (C 63) at Årungen, and one in zone F in the city of Oslo. Three specimens occurred in E. B. Münster's collection from the Post Glacial of Bislet, Oslo.

Remarks. – The specimens from the Post Glacial at Sandefjord and Oslo are small. Cushman (1948, p. 40) stated that this species reaches its finest development in the cold water of the Arctic, since he found specimens there with a length of 10.00 mm, or more. He found that the Arctic specimens have very heavy chalky white tests. Norgaard (1913, p. 5) and Nørvang (1942, p. 10) recorded *C. foliacea* from the Recent Foraminifera fauna of the Norwegian west coast, and Kiær (1908, 1909) from the north coast, Finnes north of Tromsø, and from Arctic Canada.

Cyclogyra involvens (Reuss)

Plate 4, figure 9

1850. *Operculina involvens* Reuss, p. 370, pl. 46, fig. 30.
1863b. *Cornuspira involvens* (Reuss) – Reuss, p. 39, pl. 1, fig. 2.
1884. *Cornuspira involvens* (Reuss) – Brady, p. 200, pl. 11, figs. 1–3.
1929. *Cornuspira involvens* (Reuss) – Cushman, p. 80, pl. 20, figs. 6, 8.
1953. *Cornuspira involvens* (Reuss) – Loeblich and Tappan, p. 49, pl. 7, figs. 4, 5.

The test of this species is nearly circular in side view. The chambers consist of a globular proloculus and a long undivided tubular second chamber increasing only slowly in width during growth.

Greatest diameter of the hypotype of figure 9, 0.30 mm. Greatest diameter of unfigured specimen from Valle, Sarpsborg, 0.32 mm; the specimen was broken.

Occurrence. – This species seems to be very rare in the Late Quaternary of the Oslofjord area. One specimen was found in a sample from core level 12.7 m of boring no. 22 at Valle. The sample belongs to the Post Glacial zone F. Another one in zone F of boring no. 2, profile C, Fredrikstad, and one in zone F of a boring at Fornebo. There was one specimen also in zone F of boring no. 31, Akerselva, Oslo, and one in zone F at Skøyen, Oslo. A fragment of a test, probably belonging to this species, occurred at core level 7.2 m in boring no. 1, Valle, this sample belonging to the Late Glacial zone A. Another specimen was found in the middle part of zone A at Onsøy, Østfold, core level 18.0 m.

Remarks. – Cushman (1929, p. 81) stated that this species occurs in very shallow warm water of tropical coral-reef environment, but that similar forms are found also in deeper cooler waters. Nørvang (1945, p. 74) recorded *C. involvens* from West Greenland and from the Norwegian west coast. And Loeblich and Tappan (1953, p. 49) found it at 24 stations from Alaska, Baffin Land, Frobisher Bay, Northwest-, North-, and Northeast Greenland, in depths varying between 13 m and 223 m. Only at three of these stations was it taken at depths greater than 100 m. The greatest diameter of the specimens treated by Loeblich and Tappan ranged from 0.21 to 2.05 mm.

Subfamily **Ophthalmidiinae** Cushman, 1927
Genus Hauerinella Schubert, 1920
Hauerinella inconstans (Brady)
Plate 4, figure 10

1879. *Hauerina inconstans* Brady, p. 268.
1884. *Ophthalmidium inconstans* (Brady) – Brady, p. 189, pl. 12, figs. 5, 7, 8.
1899. *Ophthalmidium inconstans* Brady – Flint, p. 302, pl. 47, fig. 3.
1917. *Ophthalmidium inconstans* Brady – Cushman, p. 28, pl. 3, figs. 1–4.
1920. *Hauerinella inconstans* (Brady) – Schubert, p. 162.
1929. *Ophthalmidium inconstans* (Brady) – Cushman, p. 89, pl. 21, figs. 8–11.
1946. *Hauerinella inconstans* (Brady) – Wood and Barnard, p. 85.
1954a. *Ophthalmidium inconstans* (H. B. Brady) – Feyling-Hanssen, p. 128, pl. 1, fig. 7.
1960. *Hauerinella inconstans* (Brady) – Barker, p. 24, pl. 12, figs. 5, 7, 8.

Greatest diameter of hypotype of figure 10, 0.27 mm.

Occurrence. – This species is quite rare in the Late Quaternary of the Oslofjord area. It was found in Holocene strata only, viz., in zone D in the city of Oslo and Drammen, in zone E and F in Oslo and Drammen, zone F in Sandefjord and at Valle.

Remarks. – Cushman (1929) regarded *H. inconstans* as being distributed on both sides of the Atlantic Ocean, about the British Isles and off the coast of the United States, usually in fairly deep water. Brady (1884) recorded it also from the North Pacific. Nørvang (1945) recorded it from Norway, south of Lofoten, and Flint (1899) also obtained it from the Gulf of Mexico. Its main distribution seems to be Boreal – Lusitanian.

The specimens from the Late Quaternary deposits of the Oslofjord area are small for the species. Cushman (l.c.) recorded specimens with diameters up to 1.50 mm.

Family **MILIOLIDAE** Ehrenberg, 1839
Genus Quinqueloculina d'Orbigny, 1826
Quinqueloculina agglutinata Cushman
Plate 4, figure 11

1917. *Quinqueloculina agglutinata* Cushman, p. 43, pl. 9, fig. 2.
1948. *Quinqueloculina agglutinata* Cushman – Cushman, p. 33, pl. 3, fig. 13.
1953. *Quinqueloculina agglutinata* Cushman – Loeblich and Tappan, p. 39, pl. 5, figs. 1–4.
?1957. *Quinqueloculina agglutinata* Cushman – van Voorthuysen, p. 37, pl. 26, fig. 45.

Few specimens of this large and robust form were represented in the present material.

Length of hypotype of figure 11, 1.22 mm, breadth 0.84 mm, thickness 0.57 mm. A specimen from a Late Glacial terrace, 88 m a.s.l. at Birtavarre, Troms in northern Norway, had a length of 1.03 mm.

Occurrence. – This species occurred in Pleistocene as well as Holocene sediments, it was found in the middle part of zone A, of boring no. 27 at Valle, Sarpsborg, in zone D in the city of Drammen, and also in the lower part of the Post Glacial zone F at Årungen (C 63).

Remarks. – Cushman (1917, l.c.) described this species from off North Alaska in the North Pacific. Loeblich and Tappan (l.c.) recorded it from 26 stations in the Barrow area, northern Alaska, and from the Greenland and Canadian Arctic areas at depths varying from 22 m to 149 m. The present author collected this species at a depth of 8 m in the Wijdefjord at Spitsbergen. Cushman (1948, l.c.) assumed that this species is one of the most common arenaceous miliolid species in the Arctic.

Boltovskoy (1957, p. 24, pl. 4, figs. 1–4, and 1959, p. 47, pl. 3, fig. 12) recorded *Quinqueloculina* cf. *agglutinata* Cushman from the estuary of Rio de la Plata and from the Brazilian shelf. These forms seem to be broader than the ordinary *Q. agglutinata,* they are less angular and their colour is grey; maximum length is 0.8 mm. Van Voorthuysen (l.c.) recorded *Q. agglutinata* from Riss – Würm Inter-glacial deposits at Amersfoort, Netherlands. Specimens from the Upper Miocene of Kruisschans, Belgium, which were referred to *Q. agglutinata* (Voorthuysen, 1958, p. 7, pl. 1, fig. 10) are probably not conspecific with this species. The figured specimen shows a very roughly finished wall, resembling that of *Q. agglutinans* d'Orbigny, 1839.

Quinqueloculina arctica Cushman

1933. *Quinqueloculina arctica* Cushman, p. 2, pl. 1, fig. 3.
1948. *Quinqueloculina arctica* Cushman – Cushman, p. 35, pl. 4, fig. 2.
1952a. *Quinqueloculina arctica* Cushman – F. L. Parker, p. 405, pl. 3, fig. 19.
1953. *Quinqueloculina arctica* Cushman – Loeblich and Tappan, p. 40, pl. 5, figs. 11, 12.

Length of a specimen from boring no. 5, Sandefjord, core level 22.8 m, 0.51 mm, breadth 0.35 mm, thickness 0.30 mm. A specimen from boring no. 1, Rakkestad, core level 9.0 m, measured: length 0.46 mm, breadth 0.30 mm, thickness 0.19 mm.

Occurrence. – This species was very rare in the Late Quaternary of the Oslofjord area. Two specimens were found in zone E of boring no. 5 in Sandefjord, and one in subzone B_{II} of boring no. 1 in Rakkestad.

Remarks. – This species differs from *Quinqueloculina seminulum* in having distinctly angled margins and concave, or excavated, sides.

Cushman (1933, 1948) recorded *Q. arctica* from Northeast Greenland at depths from 14 m to 130 m. Loeblich and Tappan (1953) found it off Point Barrow, Alaska, at depths between 21 and 126 m. They found it in samples from North Greenland ranging from 13 to 122 m in depths. F. L. Parker (1952 a) recorded it from the Portsmouth area at Cape Cod on the North American east coast.

Quinqueloculina bicornis (Walker and Jacob)
Plate 5, figures 1, 2.

1798. *Serpula bicornis* Walker and Jacob, p. 633, pl. 14, fig. 2.
1858. *Miliolina bicornis* (Walker and Jacob) – Williamson, p. 87, pl. 7, figs. 190–194.
1884. *Miliolina bicornis* (Walker and Jacob) – Brady, p. 171, pl. 6, fig. 9.
1895a. *Miliolina bicornis* (Walker and Jacob) – Madsen, p. 180, pl. 1, fig. 1.
1929. *Quinqueloculina bicornis* (Walker and Jacob) – Cushman (Bull. 104), p. 32, pl. 5, figs. 5–7; pl. 6, figs. 1, 2.
1943. *Quinqueloculina bicornis* (Walker and Jacob) – Hessland, p. 242, pl. 1, fig. 10.

A few specimens of this large and broad species occurred in Münster's collection from a Lower Tapes bed at Smedholmen by Brevik, probably of Sub-Boreal age, zone F.

The figured specimen had a length of 1.40 mm, breadth 1.16 mm, thickness 0.67 mm.

Remarks. – Kiær (1900, p. 28) did not include this species among the Recent Foraminifera of Norway, but Nørvang (1945, p. 73) listed it as occurring in Norway south of Lofoten. According to Cushman (l.c.) it is common about the British Isles, off the European coast and in the Mediterranean.

Brøgger (1900–1901, p. 520) listed it from Münster's manuscript as *Quinqueloculina lyra* d'Orbigny. Madsen (l.c.) found it in Danish Quaternary deposits with temperate fauna, and Bagg (1912, p. 27) recorded it from the Pleistocene of Santa Barbara, though he figured *Quinqueloculina intricata* Terquem together with it (his plate 3, figs. 4, 5).

Quinqueloculina horrida Cushman

1947. *Quinqueloculina horrida* Cushman, p. 88, pl. 19, fig. 1.
1954a. *Quinqueloculina* aff. *horrida* Cushman – Boltovskoy, p. 126, pl. 2, fig. 4.
1959. *Quinqueloculina horrida* Cushman – Boltovskoy, p. 48, pl. 4, fig. 6.

A specimen referable to this species occurred in subzone B_u, the deepest part of boring F 1 at Fornebo, near Oslo. Its length was 0.35 mm, breadth 0.22 mm, thickness 0.14 mm.

It resembles *Quinqueloculina* sp. Asano (1956, pt. 2, p. 65, pl. 8, fig. 13) from Japanese waters.

Quinqueloculina lata Terquem

Plate 4, figure 12

1876. *Quinqueloculina lata* Terquem, p. 82, pl. 11, fig. 8.
1944. *Quinqueloculina lata* Terquem – Cushman, p. 14, pl. 2, fig. 16.
1949. *Quinqueloculina lata* Terquem – Cushman, p. 10, pl. 2, fig. 1.
1961. *Quinqueloculina lata* Terquem – Todd and Low, p. 15, pl. 1, figs. 10–13, 15.

The length of the specimen of figure 12 was 0.43 mm, breadth 0.26 mm, thickness 0.15 mm.

Occurrence. – A few specimens of this translucent shallow-water species were observed in samples from zone G in the southern as well as in the northern part of the Oslofjord area. It also occurred in subzone F_u of boring no. 2, profile C, Fredrikstad.

Quinqueloculina pulchella d'Orbigny

Plate 5, figs. 3–6

1826. *Quinqueloculina pulchella* d'Orbigny, p. 303, no. 42.
1884. *Miliolina pulchella* (d'Orbigny) – Brady, p. 174, pl. 6, figs. 13, 14.
1929. *Quinqueloculina pulchella* d'Orbigny – Cushman, Bull. 104, pt. 6, p. 34, pl. 6, fig. 7 (with extensive synonymy).

Length of hypotype of figures 3–5, 1.65 mm, breadth 1.08 mm, thickness 0.70 mm. Length of hypotype of figure 6, 1.67 mm, breadth 1.00 mm, thickness 0.67 mm.

Occurrence. – A few specimens of this species occurred in Münster's collection of Foraminifera from Post Glacial Warm interval terraces near

Brevik (p. 30 of the present paper). The specimen of figures 3–5 is from an Upper Tapes bed at Lunde. It was referred to *Q. ferussacii* d'Orbigny (Cp. Brøgger, 1900–1901, p. 436, there by misprint called *Q. Terusacii*). The specimen of figure 6 is from a Lower Tapes bed at Trosvik (by Münster, ms., and Brøgger, p. 520, listed as *Q. lyra*.) A "*Q. ferussacii*" from Smedholmen (p. 31) is also this species. *Q. pulchella* was not observed in clay samples from the borings.

Remarks. – This species is not recorded in the Recent Norwegian fauna of Foraminifera. Terquem and Terquem (1886, p. 338) recorded it from Reykjavik, West Iceland, but Nørvang (1945, p. 10) considered its main Recent distribution to be the Boreal and Lusitanian parts of the Atlantic.

Quinqueloculina seminulum (Linné)

Plate 6, figure 1

1767. *Serpula Seminulum* Linné, p. 1264.
1826. *Quinqueloculina seminulum* (Linné) – d'Orbigny, p. 303.
1858. *Miliolina seminulum* (Linné) – Williamson, p. 85, figs. 183–185.
1917. *Quinqueloculina seminulum* (Linnaeus) – Cushman, Bull. 71, pt. 6, p. 44, pl. 11 ,fig. 2.
1929. *Quinqueloculina seminulum* (Linnaeus) – Cushman, Bull. 104, pt. 6, p. 24, pl. 2, figs. 1, 2.
1954a. *Quinqueloculina seminulum* (Linnaeus) – Boltovskoy, p. 120, pl. 1, figs. 1–3.

Length of hypotype of figure 1, 1.11 mm, breadth 0.73 mm, thickness 0.54 mm. Specimens collected by Münster in Upper Tapes beds at Lunde by Brevik measured up to 1.84 mm in length.

Occurrence. – This species seems to be distributed throughout the marine Late Quaternary sequence of the Oslofjord area. In zone G, it has, however, only been found once, viz. one specimen at 6.3 m depth in boring no. 4 (O 301 – 1 – 26) in Fredrikstad. It is, on the whole, usually represented only by a few specimens. It seems to be most frequent in the Late Glacial zone C and in the Post Glacial zone E, at a maximum accounting for 5–10 per cent of the fauna. It was quite common also in the lower part of subzone F_1. In Münster's collection from Tapes beds at Brevik, near Skien, this species was very frequent. The Tapes beds are shallow-water equivalents to clay sediments of zone F.

Remarks. – The Recent distribution of this species is very wide, it has been recorded from the northern as well as from the southern hemisphere, from the Pacific as well as from the Atlantic Ocean (Parker and Jones, 1865). The typical form seems to be most frequent in cool waters, it is abundant in fairly shallow waters of the northeastern coast of America and of the European coasts (Cushman, 1929, p. 25; 1949, p. 8). Goës (1894, p. 108) recorded it from the Greenland waters, other Arctic records were given by Nørvang (1945) and Cushman (1948). Heron-Allen and Earland (1932a, p. 313) recorded it from 24 stations from the ice-free area of the Falkland Islands (Malvin Islands) and adjacent seas, only three of these dredgings were from depths greater than 200 m. Parr (1950, p. 289) found it in the Kerguelen area, Macquaria Island and Tasmania. He Found it to be commonest in shallow water dredgings around Kerguelen. On the continental shelf from the Gulf of Maine to Maryland, North America, F. L. Parker (1948) found that *Q. seminulum* accounted for 20–50 per cent of the foraminiferal fauna in the depth zone 15–90 m with temperature ranging from 3°–16° C and a mean salinity of 33 ‰. Between the Connecticut River and Gardiners Bay, she found (Parker, 1952 b) *Q. seminulum* to be most frequent within the temperature zone 3°–15° C with a salinity of 32–33 ‰. In the Atlantic as well as in the Pacific *Q. seminulum* has been met with at depths down to approximately 6000 m (Brady, 1884, p. 160; Cushman, 1917, Bull. 71, pt. 6, p. 45). It was recorded as living all along the Norwegian coast (Parker and Jones, 1857; M. Sars, 1865; Kiær, 1900, 1908; Nordgaard, 1913; Nørvang, 1942).

In good accordance with its very wide Recent distribution M. Sars (1865) recorded it from Late Glacial as well as Post Glacial deposits of the Oslofjord area, Madsen (1895 a) found it in Pleistocene as well as Holocene strata in Denmark, and Hessland (1943) recorded a similar distribution for it in Southwest Sweden.

Quinqueloculina stalkeri Loeblich and Tappan
Plate 4, figures 13–18

1953. *Quinqueloculina stalkeri* Loeblich and Tappan, p. 40, pl. 5, figs. 5–9.
1954a. *Quinqueloculina stalkeri* Loeblich and Tappan – Feyling-Hanssen, p. 127, pl. 1, fig. 2.

Length of hypotype of figure 13, 0.27 mm, breadth 0.14 mm, thickness 0.11 mm. Length of hypotype of figure 14, 0.28 mm, breadth 0.16 mm, thickness 0.12 mm. Length of hypotype of figure 15, 0.29 mm, breadth 0.16 mm, thickness 0.11 mm. Length of hypotype of figure 16, 0.27 mm, breadth 0.16 mm, thickness 0.12 mm. Unfigured specimens from the same sample range from 0.22 to 0.28 mm in length. This sample was taken from subzone B_1 in the Late Glacial part of boring no. 22, Valle, by Sarpsborg, at a depth of 19 m. Two specimens from a sample in the Post Glacial part of the boring (zone F, core level 15.2 m) had lengths of 0.22 and 0.27 mm. For the purpose of comparison, two Recent specimens from Trygghamna in Isfjorden, Spitsbergen, is figured; the length of the specimen of figure 17 is 0.40 mm and of figure 18, 0.36 mm. The author has a specimen from Mackenziebugten, Northeast Greenland, which has a length of 0.52 mm. Specimens from northern Alaska and Greenland, studied by Loeblich and Tappan (1953), ranged from 0.26 to 0.57 mm in length.

Occurrence. – *Q. stalkeri* occurs mainly in the Late Glacial parts of the Late Quaternary deposits of the Oslofjord area, in the Pleistocene as well as in the Holocene. In the southern part of the area it is usually common in zone B. In the northern part, around the city of Oslo, it is especially common in the very youngest zone of the Late Glacial, zone D. In most borings it is present also in zone E, the oldest part of the Post Glacial sequence, and scattered specimens may occur in zone F. A few specimens, only, have been found in zone A.

Remarks. – This species was referred to *Quinqueloculina fusca* Brady by Cushman (1948), it differs from this in having a calcareous wall with agglutinated material, not a siliceous one. It resembles *Q. nitida* Nørvang (1945), which was renamed *Q. norvangi* Boltovskoy (1954 a, p. 126), but differs in possessing an apertural tooth and a prominent lip around the aperture.

Q. stalkeri is mainly an Arctic species. In the Barrow area, Alaska, it was found only in depths of less than 50 m. In 1950 the writer found it in bottom samples from Spitsbergen: van Keulenfjorden, at a depth of 8 m, Fridtjofhamna, 15 m and 18 m, Adolfbukta, 15 m. In 1951 the author found it in two bottom samples from Northeast Greenland: Mackenziebugten (Myggbukta), at a depth of 10 m, and Kapp Stosch, Claveringfjorden, 28 m. This latter station was previously visited by Captain Bartlett's expedition in 1931, where they obtained *Q. stalkeri* from a depth of 12.8 m.

Genus Massilina Schlumberger, 1893

Massilina secans d'Orbigny

Plate 6, figures 2, 3

1826. *Quinqueloculina secans* d'Orbigny, p. 303, No. 43, Modèles, No. 96.
1893. *Massilina secans* (d'Orbigny) – Schlumberger, p. 218, pl. 4, figs. 82, 83; text figs. 31–33.
1894. *Miliolina secans* (d'Orbigny) – Goës, p. 112, pl. 20, figs. 856–856 g.
1900. *Quinqueloculina secans* d'Orbigny – Kiær, p. 28.
1945. *Massilina secans* (d'Orbigny) – Nörvang, p. 74.

Length of hypotype of figures 2 and 3, 0.40 mm, breadth 0.27 mm, thickness 0.11 mm.

Occurrence. – One specimen was found in the upper part of zone F in a boring from Tohellinga, Nesset, 21 km due south of the city of Oslo, another in subzone F_u of boring no. 2 ((O 700–1) at Fornebo near Oslo, and a third one in subzone F_u of boring no. 1 (F 226) at Skøyen, Oslo.

Remarks. – Münster (in Brøgger, 1900–1901, p. 436 and 520) found this species in two samples from the Post Glacial Warm Interval, Upper and Lower Tapes beds, at Brevik, southwest of the Oslofjord. Its Recent distribution is quite wide; it has been recorded off the coasts of western Europe and in the Mediterranean (Cushman, 1929). Along the Norwegian coasts it has been found to the south of Lofoten (Kiær, 1900; Nørvang, 1945). It is probably restricted to Boreal and Lusitanian waters.

Genus Spiroloculina d'Orbigny, 1826

Spiroloculina norvegica Cushman and Todd

Plate 8, figures 1, 2

1858. *Spiroloculina depressa* d'Orbigny, var. *rotundata* Williamson, p. 82, pl. 7, fig. 178.
1944. *Spiroloculina norvegica* Cushman and Todd, p. 43, pl. 6, figs. 19, 27.

The figured specimen had a length of 1.22 mm, breadth 0.97 mm, thickness 0.32 mm.

Occurrence. – A few specimens of this species occurred in Münster's collection from Tapes beds near Brevik, west of the outer part of the Oslofjord (recorded as *S. planulata* in Brøgger, 1900–1901, p. 436). They were partly from Upper Tapes beds at Isdammen, partly from Lower Tapes beds at Smedholmen and Trosvik, and had lengths from 0.73 mm to 1.22 mm. The Tapes beds were formed during the Post Glacial Warm Interval.

Genus Scutuloris Loeblich and Tappan, 1953
Scutuloris cf. **tegminis** Loeblich and Tappan
Plate 6, figure 4

1953. *Scutuloris tegminis* Loeblich and Tappan, p. 41, pl. 5, fig. 10.

The test of the present specimens is ovate in outline with rounded periphery; chambers in a quinqueloculine arrangement, somewhat inflated; sutures distinct, depressed; wall calcareous imperforate, white porcellaneous in appearance, smooth but with faint transverse wrinkles; aperture at the end of the last-formed chamber, semicircular, with a broad flap.

Length of specimen of figure 4, 0.32 mm, breadth 0.22 mm, thickness 0.16 mm. Unfigured specimens had lengths from 0.24 mm to 0.38 mm.

Occurrence. – Two specimens occurred in the lowest part of the Late Glacial zone A in boring no. 27 at Valle, 7.5 m below the surface. Three specimens occurred in the lowest part of the Post Glacial zone E, in boring no. 1 at Sandefjord and one in zone B of boring no. 5 there. The species was also present in zone D, 16.7 m below the surface, of boring F 1 at Fornebo.

Remarks. – The species here described seems to differ from *Scutuloris tegminis* Loeblich and Tappan (1953, p. 41, pl. 5, fig. 10) in size. The holotype of the latter has a length of 0.75 mm, paratypes range from 0.31 mm to 0.60 mm in length. The present specimens are small, varying from 0.38 to 0.24 mm in length. Furthermore the sutures of the present species are distinctly depressed whereas *S. tegminis* has slightly depressed sutures. The present species has very faint transverse wrinkles on the surface; in the description of *S. tegminis* such wrinkles are not mentioned, they seem, however, to be present on the figure of the holotype.

As a quinqueloculine form with a broad apertural flap, the present species should be referred to the genus *Scutuloris*.

Genus Pateoris Loeblich and Tappan, 1953

Pateoris hauerinoides (Rhumbler)

Plate 6, figure 5

1858. *Miliolina seminulum* (Linné) var. *disciformis* (Macgillivray) – Williamson (not *Vermiculum disciforme* Macgillivray, 1853), p. 86, pl. 7, figs. 188, 189.

1865. *Miliola* (*Quinqueloculina*) *subrotunda* (Montagu) – Parker and Jones (not *Vermiculum subrotundum* Montagu, 1803), p. 411, pl. 15, fig. 38 (erroneously numbered 28 on the plate).

1936. *Quinqueloculina subrotunda* (Montagu) forma *hauerinoides* Rhumbler, pp. 206, 217, 226, text figs. 167 (p. 205), 208–212 (p. 225).

1948. *Quinqueloculina subrotunda* (Montagu)? – Cushman (not *Vermiculum subrotundum* Montagu, 1803), p. 35, pl. 3, figs. 20, 21, pl. 4, fig. 1.

1952a. *Quinqueloculina subrotunda* (Montagu) – Parker, p. 406, pl. 4, fig. 4.

1953. *Pateoris hauerinoides* (Rhumbler) – Loeblich and Tappan, p. 42, pl. 6, figs. 8–12; text figs. 1 A, B (p. 44).

Greatest diameter of hypotype of figure 5, 0.41 mm, thickness 0.18 mm. Unfigured specimen from Sandefjord (boring no. 5, zone A) had a greatest diameter of 0.43 mm, thickness 0.22 mm, and one from boring no. 27 at Valle had a greatest diameter of 0.36 mm, thickness 0.19 mm.

Occurrence. – This species seems to be rare in Late Quaternary deposits of the Oslofjord area. It occurred in the Late Pleistocene zone A in Sandefjord and at Valle. In boring 5, Sandefjord, it also occurred in the Late Glacial subzone B_1 at a depth of 26.4 m. At boring no. 86 at Onsøy, 8 km northwest of Fredrikstad, one specimen was found 17 m below the surface and one 18 m below the surface, both in zone A. It occurred also in a zone D sample from Skådalen, Oslo.

In a boring through Late Glacial deposits in the harbour of the city of Bodø (O 583, boring no. 5), northern Norway, *Pateoris hauerinoides* occurred in 4 samples, 1 specimen in each.

Remarks. – As pointed out by Loeblich and Tappan (l. c., p. 43), this species has been often confused with *Miliolinella subrotunda* (Montagu). *P. hauerinoides* differs from *M. subrotunda* in having a completely open aperture, and in being quinqueloculine, becoming hauerine in later stages, whereas *M. subrotunda* is triloculine.

Rhumbler (l.c.) described *P. hauerinoides* from the Kieler Bucht, northern Germany, and Williamson (l. c.) found it on the coasts of Great Britain. Otherwise it is distributed throughout the Arctic regions from Alaska to Greenland (Loeblich and Tappan l. c., p. 44). The present author found it, 1950, at Sarsbukta and Wijdefjorden in Spitsbergen, at depths of 7 and 8 m respectively.

Genus Triloculina d'Orbigny, 1826

Triloculina oblonga (Montagu)

Plate 6, figures 9, 10

1803. *Vermiculum oblongum* Montagu, pt. 2, p. 522, pl. 14, fig. 9.
1826. *Triloculina oblonga* (Montagu) – d'Orbigny, p. 300, No. 16, Modèles No. 95.
?1884. *Miliolina oblonga* (Montagu) – Brady, p. 160, pl. 5, fig. 4.
1929. *Triloculina oblonga* (Montagu) – Cushman, p. 57, pl. 13, fig. 4 (not fig. 5).
1948. *Triloculina oblonga* (Montagu) – Cushman, p. 38, pl. 4, figs. 5, 6.
1954a. *Triloculina oblonga* (Montagu) – Boltovskoy, p. 129, pl. 2, fig. 5.
1957. *Triloculina oblonga* (Montagu) – Todd and Bronnimann, p. 27, pl. 3, figs. 15, 16.

Test elongate, somewhat compressed, with sides broadly rounded; chambers in a triloculine arrangement, inflated, the adult with three chambers visible, the last-formed chamber broadest near the initial end and longer than the preceding ones; sutures distinct, depressed, on one side a single longitudinal suture, that seems to divide the test into two parts, on the other side two sutures; wall calcareous, opaque, smooth and glossy; aperture oval, with a bifid tooth.

Length of hypotype of figures 9 and 10, 0.38 mm, breadth 0.16 mm, thickness 0.14 mm. A specimen from zone F of boring no. 2 (O 700–1) at Fornebo had a length of 1.37 mm, breadth and thickness 0.41 mm.

Occurrence. – This species is rare in the Late Quaternary of the Oslofjord area. A few specimens were found in zone A at Fredrikstad, it occurred also in zone D layers at Bryn, Oslo, and in the middle part of zone F at Sandefjord and Fornebo. In boring no. 1 (F 226), Skøyen, Oslo, it occurred in subzone F_u.

Remarks. – The specimen here figured is small. In Arctic samples Cushman (1948, p. 38) found specimens reaching 1.00 mm in length. Larger forms occur also with the present material but the smaller ones are more common.

In a similar way as with *Miliolinella subrotunda*, many different forms, different species as well as different genera, have been fused into *Triloculina oblonga*. Almost every elongated miliolid form has, at least temporarily, been referred to this species. *Vermiculum oblongum* as described and figured by Montagu (1803) is a clearly triloculine species. Quinqueloculine and biloculine forms, therefore, should be excluded.

Triloculina tricarinata d'Orbigny

Plate 6, figures 7, 8

1826. *Triloculina tricarinata* d'Orbigny, p. 299. no. 7, Modèle no. 94.
1917. *Triloculina tricarinata* d'Orbigny – Cushman, p. 66, text fig. 32.
1954. *Triloculina tricarinata* d'Orbigny – F. Parker, p. 500, pl. 4, fig. 22.
1956. *Triloculina tricarinata* d'Orbigny – Asano, p. 73, pl. 8, fig. 6.
1959. *Triloculina tricarinata* d'Orbigny – Boltovskoy, p. 52, pl. 4, fig. 17.

The present tests are small to medium-sized, triangular in section with sharp to carinate angles and concave sides; chambers triloculine in arrangement; sutures distinct, almost flush with the surface; wall calcareous, smooth and polished, opaque or slightly translucent; aperture terminal, rounded with a narrow bifid tooth.

Length of hypotype of figures 7 and 8, 0.46 mm, breadth 0.40 mm, thickness 0.35 mm. Length of a specimen from Valle, Sarpsborg, 0.59 mm, breadth 0.46 mm, thickness 0.38 mm. A small specimen from boring no. 2, profile B, Fredrikstad, measured 0.30 mm in length and a juvenile specimen from Majorstuen, Oslo, (boring 5), had a length of 0.25 mm.

Occurrence. – This species is very rare in the Late Quaternary of the Oslofjord area, and seems to be exclusively associated with the Warm Interval deposits of zone F. In southwestern Sweden Brotzen (1951, p. 62) recorded it from the Post Glacial zone 7 of his Surte boring.

Remarks. – This is a decidedly more thermophilous species than *Triloculina trihedra*. As mentioned in the remarks about this latter species, the numerous records of *T. tricarinata* from Arctic waters should most probably be referred to *T. trihedra*.

Triloculina trigonula (Lamarck)

Plate 6, figures 11–13

1804. *Miliolites (trigonula)* Lamarck, p. 351, No. 3, pl. 17, fig. 4 (1807).
1858. *Miliolina trigonula* (Lamarck) – Williamson, p. 84, pl. 7, figs. 180–182.
1884. *Miliolina trigonula* (Lamarck) – Brady, p. 164, pl. 3, figs. 15, 16.
1929. *Triloculina trigonula* (Lamarck) – Cushman, p. 56, pl. 12, figs. 10, 11; pl. 13, figs. 1, 2.
1949. *Triloculina trigonula* (Lamarck) – Cushman, p. 14, pl. 2, fig. 10.
1954a. *Triloculina trigonula* (Lamarck) – Boltovskoy, p. 129, pl. 2, fig 7.

Length of hypotype of figures 11–13, 0.70 mm, breadth 0.57 mm. Length of unfigured specimen from subzone F_1 of a boring at Nesset, 0.81 mm, breadth 0.70 mm.

Occurence. – A few specimens of this species occurred in the transition between zone E and the lower part of zone F in boring 297 from Nesset, 21 km south of the city of Oslo, at the head of the Bunnefjord, and two specimens were found in subzone F_{II} of boring no. 2, profile C, Fredrikstad. It was not found in Late Glacial deposits.

Remarks. – Sars (1865, p. 90) recorded *Miliolina seminulum* var. *trigonula* Williamson as being rare in Norwegian Post Glacial shell beds, and Kiær (1900, p. 53) recognized it in a Post Glacial collection made by Münster. Feyling-Hanssen (1954 a, p. 128) found one specimen in a sample of *Isocardia* clay from Valle by Sarpsborg. Kiær (1900, p. 27) found it living in the Oslofjord, at Drøbak, at a depth of 100 m, and in certain localities along the Norwegian coast from Mandal in the south to Vadsø in the north at depths varying between 50 and 1200 m. It has never been found in the Arctic or the Antarctic (Nørvang, 1945, p. 11). According to the numerous records of this species it seems to be widely distributed in temperate and tropical waters at depths varying between 50 and 4400 m. This species was originally described from the Eocene of France, and Cushman (1929, p. 56) questioned the correctness of even a large portion of the Recent records.

Triloculina trihedra Loeblich and Tappan

Plate 6, figure 6

1953. *Triloculina trihedra* Loeblich and Tappan, p. 45, pl. 4, fig. 10.
1954a. *Triloculina trihedra* Loeblich and Tappan – Feyling-Hanssen, p. 128, pl. 1, fig. 4.

Length of hypotype of figure 6, 0.56 mm, its sides are of equal breadth, 0.43 mm. Unfigured specimens from the Late Glacial of Sandefjord and Fredrikstad varied in length from 0.27 mm to 0.56 mm. A specimen from Pleistocene deposits at Ytterland, Ørlandet near Trondheim, measured 0.65 mm in length.

Occurrence. – This species is rare in the Late Quaternary of the Oslofjord area. It is recorded from the Late Glacial zones A and B of the southern parts of the region, and from the Late Glacial zone D of the northern parts. In the text to plate 1, figure 4 in Feyling-Hanssen (1954 a) it is said that the specimen of *Triloculina trihedra* figured there is from a sample of *Isocardia clay* from Oslo. This is obviously erroneous as the text, p. 128, informs us that the only specimen of *T. trihedra* recorded in that paper was found in a sample of *Yoldia clay* (zone A). Two juvenile specimens, probably belonging to this species, were observed in a zone E - sample from a boring at Grønlandsleret (no. 48) in the city of Oslo. In most cases, however, *T. trihedra* seems to be restricted to the older, Late Glacial Pleistocene and early Holocene parts of the deposits of the Oslofjord area.

Remarks. – Loeblich and Tappan (1953, p. 45) recorded *T. trihedra* from 10 stations on the northern coasts of Alaska and Greenland at depths varying from 21.6 m to 45.7 m. The present author obtained it from 8 m depth in Trygghamna, Spitsbergen, and from 10 m in Myggbukta, Northeast Greenland. As assumed by Loeblich and Tappan (l.c.), the majority of Arctic and northern references to the Mediterranean species *Triloculina tricarinata* d'Orbigny and *Triloculina* (*Miliolites*) *trigonula* (Lamarck) should probably be included in the species *T. trihedra*.

T. trihedra differs from *T. tricarinata* in having less excavated sides and more rounded angles. *T. trigonula* is nearly circular in section and ovate in side view (Loeblich and Tappan).

Hessland (1943, pl. 1, fig. 5) recorded this species, under the name of *Triloculina tricarinata* d'Orbigny, from the Late Glacial of Klätta, Southwest Sweden.

Genus Miliolinella Wiesner, 1931
Miliolinella cf. **enoplostoma** (Reuss)
Plate 7, figures 2–4

1851. *Triloculina enoplostoma* Reuss, p. 86, pl. 7, fig. 57.
1884. *Miliolina circularis* (Bornemann) – Brady (not *Triloculina circularis* Bornemann), p. 169, pl. 4, fig. 3.

Test medium-sized to large, ovate in side view, subtriangular with broadly rounded margins in section; chambers in the adult in a triloculine arrangement, inflated, the two latest chambers large with only a small part of the previous chamber visible between them on one side of the test; sutures fairly distinct; wall calcareous imperforate, surface smooth; aperture a semicircular opening at the end of the chamber, nearly filled by a broad flap, which leaves open only a slit-like crescent; colour white.

Length of the hypotype of figures 2–4, 0.54 mm, breadth 0.44 mm.

Occurrence. – Some specimens of this species occurred in the lower part of the Post Glacial zone F in a boring (No. 297,) from Nesset, 21 km south of the city of Oslo. Another specimen occurred in subzone F_{II} of a boring at Skøyen, Oslo. It seems to be very rare in the Late Quaternary of the Oslofjord area.

Remarks. – *Miliolinella enoplostoma* was described from the Eocene of Berlin (Reuss, 1851, p. 49). Our specimens from the Late Quaternary seems to be referable to this species. They do not, however, show any furrow along the penultimate chamber close to and parallel with the suture between the penultimate chamber and the preceding one. The Eocene specimens were also larger than the present ones, their lengths varied between 0.80 and 1.05 mm.

Miliolinella cf. *enoplostoma* is very close to *Miliolinella cryptella* (= *Triloculina cryptella* d'Orbigny, 1839 b, p. 70, pl. 9, figs. 4, 5) collected from the shore sand of the Falkland Islands, but differs from it in being subtriangular in section, whereas *M. cryptella* is almost circular. *M.* cf. *enoplostoma* differs from *Triloculina circularis* Bornemann (1855, p. 349, pl. 19, fig. 4) in being larger and in possessing an apertural plate whereas *T. circularis* has an open aperture. It differs from *Triloculina trigonula* (Lamarck, 1804, pl. 17, fig. 4) in having an apertural plate instead of a bifid tooth. It differs from *Miliolinella subrotunda* in being larger and in only a small part of the previous chamber being visible between the two latest ones on one side of the test.

Barker (1960, p. 8) refers *Miliolina circularis* (Bornemann), as figured by Brady (1884, pl. 4, fig. 3), to *Miliolinella subrotunda* (Montagu) stating that Wiesner (1931, p. 107) referred that figure to his new genus *Miliolinella*. However, Wiesner (l.c.) referred only to Brady's figures 10 and 11 on plate 5 as type species for *Miliolinella*.

Miliolinella cf. **subrotunda** (Montagu)
Plate 7, figure 1

1784. "*Serpula subrotunda dorso elevato*" Walker and Boys, p. 2, pl. 1, fig. 4.
1803. *Vermiculum subrotundum* Montagu, pt. 2, p. 521.

Test small, sub-orbicular, nearly circular in outline, somewhat compressed, periphery rounded; chambers in a triloculine arrangement, rounded, inflated, in some specimens, apparently young microspheric forms, a fourth chamber may be visible; sutures distinct depressed; wall calcareous imperforate, smooth and glossy, slightly translucent by young specimens; aperture semicircular, at the open end of the chamber, partially covered by a broad flap which leaves only a crescentic opening.

Length of specimen of figure 1 (sample no. O 287–37), 0.35 mm, breadth 0.28 mm, thickness 0.19 mm.

Occurrence. – This species is met with in several samples from the Late Quaternary of the Oslofjord area, but is always sparingly represented. It occurs in the Pleistocene and the Holocene, in Late Glacial strata as well as Post Glacial, but was not found in zone G.

Remarks. – This species should possibly be referred to *Miliolinella subrotunda* (Montagu) (= *Vermiculum subrotundum* Montagu). *V. subrotundum* was not figured by Montagu, he referred only to the figure 4, pl. 1, of Walker in Walker and Boys (1784) "*Serpula subrotunda dorso elevato*". This figure shows a clearly triloculine test, rounded, almost circular in outline, three chambers visible on one side, two on the other. However, as pointed out also by Loeblich and Tappan (1953, p. 46), the characters of the aperture is not visible on this figure. In his description Montagu (p. 521) briefly states: "aperture small, angulated".

Later writers, i.a. Cushman, 1917, 1929; Rhumbler, 1936; Boltovskoy, 1954 a, b, 1957, 1959, seems to have based their concept of *V. subrotundum* on the description and figures given by Brady (1884, p. 168, pl. 5, figs. 10, 11). Brady's figures show quinqueloculine specimens, one of them with a large apertural flap. Wiesner (1931, p. 63), who made *Vermiculum subrotundum* Montagu the type species (genotype) of the genus *Miliolinella,* also based his concept of the species on Brady's figures. Wiesner (l.c.), therefore, in his genus *Miliolinella* included biloculine, triloculine, and quinqueloculine forms characterized by large apertural flaps. However, as emphasized by Loeblich and Tappan (1953, p. 46) "The genus *Miliolinella* can only include species agreeing in character with the type species and as Montagu's illustration shows a distinctly triloculine test, the biloculine and quinqueloculine species should be excluded."

On the other hand Rhumbler (1936, p. 215) simply suggested that *Miliolinella subrotunda* in Wiesner's (p. 107) concept should be given the new name *M. wiesneriana*, whereas Montagu's old species *Vermiculum subrotundum* should be referred to the genus *Quinqueloculina*, and should only include forms without an apertural plate or with entirely open aperture or with an ordinary longitudinally placed tooth. Thus the type species of the genus *Miliolinella* was referred to another genus. As mentioned above, Rhumbler also based his concept of Montagu's species on Brady's illustrations (1884, pl. 5, figs. 10, 11).

Rhumbler (l.c., p. 211) fused into one group calcareous forms with circular or subcircular peripheral outline, previously referred partly to *Miliolina subrotunda* (Montagu), partly to *Miliolina circularis* (Bornemann) (= *Triloculina circularis* Bornemann), and called this the *Subrotunda – circularis* – group. Already Brady (l.c., p. 169) questioned "whether there is any constant or reliable distinction between the *Triloculina circularis* of Bornemann and *Miliolina subrotunda*, and whether any good purpose is served by endeavouring to retain both species". As a consequence of this Boltovskoy (1954 a, p. 127; cp. also 1954 b, p. 262, and 1959, p. 52) suppressed *Triloculina circularis* Bornemann as a junior synonym of *Vermiculum subrotundum* Montagu, which species he referred to the genus *Triloculina*. Boltovskoy, however, based his concept of Bornemann's species as well as Montagu's on Brady's illustrations and descriptions (1884, p. 168, 169). *Triloculina circularis*, as described by Bornemann (1855, p. 349), has no apertural tooth ("Die Mündung ist eine sichelförmige Spalte, welche schief nach vorn gerichtet ist, und ohne Zahn"). This is also clearly shown in his illustration, pl. 19, fig. 4 a (Cp. also Parr, 1950, p. 293). In spite of this, nearly all subsequent writers have described and figured *T. circularis* as possessing a well-developed apertural flap. It seems unreasonable that Bornemann by the term tooth (Zahn) meant only a bifid *Quinqueloculina* type of a tooth, and that his species might very well have been provided with an apertural flap. For in his paper the description of *T. circularis* is followed by the description of *T. laevigata* Bornemann. And in this latter species the presence of a large, semicircular apertural flap is emphasized ("Die Mündung ist eine enge sichelförmige Spalte, indem der grösste Theil von einem grossen halbkreisförmigen Zahne eingenommen ist."). Consequently, *Triloculina circularis* Bornemann, with no apertural tooth, belongs neither to the genus *Triloculina*, one of the characters of the forms of this genus being the presence of a bifid tooth, nor to the genus *Miliolinella*, which is characterized by forms possessing a broad apertural flap.

Rhumbler (l.c., p. 229) who found numerous specimens of *T. circularis*, all without apertural tooth, surprisingly enough seperated this apparently true. *T. circularis* into a new variety *elinguis*.

Miliolinella, cf. *subrotunda*, from the Late Quaternary of the Oslofjord area is a true *Milionella* in Wiesner's conception. Until it is possible to compare it with specimens of *Vermiculum subrotundum* from Montagu's collection, the writer prefers to use open nomenclature for the present species.

Genus Pyrgo Defrance, 1824

Pyrgo comata (Brady)

Plate 7, figure 7

1884. *Biloculina comata* Brady, p. 144, pl. 3, fig. 9.
1894. *Biloculina comata* Brady – Göes, p. 117, pl. 22, fig. 884.
1899. *Biloculina comata* Brady – Flint, p. 294, pl. 39, fig. 3.
1900. *Biloculina comata* Brady – Kiær, p. 26.
1917. *Biloculina comata* H. B. Brady – Cushman, p. 81, pl. 34, fig. 1.
1929. *Pyrgo comata* (H. B. Brady) – Cushman, p. 73, pl. 19, fig. 8.
1959. *Pyrgo comata* (Brady) – Boltovskoy, p. 56, pl. 6, fig. 12.

Length of the hypotype of figure 7, 1.84 mm, breadth 1.65 mm, thickness 1.67 mm. Length of unfigured specimen from the same sample 1.65 mm, breadth 1.48 mm, thickness 1.49 mm.

Occurrence. – This species is rare in the Late Quaternary of the Oslofjord area. It was fairly frequent in a sample from zone E of boring no. 15 in the city of Drammen, at core level 3.2 m.

Remarks. – Nørvang (1945, p. 12) found the main geographical distribution of this species to be the Boreal and Lusitanian parts of the Atlantic and the Pacific Ocean. It is usually found in deep water, from about 500 m down to 2000 m.

Pyrgo williamsoni (Silvestri)

Plate 7, figure 5, 6; plate 8, figures 3–5

1858. *Biloculine ringens* (Lamarck) *typica* Williamson (not *Miliolites ringens* Lamarck, 1804), p. 79, pl. 6, figs. 169, 170, pl. 7, fig. 171.
1923. *Biloculina williamsoni* Silvestri, p. 73.
1953. *Pyrgo williamsoni* (Silvestri) – Loeblich and Tappan, p. 48, pl. 6, figs. 1–4.
1954a. *Pyrgo* sp., Feyling-Hanssen, p. 128, pl. 1, figs. 5, 6.
1954b. *Pyrgo williamsoni* (Silvestri) – Feyling-Hanssen, p. 189, pl. 1, figs. 1–3.

Length of hypotype of figures 3–5, plate 8, an irregular form from Münster's collection, 1.10 mm, breadth 0.78 mm, thickness 0.73 mm. Hypotype of figures 5 and 6, plate 7, a specimen from subzone B_1, boring no. 22, Valle (core level 19.2 m), measured: length 1.00 mm, breadth 0.78 mm, thickness 0.73 mm. A specimen from a sample of Isocardia clay (zone F) from Monrads gate, Oslo (Feyling-Hanssen, 1954 a, pl. 1, fig. 6) had a length of 0.95 mm, breadth 0.76 mm, thickness 0.68 mm.

Occurrence. – This species occurs in several samples from the Late Pleistocene and Holocene of the Oslofjord area, usually, however, represented only by a few specimens. It was found in Post Glacial as well as in Late Glacial deposits, being, as a rule, most frequent in Late Glacial strata. By many borings it seems to accompany *Nonion labradoricum*, especially in the middle part of zone A and also in subzone B_1 (C and D).

Remarks. – *Pyrgo williamsoni* shows great similarities to *Pyrgo elongata* (d'Orbigny). Many Arctic records have been given under this latter name, and young specimens of *P. williamsoni* can hardly be separated from *P. elongata*, even though the latter does not have the last chamber surrounding the penultimate one on all sides. It would, on the whole (cp. Boltovskoy, 1954 a, p. 132–134), certainly be of some interest to study a sufficient number of specimens of the species *Pyrgo williamsoni*, *P. elongata*, *P. patagonica* (d'Orbigny), *P. peruviana* (d'Orbigny), *P. fornasinii* (Chapman and Parr), and *P. subsphaerica* (d'Orbigny) to see if it is justified to maintain specific differentiation between them or if these forms should possibly be separated only by lower systematic ranks. Specimens collected by Münster, in an old clay pit at Bislet in Oslo (plate 8, figs. 3–5) were somewhat irregularly finished compared with the form commonly met with in the borings (plate 7, figs. 5, 6).

Genus Biloculinella Wiesner, 1931
Biloculinella depressa (d'Orbigny)
Plate 7, figures 8–10

1826. *Biloculina depressa* d'Orbigny, p. 298, No. 7, Modèles No. 91.
1858. *Biloculina ringens*, var. *carinata* Williamson, p. 79, pl. 7, figs. 172–174.
1866. *Biloculina depressa* d'Orbigny – Jones, Parker and Brady, p. 6, pl. 3, figs. 29, 30.
1884. *Biloculina depressa* d'Orbigny – Brady, p. 145, pl. 2, figs. 12, 16; pl. 3, figs. 1, 2.
1894. *Biloculina depressa* d'Orbigny – Goës, p. 120, pl. 25, figs. 922, 924.
1929. *Pyrgo depressa* (d'Orbigny) – Cushman, p. 71, pl. 19, figs. 4, 5.
1931. *Biloculina depressa* d'Orbigny – Wiesner, p. 110, pl. 17, fig. 196.
1959. *Pyrgo depressa* (d'Orbigny), forma *typica* Boltovskoy, p. 55, pl. 5, fig. 10.
1960. *Pyrgo depressa* (d'Orbigny) – Barker, pl. 2, figs. 12, 16; pl. 3, figs. 1, 2.

Length of hypotype of figure 8, 0.43 mm, breadth 0.35 mm, thickness 0.18 mm. Length of hypotype of figures 9 and 10, 0.68 mm, breadth 0.65 mm, thickness 0.30 mm. Length of unfigured specimen from boring no. 2 at Fornebo, 1.05 mm.

Occurrence. – This species is rare in the Late Quaternary of the Oslofjord area. One specimen occurred in boring no. 5 in Sandefjord, at core level 11.6 m, zone F, and one specimen in boring no. 22 at Valle, core level 7.7 m, also zone F. E. B. Münster (Cp. p. 31 of this paper, and

Brøgger, 1900–1901, p. 520) found one specimen in a Lower Tapes bed at Smedholmen by Brevik. In the northern part of the area one specimen was found in the upper part of zone F of boring 297 at Nesset, 21 km south of the city of Oslo, and at Fornebo and in the city of Oslo, boring no. 31 at Akerselva, it was fairly common, also there in zone F.

Remarks. – In the Late Quaternary of the Oslofjord area this species seems to be restricted to deposits from the Post Glacial Warm Interval. In good agreement with this is its Recent distribution, which in the eastern Atlantic, seems to be mainly Lusitanian. It is recorded from the southwest coast of Ireland (Williamson, 1858; Brady, 1884; Cushman, 1929), west of Scotland (Heron-Allen and Earland, 1913a and 1916b), at the Belgian coast (Cushman, 1949), from the coast of Galicia, north of Portugal, in shallow water (Colom, 1952), from the Mediterranean (i. a. Todd, 1958; Chierici, Busi, and Cita, 1962) and from the northern west coast of Afrika (Schott, 1935; Colom, 1950). D'Orbigny (1826) described this species from the Adriatic Sea, near Rimini.

The present writer has found no record referable to this species from Arctic regions. Goës (1894, p. 120, pl. 25, fig. 923) figured a transverse section of a species from "mari Spitsbergensi, profund. metr. 4600". The figured specimen, however, is thick and uncarinated, and does evidently not belong to *Biloculinella depressa*. The *Biloculina depressa* from the North Atlantic recorded by Parker and Jones (1865, p. 409, pl. 17, fig. 89) is not this species but rather *Pyrgo murrhina* (Schwager).

Kiær (1900, p. 26) and Nørvang (1942, p. 10) recorded *Biloculina depressa* from the coast of Norway, but they did not give any illustration.

Cushman (1917, p. 74, pl. 28, figs. 1, 2) and Asano (1956, p. 76, pl. 9, figs. 4, 6) recorded *Pyrgo depressa* from the North Pacific, but figured specimens with single or bifid tooth instead of a broad apertural plate.

Wiesner (1931, p. 110, pl. 17, fig. 196) found *B. depressa* in bottom samples from two stations in the Antarctic region (65° south latitude and 45° south latitude), and Jones, Parker and Brady (1866, p. 6) recorded it from the Crag at Sutton.

Biloculinella inflata (Wright)
Plate 7, figures 11, 12

1885. *Biloculina ringens* Lamarck var. – Balkwill and Wright, p. 322, pl. 12, figs. 6, 7.
1902. *Biloculina inflata* Wright, p. 183, pl. 13, figs. 1–4.
1916b. *Biloculina inflata* Wright – Heron-Allen and Earland, p. 206.
1929. *Pyrgo inflata* (J. Wright) – Cushman, p. 74.
1942. *Biloculinella inflata* (Wright) – Nörvang, p. 10.
1945. *Biloculinella inflata* (Wright) – Nörvang, p. 14.
1954b. *Pyrgo* cf. *simplex* (d'Orbigny) – Feyling-Hanssen (not *Biloculina simplex* d'Orbigny, 1846), p. 190, pl. 1, figs. 4–6; text figs. 2.

The test of the present specimens is oval to nearly circular in outline, much inflated, the last chamber extending beyond the penultimate one on all margins; sutures distinct, depressed; wall calcareous, imperforate, white or slightly translucent, surface smooth; aperture broad, curved, with a broad and thin apertural plate or flap, projecting from the surface of the previous chamber.

Length of hypotype of figure 11, 0.31 mm, breadth 0.27 mm, thickness 0.24 mm. Length of hypotype of figure 12, 0.38 mm, breadth 0.31 mm, thickness 0.27 mm. Length of unfigured specimen from zone D, Bryn, Oslo (sample no. O 199–44, core level 17.7 m of boring no. 18), 0.50 mm, breadth 0.40 mm, thickness 0.38 mm. Another specimen from the same boring, core level 19.2 m, measured: length 0.35 mm, breadth 0.25 mm, thickness 0.24 mm. A specimen from zone E, boring no. 5 in Sandefjord, had a length of 0.43 mm, breadth 0.36 mm, thickness 0.32 mm.

Occurrence. – This species is not common in the Late Quaternary of the Oslofjord area, but it occurs, in small numbers, both in Late Glacial and Post Glacial deposits. It seems to be more frequently met with in the Late Glacial zones C and D, in the area around the city of Oslo, than in other strata. It was not found in zone A, the *Yoldia* clay.

Remarks. – *Biloculinella inflata* from the Late Pleistocene deposits of the Oslofjord area shows some resemblance to *Biloculinella isabelleana* (d'Orbigny 1839 b, p. 66, pl. 8, figs. 17–19) from the Falkland area, but is usually smaller. D'Orbigny gave 0.5 mm as diameter for *B. isabelleana*, Heron-Allen and Earland (1932 a, p. 312, pl. 6, figs. 1–3) gave 0.70–0.80 mm as length for their specimens from the same area. It shows affinities also to *Biloculinella subglobulus* (Parr, 1950, p. 298, pl. 7, fig. 10) from Tasmania. It also resembles figure 16 of *Biloculinella ezo* (Asano, 1956, p. 77, pl. 9), except that the specimen from the Bungo Channel, Japan, figured by Asano, is considerably compressed rather than much inflated.

By many specimens of *B. inflata* from the Holocene deposits here dealt with, the plate-like tooth, or lip, was broken away. Examination of specimens lacking the apertural plate, proved that it was preserved in earlier chambers of such tests.

Biloculinella inflata was described from Post Glacial clays near Lancaster in England, and was also recorded from dredgings in the Irish Sea near Dublin at depths of 80 and 90 m (Wright, 1902, p. 183). Heron-Allen and Earland (1916 b, p. 206) recorded it from the west coast of Scotland, and Nørvang (1942, p. 10; 1945, p. 14) recorded it from off Bergen on the Norwegian west coast, 350–400 m, and from the south coast of Iceland, 109 m. He assumed that its main distribution is Boreal.

Superfamily NODOSARIOIDEA Ehrenberg, 1839
Family **NODOSARIIDAE** Ehrenberg, 1839
Genus Nodosaria Lamarck, 1812
Nodosaria pyrula d'Orbigny
Plate 8, figures 6–8

1826. *Nodosaria pyrula* d'Orbigny, p. 253, Modèle No. 13.
1858. *Nodosaria pyrula* d'Orbigny – Williamson, p. 17, pl. 2, fig. 39.
1884. *Nodosaria pyrula* d'Orbigny – Brady, p. 497, pl. 62, figs. 10–12.
1885. *Nodosaria pyrula* d'Orbigny – Balkwill and Wright, p. 343, pl. 12, fig. 23.
1923. *Nodosaria pyrula* d'Orbigny – Cushman, Bull. 104, pt. 5, p. 69, pl. 16, figs. 1–4.
1948. *Nodosaria pyrula* d'Orbigny – F. L. Parker, p. 239, pl. 5, fig. 2.
1956. *Nodosaria pyrula* d'Orbigny – Asano, p. 20, pl. 4, fig. 42.
1959. *Nodosaria pyrula* d'Orbigny – Boltovskoy, p. 64, pl. 8, fig. 9.
1960. *Dentalina guttifera* d'Orbigny – Barker, p. 130, pl. 62, figs. 11, 12.

Occurrence. – A broken specimen occurred in the middle part of the Post Glacial zone F of boring no. 28, profile A, Fredrikstad, in the southern part of the Oslofjord area. Another specimen occurred in the middle part of the same zone in boring B (core level 9.5 m) at Onsøy in Østfold, also in the southern part of the area.

Remarks. – The length of the phragment from Fredrikstad, fig. 8, was 0.92 mm, its greatest diameter 0.17 mm. On plate 8, figures 6, 7, are also figured two phragments of this species from a Post Glacial deposit at Furre, Namdalen (boring no. 33^{II}, core level 12.8 m, F 169–266). The largest of these had a length of 1.01 mm and a greatest diameter of 0.12 mm.

As to its Recent distribution, Kiær (1900, p. 35) found a single specimen of this species at a depth of c. 100 m in the Oslofjord at Drøbak, and recorded it also from Stavanger on the Norwegian southwest coast. *N. pyrula* seems to be widely distributed in tropical and temperate waters.

Genus Dentalina d'Orbigny, 1839

Dentalina advena (Cushman)

Plate 8, figure 9

1884. *Nodosaria (D.) roemeri* Neugeboren – Brady (not *Dentalina roemeri* Neugeboren, 1856), p. 505, pl. 63, fig. 1.
1923. *Nodosaria advena* Cushman, Bull. 104, pt. 4, p. 79. pl. 14, fig. 12.
1943. *Dentalina* sp. ("*communis*" d'Orbigny) – Hessland, p. 347, pl. 2, fig. 17.

This species is only very slightly tapering towards the broadly rounded initial end. It is also characterized by its oblique sutures and excentric aperture. The wall of the specimens from the Holocene of the Oslofjord area is semitranslucent to milky white.

Length of hypotype of figure 9, 2.10 mm, greatest breadth 0.43 mm. Other specimens from the area had lengths varying between 1.51 mm and 0.95 mm.

Occurrence. – This species was found in several samples from Holocene deposits in the Oslofjord area, represented, however, only by a few or a single specimen per sample. It was most frequent in core samples from the Post Glacial zone F, both in inner and outer parts of the area. A juvenile specimen occurred in zone E of boring no. 1, Sandefjord, and some small forms in zone E of boring no. 297 at Nesset, 21 km south of the city of Oslo. Another small specimen occurred in the Late Glacial zone B, lower part, of boring no. 22 at Valle by Sarpsborg. Hessland's (1943, p. 239, 347) record of *Dentalina* sp. ("*communis*"), included in the present synonymy, refers to specimens from Southwest Swedish deposits corresponding to zone F of the Oslofjord area.

Remarks. – The Late Quaternary specimens from the Oslofjord area seem to be somewhat small for the species. The specimen figured by Cushman (1923, pl. 14, fig. 12) had a length of c. 5 mm, and he recorded specimens with length up to 7 mm (p. 79). The specimen from the West Indies (390 fathoms), figured by Brady (1884, pl. 63, fig. 1) measured, however, 2.6 mm in length.

The present species differs from *Dentalina baggi* Galloway and Wissler in having oblique sutures instead of nearly horizontal. It differs from *D. pauperata* d'Orbigny in the absence of an apical spine. According to Cushman (1923, p. 79) *D. advena* has been most frequently met with in the western part of the Atlantic from the Caribbean to the northeastern coast of the United States, with occurrence also in the eastern Atlantic. The *Challenger* expedition observed it chiefly in the North Atlantic (Brady 1884, p. 506).

Dentalina drammenensis n. sp.
Plate 8, figures 10–13

1950. *Dentalina californica* Cushman and Gray – Cushman and McCulloch (not *Dentalina californica* Cushman and Gray, 1946), p. 312, pl. 41, figs. 8, 9.
1954a. *Dentalina* sp. Feyling-Hanssen, p. 129.

Name. – From the City of Drammen where this species occurs quite commonly in Late Glacial clays.

Type data. – Holotype is a complete specimen (P.M.O. no. 73340) from the transition between the Post Glacial zones E and F in boring no. 5 at Majorstuen (Sørkedalsveien no. 8) in the city of Oslo. The boring was carried out by the Norwegian Geotechnical Institute, the specimen collected by Rolf W. Feyling-Hanssen 1959.

Diagnosis. – A small, hyaline *Dentalina* with about 3 chambers of nearly uniform diameter, higher than broad, initial end with a very short spine.

Description. – Test small, elongate, circular in section, of nearly uniform diameter throughout, initial end with a very short spine; chambers few, 2–5, elongate, pyriform, uniserially arranged, latest chamber longer than the other, nearly 3 times as long as broad, initial chamber usually shorter than the other; sutures distinct, depressed, slightly oblique; wall calcareous, hyaline, finely and densely perforate; aperture terminal, eccentric, radiate with the slits slightly diverging at the end of the test; colour glassy to grayish.

Length of holotype (fig. 11) 0.54 mm, greatest breadth 0.11 mm. Lenght of two-chambered paratype of figure 10, 0.37 mm, breadth 0.11 mm. Length of five-chambered paratype of figure 13, 0.80 mm, breadth 0.11 mm. A three-chambered, unfigured specimen from the Late Glacial of boring no. 1 at Rakkestad had a length of 0.43 mm, breadth 0.09 mm, a four-chambered specimen from the same boring had a length of 0.65 mm, the breadth of its proloculus was 0.11 mm, breadth of later chambers 0.10 mm.

Occurrence. – This species occurred in the Holocene of the Oslofjord area. It was rare, but less rare in the Late Glacial part of the Holocene than in the Post Glacial. It is quite characteristic for the Late Glacial zone D in the northern parts of the area, was also found in the lowest part of the Post Glacial zone F but not in zone G.

Remarks. – This species seems to be identical with *Dentalina californica* figured by Cushman and McCulloch (1950, pl. 41, figs. 8, 9; not *D. californica* Cushman and Gray, 1946). The proluculus of *D. californica* Cushman and Gray is longer than any of the succeeding chambers and the sutures are strongly oblique. One specimen of *D. drammenensis* n. sp. had two very short initial spines. *D. drammenensis* resembles the Cretaceous species *D. deflexa* Reuss (1863 a, p. 43, pl. 2, fig. 19) which is only slightly longer, Reuss gave 0.84 mm as length. However, *D. deflexa* has strongly oblique sutures and no apical spine, this is emphasized by Reuss (l.c.). *D. drammenensis* differs from *D. emaciata* Reuss by having less than half the number of chambers. It also resembles *Nodosaria* (*Dentalina*) *abnormis* Reuss (Cp. Reuss, 1866, pl. 2, fig. 10).

It is possible that the present species may have been recorded under the name *Dentalina consobrina* d'Orbigny = *Stilostomella consobrina* (d'Orbigny) (Cp. Stainforth, 1952, p. 12; Barker, 1960, p. 130).

Dentalina filiformis (d'Orbigny)

1826. *Nodosaria filiformis* d'Orbigny, p. 253.
1884. *Nodosaria filiformis* d'Orbigny – Brady, p. 500, pl. 63, figs. 3–5.
1950. *Dentalina filiformis* (d'Orbigny) – Cushman and McCulloch, p. 314, pl. 40, fig. 17 (with extensive synonymy).

A specimen referable to this species occurred in the lower part of zone G of boring no. 26, profile A, Fredrikstad. Its length was 1.35 mm, its thickness 0.19 mm. It occurred also in subzone A_u and subzone B_l of boring no. 1 at Rakkestad.

Dentalina inornata bradyensis (Dervieux)
Plate 9, figure 8

1884. *Nodosaria communis* d'Orbigny – Brady (not *Nodosaria (Dentalina) communis* d'Orbigny, 1826), p. 504, pl. 62, figs. 19, 20.
1894. *Nodosaria communis* d'Orbigny – Goës (not *Nodosaria (D.) communis* d'Orbigny, 1826), p. 67, pl. 12, figs. 667–669.
1894. *Nodosaria inornata* d'Orbigny, var. *bradyensis* Dervieux, p. 610.
1899. *Nodosaria communis* d'Orbigny – Flint (not *Nodosaria (D.) communis* d'Orbigny, 1826), p. 310, pl. 56, fig. 2.
1913. *Nodosaria communis* d'Orbigny – Cushman (not *Nodosaria (D). communis* d'Orbigny, 1826), Bull. 71, pt. 3, p. 54, pl. 28, fig. 1.
1923. *Nodosaria communis* d'Orbigny – Cushman (not *Nodosaria (D.) communis* d'Orbigny, 1826), Bull. 104, pt. 4, p. 75, pl. 12, figs. 15–17.
1948. *Dentalina mucronata* (Neugeboren) – F. L. Parker (not *Dentalina mucronata* Neugeboren, 1856), pl. 5, fig. 1.
1955. *Dentalina communis* d'Orbigny – Cushman (not *Nodosaria (D.) communis* d'Orbigny, 1826), pl. 21, fig. 11 (4th ed.).
1959. *Dentalina communis* d'Orbigny – Boltovskoy (not *Nodosaria (D.) communis* d'Orbigny, 1826), p. 63, pl. 9, fig. 1.
1960. *Dentalina inornata* d'Orbigny, var. *bradyensis* (Dervieux) – Barker, p. 310, pl. 62, figs. 19, 20.

Length of hypotype of figure 8, 2.35 mm, greatest breadth 0.46 mm.

Occurrence. – This species was rare in the Late Quaternary of the Oslofjord area and it was only found in the zone F of Holocene deposits. The figured specimen occurred in the upper part of zone F of boring no. 3 at Glemmen Church, Fredrikstad. A broken specimen was found in the lower part of zone F of boring 297 at Nesset, and another broken specimen occurred in the lower part of the same zone in boring no. 48, core level 18.2 m, at Grønlandsleret in the city of Oslo.

Remarks. – After the appearance of Brady's fundamental study of the Foraminifera collected on the Challenger Expedition, the present species, as seen from the above synonymy list, has been frequently recorded as *Dentalina communis* d'Orbigny (or *Nodosaria communis* d'Orbigny) Dervieux (1894, p. 610) referred Brady's figures 19 and 20, pl. 62, to a new variety of *Nodosaria inornata* d'Orbigny, and Cushman (1913, p. 54) questioned whether Brady (1884, p. 504) was correct in placing Recent material with d'Orbigny's Cretaceous species (*D. communis*). But later authors have nevertheless, together with Cushman, to a great extent based their concept of *D. communis* on Brady's figures (1884, pl. 62, figs. 19–22).

In his description of *Dentalina communis* d'Orbigny (1826, p. 254; 1840, p. 13) emphasized the character of the initial chamber, viz., that it was larger than the succeding one and that it was provided with a basal point. Furthermore he stressed that the chambers were broader than high and that the sutures were oblique throughout the test. As length of the species he gave 1 mm. Our present form differs from *D. communis* d'Orbigny in being larger, in having no high initial chamber and in its sutures which become almost horizontal towards the aperture instead of being oblique throughout the test. It differs from *D. pseudocommunis* Franke (1936, p. 30, pl. 2, fig. 20; Tappan, 1955, p. 66, pl. 21, figs. 29–33), of Liassic age, in being larger and having the chambers more inflated towards the apertural end. It differs from *D. costai* (Schwager) (*Nodosaria costai* Schwager, 1866, p. 229, pl. 6, fig. 62), from the Pliocene of Kar Nikobar in the Pacific, in being larger, less slender, in having fewer chambers, and in having the later chambers inflated, not only the latest one. Furthermore, the chambers of *D. costai* are relatively higher than the chambers of *D. inornata bradyensis*. The present subspecies differs from *D. inornata inornata* in being more slender, having more chambers and less oblique sutures.

Dentalina inornata bradyensis seems to have its main distribution at the present-day in temperate waters. Nørvang (1945, p. 14) found *D. communis* at the coast of Iceland. He did not figure his specimens, but referred to Cushman's figures (1923, pl. 12, figs. 3, 4, 15–17). The writer has ommitted from the above synonymy list Cushman's figures 3 and 4; figure 3 because of the distinct spine and high initial chamber, figure 4 because of its very broadly rounded initial end and high initial chamber. It is not certain which of the forms figured by Cushman Nørvang found at Iceland. Goës (1894, pl. 12, figs. 667–669) recorded the present form from the Swedish west coast and from the Azores. His figure 670, of a specimen from the Greenland Sea, does not apply to the present subspecies. Boltovskoy (1959, p. 63, pl. 9, fig. 1) recorded the present form as rare off the coast of Brazil (Lat. S 32° 36′).

Dentalina ittai Loeblich and Tappan
Plate 9, figures 1, 2

1933. *Nodosaria calomorpha* Reuss – Earland (not *Nodosaria (Nodosaria) calomorpha* Reuss, 1866), p. 117, pl. 4, fig. 19.
1948. *Dentalina* cf. *calomorpha* (Reuss) – Cushman (not *Nodosaria (Nodosaria) calomorpha* Reuss, 1866), p. 44, pl. 5, figs. 4, 5.
1950. *Dentalina* cf. *calomorpha* (Reuss) – Cushman and McCulloch (not *Nodosaria (Nodosaria) calomorpha* Reuss, 1866), p. 317, pl. 41, fig. 6.

The tests of the present specimens of this species are in good keeping with the original description, narrow and arcuate or somewhat irregularly arcuate, the chambers elliptical in side view and of nearly equal diameter, or the diameter differs irregularly from one chamber to another so that a succeeding chamber may be narrower than its preceding one. In all my specimens the sutures are at right angle to the long axis of the test.

Length of hypotype of figure 2, 0.73 mm, greatest breadth 0.11 mm. Length of hypotype of figure 1, 0.57 mm, greatest breadth 0.11 mm. The latter specimen, which is from boring no. 5 at Majorstuen, Oslo, is broken so that only four chambers plus a small part of a fifth remains; the length given is that of this remaining part of the test. Length of unfigured five-chambered specimen from zone F of boring no. 3 at Fornebo, 0.47 mm.

Occurrence. – One specimen of this species occurred, as already mentioned, in zone F of boring no. 3 at Fornebo, and a broken specimen in zone C of boring no. 5 at Majorstuen, Oslo. The other figured specimen is from a Post Glacial deposit at Furre in Namdalen, north of the Trondheimsfjord in central Norway (F 169, boring no. 33^{II}, core level 10.8 m), a deposit probably corresponding to zone E of the Oslofjord area.

Remarks. – The author has included in the present synonymy *Nodosaria calomorpha* from four stations around South Georgia, recorded by Earland (l.c.). This was not done by Loeblich and Tappan probably because in their description of *D. ittai* they limited the number of chambers for the species to 6 (from 2 to 6). At two of the South Georgian stations Earland found "specimens ranging up to the exceptional number of 6–9 chambers", and he figured a form with the maximum number of chambers (pl. 4, fig. 19). The length of that figured specimen was 1.20 mm; the longest specimen of *D. ittai* figured by Loeblich and Tappan (pl. 10, fig. 10) measured 1.01 mm. Furthermore Earland recorded from the same South Georgian waters specimens of "normal" type with 2–3 chambers.

The specimen of *Dentalina* cf. *calomorpha* figured by Cushman and McCulloch (1950, pl. 41, fig. 6) tapers very slightly towards the initial end, but it can hardly be separated from *D. ittai*. The latest chamber is of equal breadth as the penultimate, if not narrower, and the length of the test is 1.00 mm, i. e., within the range of *D. ittai*.

As to its Recent distribution, Cushman and McCulloch recorded *Dentalina* cf. *calomorpha* (= *D. ittai*) from 7 Pacific stations, among them the Gulf of California and off Columbia, South America. They found it, however, to be more frequent at Wrangell, Alaska, than elsewhere.

Loeblich and Tappan recorded *D. ittai* from 15 Arctic stations and considered it to be restricted to the Arctic, Cushman (1948) recorded it from several Arctic stations, and Earland's records were from Sub-Antarctic waters.

Nodosaria calomorpha recorded by Brady (1884, p. 497, pl. 61, figs. 23–27) from the Challenger Expedition, has much in common with the present species, but Brady described the aperture to be entosolenian in many cases.

Dentalina trondheimensis n. sp.
Plate 9, figures 3–7

Name. – From the city of Trondheim, Norway.

Type data. – Holotype is a complete specimen (P.M.O. no. 73345) from the Holocene zone C of boring no. 1 at Lademoen Church in the city of Trondheim in the central region of Norway. The boring was carried out by the Norwegian Geotechnical Institute, the specimen collected by Rolf W. Feyling-Hanssen 1958.

Diagnosis. – A translucent *Dentalina* with about 7 chambers, oval to subcircular in transverse section, the subglobular proloculus with a short spine or point sometimes divided into two or three, sutures limbate.

Description. – Test elongate, often almost straight in the early portion, cecoming arcuate and lobulate in the later, somewhat compressed laterally, more so in the early part than in the later, initial chamber terminating in a short spine or point which may be divided into two or three; chambers 6–10, uniserially arranged, of approximately equal height and breadth in the early half of the test, later chambers becoming elongated and inflated, proloculus subglobular; sutures distinct, limbate, moderately oblique, flush with the surface in the early part of the test, depressed in the later; wall calcareous with radiate structure, translucent to hyaline, finely perforate, more densely in the later chambers than in the earlier, in an area around the aperture the wall seems to be almost imperforate and glassy; aperture terminal, at the peripheral angle, radiate with the relatively long slits somewhat divergent projecting.

Length of the holotype of figure 3, 0.89 mm, greatest breadth 0.14 mm, greatest thickness 0.13 mm. Length of paratype of figure 4 (from Namdalen), 1.24 mm, greatest breadth 0.19 mm, greatest thickness 0.18 mm. Length of paratype of figure 5 and 6 (Nesset, Oslofjord area), 0.70 mm, greatest breadth 0.13 mm, greatest thickness 0.11 mm. Length of paratype of figure 7 (Fredrikstad), 0.68 mm, greatest breadth 0.12 mm, greatest thickness 0.11 mm. Length of unfigured 6-chambered paratype from the same sample as the holotype, 0.67 mm, greatest breadth 0.13 mm, greatest thickness 0.11 mm.

Occurrence. – This species was rare in the Late Quaternary of the Oslofjord area. It occurred at the transition between the Post Glacial zones E and F in boring 297 at Nesset, 21 km south of Oslo. In boring no. 28, profile A, Fredrikstad, it occurred in the middle part of zone F, and in the city of Oslo it occurred in zone F of boring no. 48, Grønlandsleret, boring no. 31, Akerselva, and boring no. 20 at Nationaltheateret. At Fornebo, near Oslo, it was observed in zone F of boring no. 3, Storøymyr. In the city of Trondheim, in the middle part of Norway, some specimens of this species occurred in boring no. 1 at Lademoen Church in layers with fossil foraminiferal assemblages corresponding to those of zone C and zone D of the Oslo area. At Furre in the valley of Namdalen, north of Trondheim, it was found in the early Post Glacial part of boring no. 33^{II}.

Remarks. – Because of its laterally somewhat compressed test this species has some resemblance with the genus *Vaginulina* d'Orbigny, 1826. Its affinity to this genus is, however, vague, though less so in the early part of the test than in the later. The proloculus is globular or subglobular, not compressed. The subsequent five chambers are quite distinctly compressed, their transverse section being oval or elliptical (Cp. pl. 9, fig. 6), but the later part of the test is *Dentalina*-like, arcuate with inflated chambers which are subcircular in transverse section, only very slightly compressed.

There seems to be good cause for a redefinition of the genus *Vaginulina*, narrowing its limits to comprise only the flat forms with parallel or subparallel sides (Cp. Bartenstein, 1948), and to erect a new genus for the more or less compressed forms with elliptical or oval transverse section, i.e., the forms with morphogenetic position between *Vaginulina* and *Dentalina*. *Dentalina* should then comprise only forms with circular transverse section. *Vaginilina*, defined as suggested here, would have only few representatives outside the Mesozoicum. With the material at hand, however, the present writer does not feel prepared to deal with this problem. *Dentalina* was originally defined as a subgenus of *Nodosaria* to distinguish the curved (arcuate) forms with eccentric aperture. The character of the transverse section was not specifically mentioned in the original description of the subgenus, but it was most probably considered to be circular. In many descriptions of species of this subgenus d'Orbigny applied the term *diameter* to describe the breadth or thickness of the form. However, in an amendment of the generic definition for *Vaginulina* Reuss (1874, p. 90) emphasized the convex outline of the peripheral margin by *Vaginulina,* whereas *Dentalina* is concave. He also characterized *Dentalina* as being laterally slightly compressed. In a later generic classification Marie (1941, p. 72) defined *Dentalina* as the arcuate forms with circular or oval section. For these reasons the present species is here placed in the genus *Dentalina.*

Genus Lenticulina Lamarck, 1804
Subgenus *Robulus* Montfort, 1808
Lenticulina (Robulus) cf. **angulata** (Reuss)
Plate 9, figures 9, 10

1851. *Robulina angulata* Reuss, p. 154, pl. 8, fig. 6.
1932a. *Cristellaria angulata* (Reuss) – Heron-Allen and Earland, p. 392, pl. 12, figs. 22, 23.
1954b. *Lenticulina* species Feyling-Hanssen, p. 191, pl. 1, figs. 11–13.

The test of the present specimens is small and delicate, somewhat elongate, planispiral, involute, not umbonate, with a tendency towards uncoiling in some specimens, bilaterally symmetrical, compressed, peripheral edges of the chambers usually straight, forming an angled margin to the test, periphery edge subacute to rounded; chambers 4 to 5, increasing quite rapidly in height as added; sutures distinct, slightly depressed and slightly curved; wall calcareous hyaline with radiate structure, surface smooth; aperture radiate, at the dorsal angle, with a very short robuline slit.

Length of specimen of figure 10, 0.30 mm, breadth 0.19 mm, thickness 0.11 mm. Length of specimen of figure 9, 0.27 mm, breadth 0.19 mm, thickness 0.12 mm. Other specimens varied in lengths between 0.24 mm and 0.27 mm.

Occurrence. – This species was met with in all the foraminiferal zones of the Late Quaternary of the Oslofjord area, except zone G, only a single or a few specimens per sample. It was most common in samples from the zones B, C, and D, i. e., in the Early Holocene.

Remarks. – The specimens from the Late Quaternary of the Oslofjord area are in good accordance with the forms recorded by Heron-Allen and Earland (1932a, p. 392) from off the south coast of the Falkland Islands at a depth of 135 m. They agree also in size.

This form is considerably smaller than the form described by Reuss (1851, p. 154) from the Tertiary of Silesia in northern Germany. The Tertiary form has a length of 0.9–1.0 mm, it is less elongate and has 7 chambers.

Lenticulina (Robulus) cf. **convergens** Bornemann

Plate 9, figure 12

1855. *Cristellaria convergens* Bornemann, p. 327, pl. 13, figs. 16, 17.
1884. *Cristellaria convergens* Bornemann – Brady, p. 546, pl. 69, figs. 6, 7.

The present specimen of this species is broadly lenticular, umbonate, but somewhat elongate in side view, periphery subacute, not carinate; chambers 8 in the last-formed whorl; sutures rather indistinct, oblique, slightly curved; wall densely and finely perforate, semitranslucent, glistening; aperture at the peripheral margin of the narrow apertural face, radiate, vertically elongate.

Length, or greatest diameter, of the specimen of figure 12, 0.65 mm, thickness 0.32 mm.

Occurrence. – One specimen of the present species occurred in the Post Glacial zone E of boring no. 5 at Bekkelaget, Oslo.

Remarks. – The present specimen resembles the two figured by Brady (l.c.) from the North Pacific and from Juan Fernandez. Together with these it differs from *Cristellaria convergens* Bornemann in having more chambers and in posessing a radiate aperture. About the chambers Bornemann (1855, p. 327) wrote: "Kammern breit, 5 bis 7, wovon die 5 ersten den involuten Theil des Gehäuses bilden.", and about the aperture (l.c.): "Die Mündung ist strahlenlos und befindet sich in der Spitze der allmälig verdünnten letzten Kammer."

Lenticulina (Robulus) cf. **gibba** (d'Orbigny)

Plate 9, figure 11

1839a. *Cristellaria gibba* d'Orbigny, p. 63, pl. 7, figs. 20, 21.
1884. *Cristellaria gibba* d'Orbigny – Brady, p. 546, pl. 69, figs. 6, 7.
1899. *Cristellaria gibba* d'Orbigny – Flint, p. 317, pl. 64, fig. 1.
1916b. *Cristellaria convergens* Bornemann – Heron-Allen and Earland (not *Cristellaria convergens* Bornemann, 1855), p. 262, pl. 42, figs. 12, 13.
1954a. *Robulus gibbus* (d'Orbigny) – Boltovskoy, p. 141, pl. 4, fig. 8.
1954a. *Robulus acutauricularis* (Fichtel and Moll) – Boltovskoy (not *Nautilus acutauricularis* Fichtel and Moll, 1798), p. 138, pl. 4, fig. 3.

The test of the present specimens is small, planispiral, bilaterally symmetrical, not umbonate, slightly elongate but quite broad in side view, periphery subacute, not carinate; chambers 6 to 7; sutures slightly depressed, curved; wall calcareous with radiate structure, finely perforate, translucent to hyaline; aperture radiate, with a short robuline slit.

Greatest diameter of the specimen of figure 11, from zone E of boring no. 48, Grønlandsleret, Oslo, 0.31 mm, thickness 0.14 mm. A specimen from zone D of boring no. 5 at Majorstuen, Oslo, had a greatest diameter of 0.27 mm, thickness 0.12 mm.

Occurrence. – This species was found in zone D, zone E, and lower part of zone F in the Holocene of the city of Oslo. It was very rare.

Remarks. – The specimen figured by d'Orbigny (l.c.) is more elongate than the present ones. The specimens figured by Flint (l.c.) agree well with the specimens from the Holocene of Oslo. *Robulus gibbus* recorded by Cushman (1933, p. 6, pl. 2, figs. 2, 6, 7) from the tropical Pacific is an umbonate form with a low apertural face.

Lenticulina (Robulus) limbosus chiriguanoi Boltovskoy
Plate 9, figure 14

1954a. *Robulus limbosus chiriguanoi* Boltovskoy, p. 143, pl. 5, figs. 1–5.

This subspecies is small, translucent to hyaline with a well-developed peripheral keel. Specimens with 6 and 7 chambers in the latest whorl occurred in the present material. The test is slightly evolute so that earlier whorls are visible through the glassy shell material of the central part.

Greatest diameter of the hypotype of figure 14, 0.45 mm, greatest thickness 0.19 mm. Greatest diameter of unfigured hypotypes varied between 0.32 mm and 0.76 mm.

Occurrence. – This subspecies was found in the Holocene of the Late Quaternary deposits in the Oslofjord area. It occurred in the middle part of zone F of boring no. 28, Fredrikstad Bridge, profile A, Fredrikstad and in zone F of boring no. 5 at Majorstuen, Oslo. It was found in zone E of boring no. 297 Nesset, and in the same zone of boring no. 3 and boring no. 48 at Grønland in the city of Oslo. It also occurred in zone D of boring no. 18 at Bryn, Oslo and in zone C of boring no. 5 at Majorstuen, Oslo. It was very rare.

Remarks. – *Lenticulina* (*R.*) *limbosus chiriguanoi* was described from the

Gulf of St. George (Golfo San Jorge) in Patagonia, latitude 46° South. It lived there at depths between 90 m and 98 m. The water temperature at a depth of 80 m was 7.8°–8.0° C and the salinity 32.09–32.36 ‰. The specimens from the Late Quaternary of the Oslofjord area are slightly larger than the South Argentinian form, the diameter of the latter varied between 0.2 mm and 0.5 mm. *Lenticulina* (*R.*) *limbosus limbosus* (Reuss) is a much greater species, diameter up to 2 mm, with a slight tendency to become uncoiled.

In his paper on the Recent fauna of southern Brazil, Boltovskoy (1959) included the present subspecies in the synonymy of *Robulus limbosus*.

Lenticulina (Robulus) orbicularis (d'Orbigny)
Plate 9, figure 13

1826. *Robulina orbicularis* d'Orbigny, p. 288, pl. 15, figs. 8, 9.
1899. *Cristellaria orbicularis* (d'Orbigny) – Flint, p. 317, pl. 64, fig. 3.
1954a. *Robulus orbicularis* (d'Orbigny) – Boltovskoy, p. 140, pl. 4, fig. 10.
1956. *Robulus orbicularis* (d'Orbigny) – Asano, p. 49, pl. 1, figs. 19, 21.

The present specimen of this species had only 6 chambers in the last-formed whorl.

The greatest diameter of the test measured 0.41 mm, thickness 0.19 mm.

Occurrence. – One specimen was found in the Post Glacial zone E of boring 21 at Onsøy.

Lenticulina (Robulus) rotulatus (Lamarck), forma **cultrata** Montfort
Plate 10, figures 1, 2

1808. *Robulus cultratus* Montfort, p. 214, 54ᵉ genre.
1839b. *Robulina subcultrata* d'Orbigny, p. 26, pl. 5, figs. 21, 22.
1888. *Cristellaria cultrata* Montfort – Brady, Parker and Jones, p. 224, pl. 44, fig. 13.
1923. *Cristellaria rotulata* (Lamarck)? – Cushman, Bull. 104, pt. 4, p. 108, pl. 28, figs. 1, 2 (not pl. 22, fig. 2).
1959. *Robulus rotulatus* (Lamarck), forma *cultrata* Montfort – Boltovskoy, p. 60, pl. 7, fig. 4.

This is an umbonate form with carinate or keeled periphery, usually not more than 8 chambers, and oblique and slightly curved sutures.

Greatest diameter of the figured specimen, 0.89 mm, thickness 0.43

mm. Unfigured specimen from lower part of zone F of boring no. 48, Grønlandsleret, Oslo, had a greatest diameter of 0.51 mm, thickness 0.24 mm. Another unfigured specimen from the lower part of zone F of boring no. 20, Nationaltheateret, Oslo, measured: greatest diameter, 0.92 mm, thickness 0.45 mm.

Occurrence. – This form was found only in the Post Glacial zone F of the Oslofjord area. It was rare.

Remarks. – In a way this form was already separated from the typical *Lenticulina (Robulus) rotulata* by Cushman (1923, p. 108), who described "*Cristellaria rotulata* (Lamarck)?" as strongly umbonate, carinate, the last coil being composed of few, usually not more than 7 or 8, chambers. Boltovskoy (1959, p. 60) considered *Robulus cultratus* Montfort and *Robulina subcultrata* d'Orbigny as junior synonyms of *Robulus rotulatus*. The development of a keel he considered a morphological character referable to the taxonomical category "forma" only.

It is probably this form which Buch (1955, p. 608) recorded from the Eem (Riss/Würm) Interglacial of Inder Bjergum west of Ribe in southwestern Jutland, Denmark.

Subgenus *Marginulinopsis* Silvestri, 1904

Lenticulina (Marginulinopsis) linearis (Montagu)

Plate 10, figures 4–9.

1808. *Nautilus linearis* Montagu, p. 87, pl. 30, fig. 9.
1858. *Dentalina legumen* (Linné), var. *linearis* (Montagu) – Williamson, p. 23, pl. 2, figs. 46–48.
1865. *Vaginulina linearis* (Montagu) – Parker and Jones, p. 343, pl. 13, figs. 12, 13 (fragments only).
1884. *Vaginulina linearis* (Montagu) – Brady, p. 532, pl. 67, figs. 10–12.
1894. *Vaginulina linearis* (Montagu) – Goës, p. 66, pl. 12, fig. 664.
1899. *Vaginulina linearis* (Montagu) – Flint, p. 314, pl. 61, fig. 1.
1900–1901. *Dentalina communis* d'Orbigny – Brøgger, p. 436, 520.
1923. *Vaginulina linearis* (Montagu) – Cushman, Bull. 104, pt. 4, p. 137, pl. 16, figs. 7–9 (Williamson's figures).
1923. *Vaginulina americana* Cushman, Bull. 104, pt. 4, p. 135, pl. 38, figs. 3, 4.
1960. *Vaginulina americana* Cushman – Barker, pl. 67, figs. 10–12.

The present specimens are very similar to the original description and figure. The number of chambers varied between 9 and 15, and the longitudinal striation was variably developed. Specimens with an initial spine and specimens with broadly rounded base intermingled. As illustrated by the figured specimens transitional forms occurred between the extremes. The planispiral arrangement of the early chambers was more or less pronounced.

The length of the present specimens ranged between 2.08 mm and 4.00 mm. The greatest breadth of the longest specimen (unfigured) was 0.56 mm, greatest thickness 0.51 mm. At about 1/3 of the length, reckoned from the initial end, the breadth of this specimen was 0.49 mm and the thickness 0.41 mm. The smallest specimen (unfigured), with length 2.08 mm, was 0.41 mm broad and 0.35 mm thick throughout the length.

Occurrence. – The present specimens were collected by E. B. Münster in *Upper Tapes beds* at four localities at Brevik, south of Skien, viz., Lunde, Rydningen, Jettegryten, Isdammen, and in *Lower Tapes beds* at Smedholmen and Trosvik, also by Brevik. They were identified as *Dentalina communis* d'Orbigny by Münster in a posthumous manuscript, and published under this name by Brøgger (1900–1901, p. 436 and 520). Reexamination of the specimens involved their transferrence to *Lenticulina (Marginulinopsis) linearis* (Montagu).

The Tapes beds, in Brøgger's stratigraphy, should probably be considered as littoral equivalents to sediments of zone F.

Remarks. – The genus *Vaginulina* (d'Orbigny, 1826, p. 257) is characterized by an elongate, laterally compressed test which is uniserial and somewhat rectilinear throughout (Cp. Bartenstein, 1948, p. 51). Having a spiral (*Lenticulina*-like) initial part and an only very slightly compressed oral end, the present species does not belong to this genus, but should be transferred to the subgenus *Marginulinopsis* of the genus *Lenticulina*. *Marginulinopsis* (Silvestri, 1904, p. 253) is characterized by a planispiral, laterally compressed (*Lenticulina*-like) early part which is small in proportion to the whole test, and an uncoiled somewhat rectilinear later part with round, almost circular, transverse section.

Cushman (1923, p. 135) erected the new species *Vaginulina americana* for specimens with broadly rounded initial end and showing a tendency towards coiling in the earliest part of the test. Flint (1899, pl. 61, fig. 1) figured five specimens which agree very well with Cushman's, and which Cushman also included in his synonymy of *V. americana*. The uppermost of Flint's figured specimens shows a slight initial point, however. Cushman (l.c., p. 137) regarded specimens with pointed initial end "initial end pointed with a short spine" as belonging to *Vaginulina linearis* (Montagu). He also mentioned that the earlier chambers of this latter species were somewhat compressed but not that any tendency toward coiling was present. The occurrence of spines is generally a vague character on which to base a species and the coiling in the earliest part of the test may have been overlooked in some specimens; in others, presumably megalospheric specimens, it does not occur.

In Münster's collection from the Post Glacial of Brevik typical *V. americana* intermingled, with transitions, with as typical *V. linearis*. The writer therefore feels compelled to suppress *Vaginulina americana* Cushman as a junior synonym of *V. linearis* (Montagu), and, for reasons mentioned above, transfer this species to the subgenus *Marginulinopsis*. Barker (1960, p. 142, pl. 67, figs. 10–12) transferred Brady's figures of *Vaginulina linearis* from the Challenger expedition (1884, pl. 67, figs. 10–12) to *V. americana* because Cushman (1923) put this record in the synonymy of his new species. However, for some reason the same record is also found in the synonymy of *V. linearis* (Cp. Cushman 1923, p. 137).

Cushman regarded *V. linearis* as being restricted to the European side of the North Atlantic and *V. americana* to the American side. Considering the two as conspecific, the Recent distribution of *Lenticulina (Marginulinopsis) linearis* (Montagu) seems to be the North Atlantic, where it has been collected to a depth of approximately 2000 m (southeast of Cape Cod). The northernmost record is from Lofoten on the Norwegian coast, Latitude 68° N, where it was obtained from a depth of 500 m (Kiær 1900, p. 37). M. Sars found it at Bygdø in the innermost part of the Oslofjord, at 40 m depth, and at Drøbak, at 100 m depth (Kiær, l.c.). Brady (1884, p. 533) recorded it also from South America, off Culebra Island, at a depth of 713 m.

Genus Marginulina d'Orbigny, 1826
Marginulina glabra d'Orbigny
Plate 10, figure 3

1826. *Marginulina glabra* d'Orbigny, p. 259, Modèles, No. 55.
1865. *Marginulina glabra* d'Orbigny – Balkwill and Wright, p. 344, pl. 12, figs. 24, 25.

The figured specimen from the middle part of zone F of boring no. 28, Fredrikstad Bridge, profile A, Fredrikstad, has 9 chambers, proloculus included. Only two of the subsequent chambers in the spiral part of the test is in contact with proloculus. The whole test is somewhat twisted. A specimen from the lower part of zone F of this boring resembled the variety *obesa* Cushman (1923, p. 128, pl. 37, fig. 1) in form but not in size.

Length of figured hypotype, 1.25 mm, greatest breadth (diameter) 0.32 mm. Length of the other specimen mentioned above, 0.71 mm, breadth 0.30 mm.

Occurrence. – This species occurred in the middle and lower parts of zone F of boring no. 28, Fredrikstad, and boring no. 1 (F 226), Skøyen, Oslo. It was very rare.

Remarks. – The typical form of *Marginulina glabra* is recorded from numerous Recent stations about the British Isles, whereas the var. *obesa*, according to Cushman is distributed on the western side of the Atlantic. The specimen from southern Brazil, figured by Boltovskoy (1959, p. 63, pl. 7, fig. 1) seems to belong to this variety.

Genus Pandaglandulina Loeblich and Tappan, 1955 a
Pandaglandulina sp.
Plate 11, figures 1, 2

Test small, fusiform with chambers much overlapping, uniserially arranged with slightly arcuate axis; sutures slightly depressed; wall calcareous, hyaline with smooth surface; aperture terminal, radiate.

Length of specimen of figure 1, 0.38 mm, greatest breadth 0.25 mm. Length of specimen of figure 2, 0.27 mm, greatest breadth 0.20 mm.

Occurrence. – A few specimens of this species occurred in zone C and subzone F_1 at Skøyen (F 175), Oslo.

Genus Lagena Walker and Boys, 1784
Lagena apiopleura Loeblich and Tappan
Plate 11, figure 3

1953. *Lagena apiopleura* Loeblich and Tappan, p. 59, pl. 10, figs. 14, 15.
1963. *Lagena acuticosta apiopleura* Loeblich and Tappan – Bandy and Kolpack, p. 164, text fig. 31 B, 12.

Length of specimen of figure 3, 0.41 mm, width 0.29 mm.

Occurrence. – This species was rare in the Late Quaternary of the Oslofjord area. One specimen occurred in subzone B_1 of boring no. 1 in Sandefjord, another one in zone E of boring no. 5 of the same locality. It was found in the upper part of zone F in boring no. 2, profile B, Fredrikstad and in a similar stratum at Nesset south of the city of Oslo.

Loeblich and Tappan described this form from Alaska and Greenland.

Lagena clavata (d'Orbigny)
Plate 11, figure 4

1846. *Oolina clavata* d'Orbigny, p. 24, pl. 1, fig. 2.
1940. *Lagena clavata* (d'Orbigny) – Buchner, p. 416, pl. 2, figs. 28–30 (with extensive synonymy).
1954a. *Lagena clavata* (d'Orbigny) – Boltovskoy, p. 150, pl. 6, fig. 4.
1956. *Lagena clavata* (d'Orbigny) – Asano, p. 28, pl. 5, figs. 3, 8.

The figured specimen was broken at the apertural end. The figured part of the test had a length of 0.54 mm, width 0.13 mm. Unfigured specimen had a length of 0.67 mm, width 0.18 mm.

Occurrence. – Very rare in the Late Quaternary of the Oslofjord area. It was found only in Holocene deposits, one specimen in the upper part of zone B in boring no. 1, Rakkestad, a few in zone E and subzone F_{II} of boring no. 297 at Nesset, some in subzone F_{II} and F_{III} in Sanderjord and a few in subzone F_{II} and zone G of boring no. 2, profile C and in boring no. 2, profile B, Fredrikstad. It occurred also in zone F and G at Onsøy.

Remarks. – Brotzen (1951, p. 62) recorded this species from zone 7, the youngest Post Glacial zone of the boring at Surte, Southwest Sweden, and Jones (1895, part 2 of Jones, Parker and Brady, 1866–1897, p. 182) found it in the Coralline Crag at Sutton. *Lagene parri* Loeblich and Tappan, 1953, resembles this species but is more globose.

Lagena curvilineata Balkwill and Wright
Plate 11, figure 5

1885. *Lagena curvilineata* Balkwill and Wright, p. 338, pl. 14, figs. 21–24.
1913a. *Lagena curvilineata* Balkwill and Wright – Heron-Allen and Earland, p. 78, pl. 6, fig. 7.

The hypotype of figure 5 had a length of 0.57 mm, breadth 0.24 mm.

Occurrence. – A single specimen occurred in a sample of Cardium clay from Torshov, Oslo, probably referable to the transition between the Holocene, foraminiferal zones E and F. Another specimen occurred in subzone F_{II} of boring no. 31 (O 1–33) at Akerselva, Oslo, and one in the same subzone of boring no. 2, profile C, Fredrikstad.

Remarks. – Balkwill and Wright described this species from the Irish Sea where they obtained a few specimens from deep water. Cushman (1923, p. 13) did not find it in his material from the North Atlantic, and assumed that it was limited to the region of the British Isles.

Lagena distoma Parker and Jones, MS., Brady
Plate 11, figures 6–8

1857. *Lagena laevis* Walker and Montagu, var. *striata* Parker and Jones, p. 278, pl. 11, fig. 24.
1864. *Lagena distoma* Parker and Jones, MS. – Brady, p. 467, pl. 48, fig. 6.
1865. *Lagena sulcata* Walker and Jacob, var. *distoma* Parker and Jones, p. 356, pl. 13, fig. 20.
1884. *Lagena distoma* Parker and Jones – Brady, p. 461, pl. 58, figs. 11–15.
1894. *Lagena distoma* (Parker and Jones) Brady – Göes, p. 77, pl. 13, fig. 739.
1899. *Lagena distoma* Parker and Jones – Flint, p. 306, pl. 53, fig. 5.
1900. *Lagena distoma* Brady – Kiaer, p. 38.
1923. *Lagena distoma* Parker and Jones – Cushman, p. 14, pl. 3, fig. 3 (not fig. 2).
1953. *Lagena mollis* Cushman – Loeblich and Tappan, p. 63, pl. 11, fig. 26.
1954b. *Lagena elongata distoma* Parker and Jones – Feyling-Hanssen, p. 190, pl. 1, fig. 7.
1959. *Lagena distoma* Parker and Jones – Boltovskoy, p. 68, pl. 9, fig. 17.

The original description of this form runs (Parker and Jones, 1857, p. 279): "– – the body of the "flask" is still more cylindrical (than in fig. 23 of their *Lagena laevis* Walker and Montagu), the neck is shorter, the surface has several parallel ribs, and the base is perforate."

The specimens from the Late Quaternary of the Oslofjord area are very elongate with parallel or nearly parallel sides, and are thus very similar to the original description and illustration.

Length of the specimen of figure 7, 1.40 mm, breadth 0.14 mm. Length of specimen of figure 8, 1.38 mm, breadth 0.11 mm, this specimen was broken at both ends. Length of specimen of figure 6, 0.57 mm, breadth 0.08 mm, broken.

Occurrence. – *Lagena distoma* was rare in the Late Quaternary of the Oslofjord area. A few specimens occurred in Late Glacial assemblages and a few in Post Glacial. It was not observed in zone A and not in zone G. Kiær (1900, p. 54) recorded a few specimens in a sample of Arca clay zone C) from Øvre Foss in the city of Oslo (Cp. Brøgger, 1900–1901, p. 161).

Remarks. – The observation made about this form by Parker and Jones (1857, p. 279 and 1865, p. 356) that it is open at both ends, is obviously due to imperfect preservation of their specimens. Cushman (1923, p. 4 and 15) found that in completely preserved specimens of these delicate tests the extended basal end is always closed (Cp. Loeblich and Tappan, 1953, p. 63).

The common ornamentation in the present specimens consists of fine longitudinal ribs, rather few in number, which die out at the beginning of the neck. But there occur in my material specimens of this form ornamented with numerous ribs. *L. distoma* ordinarily attains a considerable length, but smaller individuals also occurred.

The present form was originally described from the northern coast of Norway, between Trondheim and North Cape, at depths between 100 m and 600 m. There are records from both sides of the Atlantic (Cushman, 1923, p. 14).

Lagena elongata (Ehrenberg)
Plate 11, figure 9

1844. *Miliola elongata* Ehrenberg, p. 274.
1884. *Lagena clavata* (Ehrenberg) – Brady, p. 457, pl. 56, fig. 29.
1884. *Lagena gracillima* (Seguenza) – Brady (not *L.gracillima* Seguenza, 1862), pl. 56, figs. 27, 28.
1899. *Lagena elongata* (Ehrenberg) – Flint, p. 306, pl. 53, fig. 1.
1901. *Lagena elongata* (Ehrenberg) – Millett, pt. 11, p. 492, pl. 8, fig. 10.
1940. *Lagena elongata* (Ehrenberg) – Buchner, p. 413, pl. 2, figs. 23, 24.
1950. *Lagena elongata* (Ehrenberg) – Cushman and McCulloch, p. 338, pl. 44, fig. 14.

Very few specimens referable to this species occurred in the Late Quaternary of the Oslofjord area. One specimen was found in zone D, Bryn, Oslo, a few in zone F in some localities. The broken specimen of figure 9 is 0.89 mm long and 0.14 mm wide. It occurred in the upper part of zone F of boring no. 28, profile A, Fredrikstad.

Lagena cf. **gracilis** Williamson
Plate 11, figure 10

1848. *Lagena gracilis* Williamson, p. 13, pl. 1, fig. 5.
1863a. *Lagena gracilis* Williamson – Reuss, p. 331, pl. 4, figs. 58–61; pl. 5, fig. 62.
1884. *Lagena gracilis* Williamson-Brady, p. 464, pl. 58, figs. 2, 3, 7, 8, 23.
1896. *Lagena gracilis* Williamson – Jones (in Jones, Parker and Brady 1866–1897), p. 189, pl. 7, fig. 6.
1901. *Lagena gracilis* Williamson – Millett, pt. 11, p. 492, pl. 8, fig. 13 (not figs. 12 and 14).
1923. *Lagena gracilis* Williamson – Cushman, Bull. 104, pt. 4, p. 22, pl. 4, figs. 3, 4 (with extensive synonymy).
1943. *Lagena gracilis* Williamson – Hessland, pl. 2, fig. 22.
1954a. *Lagena gracilis* Williamson – Boltovskoy, p. 151, pl. 6, fig. 12.

The striation of the present specimens is probably somewhat dense for the species, but, according to the original description the striae are well defined over the greater, basal, part of the test, becoming less distinct towards the upper portion.

Length of the figured specimen, 0.42 mm, width 0.15 mm. This specimen was from zone E of boring no. 5 in Sandefjord. An unfigured specimen from zone F of the same boring was 0.57 mm long.

Occurrence. – Very rare in the Late Quaternary of the Oslofjord area. It was found only in zone F and E of the Holocene. In addition to the above-mentioned occurrence one specimen was found in subzone F_u of boring no. 2, profile B, Fredrikstad, and in the subzones F_m and F_u of boring no. 22 at Valle.

Remarks. – Madsen (1895a, p. 193) found this form in the Danish Pleistocene and Jones (in Jones, Parker, and Brady, 1866–1897, p. 189) found one specimen in the Coralline Crag at Tattingstone. Crosskey and Robertson (1868, p. 361) recorded it from a clay bank 1 m to 10 m above sea level at Trondstad on the island of Håøya near Drøbak, Oslofjord.

Buchner (1940, p. 426, pl. 4, figs. 62, 63) described and figured an entirely different form as *L. gracilis.*

Lagena gracillima (Seguenza)
Plate 11, figure 11

1862. *Amphorina gracillima* Seguenza, p. 51, pl. 1, fig. 37.
1884. *Lagena gracillima* (Seguenza) – Brady, p. 456, pl. 56, figs. 21, 22, 25, 26; 20 ?, 24 ?
1923. *Lagena gracillima* (Seguenza) – Cushman, Bull. 104, pt. 4, p. 23, pl. 4, fig. 5 (with extensive synonymy).
1940. *Lagena gracillima* (Seguenza) – Buchner, p. 415, pl. 2, figs. 25–27.

Length of hypotype of figure 11, 0.78 mm, width 0.14 mm.

Occurrence. – This species was found only in the Holocene of the Oslofjord area, in the zones C to G. It was present in most borings but usually represented by one or a few specimens.

Remarks. – Crosskey and Robertson (1868) found this species in Holocene deposits in the city of Oslo and Madsen (1895a) recorded it from the Pleistocene of Denmark.

Lagena hispidula Cushman
Plate 11, figure 12

1913. *Lagena hispidula* Cushman, Bull. 71, pt. 3, p. 14, pl. 5, figs. 2, 3.
1950. *Lagena hispidula* Cushman – Cushman and McCulloch, p. 339, pl. 45, figs. 8–10.
1960. *Lagena hispidula* Cushman – Barker, pl. 56, figs. 10, 11.

Length of the specimen of figure 12, 0.53 mm, width 0.28 mm. A specimen from zone E of boring no. 5, Sandefjord, had a length of 0.35 mm, width 0.22 mm – a part of the apertural neck was broken away.

Occurrence. – Single specimens of this species occurred in the Post Glacial zone E of boring no. 5 in Sandefjord, and at Bekkelaget. Another specimen was found in the lower part of zone F of boring no. 2, Fornebo, and a few in zone E-deposits at Lodalen, Oslo.

Remarks. – A comparison of the holotype of this species with the holotype of *Lagena hispida* Reuss (1858, p. 434; 1863a, p. 335, pl. 6, figs. 77–79) would probably prove that they are identical, in what case Reuss' species would take priority.

Lagena laevis (Montagu)
Plate 11, figures 13–15

1803. *Vermiculum laeve* Montagu, p. 524.
1848. *Lagena laevis* (Montagu) – Williamson, p. 12, pl. 1, figs. 1, 2.
1865. *Lagena sulcata* Walker and Jacob, var. *laevis* Montagu – Parker and Jones, p. 349, pl. 16, fig. 9 a.
1863a. *Lagena vulgaris* Williamson – Reuss, p. 321, pl. 2, fig. 16 (pl. 1, fig. 15 ?; pl. 2, fig. 17 ?).
1866, 1896. *Lagena laevis* (Montagu) – Jones, Parker, and Brady, p. 33, p. 181, pl. 1, fig. 28.
1933. *Lagena laevis* (Montagu) – Cushman, Bull. 161, p. 19, pl. 4, fig. 5.
1943. *Lagena laevis* (Montagu) – Hessland, pl. 2, fig. 18 (not fig. 19).
1950. *Lagena laevis* (Montagu) – Cushman and McCulloch, p. 341, pl. 45, fig. 16 (not figs. 14 and 15).
1953. *Lagena laevis* (Montagu) – Loeblich and Tappan, p. 61, pl. 11, figs. 5–8.

Length of hypotype of figure 13, 0.62 mm, width 0.24 mm. Length of hypotype of figure 14, 0.57 mm, width 0.24 mm; the end of the apertural neck was broken off. The specimen of figure 15 had scattered white-ringed pores in its test, in addition to the normal perforation. Its length was 0.61 mm, width 0.22 mm.

Occurrence. – This smooth, shining, usually hyaline species was not seldom in the Late Quaternary of the Oslofjord area. It occurred in Holocene deposits from zone B through F, occasionally even in zone G-assemblages. It was always represented only by a few specimens.

Remarks. – Montagu (1803, pt. 2, p. 524) emphasized the smooth oval flask form of this species and added: "very transparent like glass". Brady (1884) in his Challenger Report did not figure any typical specimen of this species, nor did Cushman, neither from the Pacific (Bull. 71) nor from the Atlantic (Bull. 104). Buchner (1940), who fused together a considerable number of Lagenids under this name, did not figure a single one referable to the original description or to the original figures given by Williamson.

L. laevis is previously recorded from the Late Quaternary of Norway (Kiær, 1900, p. 37; Feyling-Hanssen, 1954 a, p. 129; 1954 b, p. 191, pl. 1, fig. 8), Sweden (Hessland, 1943, pl. 2, fig. 18), and from the Pleistocene of Denmark (Madsen, 1895 a, p. 190; Buch, 1955, p. 608).

Lagena mollis Cushman

Plate 11, figures 16–19

1940. *Lagena distoma* Parker and Jones – Buchner, p. 414, pl. 2, figs. 20–22.
1943. *Lagena elongata distoma* Parker and Jones – Hessland, p. 156, 262, pl. 2, fig. 28.
1944. *Lagena gracillima* (Seguenza), var. *mollis* Cushman, p. 21, pl. 3, fig. 3.
1953. *Lagena mollis* Cushman – Loeblich and Tappan, p. 63, pl. 11, figs. 25, 27.
1954a. *Lagena elongata distoma* Parker and Jones – Feyling-Hanssen, p. 129, pl. 1, fig. 9.

The present form differs from *Lagena distoma* in its inflated central part, the sides of the test not being parallel. "Mollis" means tender, graceful, which is in good accordance with the appearance of the test. It is usually smaller than *Lagena distoma*.

Length of the specimen of figure 17, 0.70 mm, breadth 0.13 mm, a part of it was broken off. Length of specimen of figure 18, 0.69 mm, breadth 0.11 mm, broken. Length of specimen of figure 19, 0.73 mm, breadth 0.11 mm. Length of specimen of figure 16, 0.78 mm, breadth 0.12 mm.

Occurrence. – This form occurred in most samples from the Late Quaternary of the Oslofjord area, not frequent, however, 1–20 specimens per sample on an average. It was more common in the middle units of the foraminiferal zonation than in zone A and G.

Remarks. – Transitional forms may probably occur between *Lagena* *mollis* Cushman and *Lagena distoma* Parker and Jones, and as the basal end of completely preserved specimens of the latter is closed and not open (Cp. p. 286), *Lagena mollis* could hardly be maintained as a distinct species, but merely as a form of *Lagena distoma*. With the present material, however, there never arose any doubt about whether to place a specimen in *L. distoma* or in *L. mollis*. The two groups are therefore here kept as two distinct species.

Lagena nebulosa Cushman
Plate 12, figure 1

1884. *Lagena laevis* (Montagu) – Brady (not *Lagena laevis* (Montagu, 1803)), pl. 56, fig. 12.
1923. *Lagena laevis* (Montagu), var. *nebulosa* Cushman, Bull. 104, pt. 4, p. 29, pl. 5, figs. 4, 5.
1940. *Lagena nebulosa* (Cushman) – Buchner, p. 421, pl. 2, fig. 32 (fig. 31 ?).
1960. *Lagena nebulosa* Cushman – Barker, pl. 56, fig. 12.

Three specimens referable to this species were found in the Post Glacial of the Oslofjord area, viz., one in zone E of boring no. 31 (O 1–33) at the river Akerselva in Oslo, one in the lower part of zone F of boring no. 1 (F 226) at Skøyen (fig. 1), Oslo, and one in the upper part of zone F of boring no. 2, profile C, Fredrikstad.

Length of the figured specimen 0.40 mm, width 0.13 mm, its apertural neck was partly broken off. An unfigured specimen had a length of 0.54 mm, width 0.22 mm.

Lagena semilineata Wright
Plate 12, figure 2

1886. *Lagena semilineata* Wright, p. 320, pl. 26, fig. 7.
1901. *Lagena semistriata* Williamson – Millett (not *Lagena striata*, var. β *semistriata* Williamson, 1848), pl. 8, fig. 3 (not fig. 2).
1950. *Lagena semilineata* Wright – Cushman and McCulloch, p. 345, pl. 46, fig. 11 (with extensive synonymy list).
1953. *Lagena semilineata* Wright – Loeblich and Tappan, p. 65, pl. 11, figs. 14–22.

Length of hypotype of figure 2, 0.60 mm, width 0.19 mm, it is a slender form and its apical spine is broken off near its base.

Occurrence. – This species was found once, viz., in the Pleistocene subzone A_m of boring no. 2, profile B, Fredrikstad.

Remarks. – The present form is less globose than *Lagena semistriata* Williamson, 1848, and possess a distinct apical spine, which is not present in *L. semistriata*.

Lagena semistriata Williamson

1848. *Lagena striata*, var. β, *semistriata* Williamson, p. 14, pl. 1, figs. 9, 10.

Only one specimen referable to this species occurred in the present material, viz., in subzone B_{II} of boring F 1 at Fornebo near Oslo. It was 0.41 mm long and 0.14 mm wide.

Lagena setigera Millett
Plate 12, figure 3

1901. *Lagena clavata* d'Orbigny, var. *setigera* Millett, p. 491, pl. 8, fig. 9.
1933. *Lagena perlucida* (Montagu) – Cushman (not *Vermiculum perlucidum* Montagu, 1803), Bull. 161, p. 20, pl. 4, figs. 6–8.
1953. *Lagena setigera* Millett ? – Loeblich and Tappan, p. 66, pl. 11, figs. 23, 24.
1953. *Lagena gracillima* (Seguenza) – Loeblich and Tappan (not *Lagena gracillima* (Seguenza, 1862)), pl. 11, fig. 3.

Length of hypotype of figure 3, 0.59 mm, width 0.15 mm. An unfigured specimen from subzone F_{II} of boring no. 297 at Nesset, south of Oslo, had a length of 0.41 mm, width 0.15 mm.

Occurrence. – This species was observed only in Post Glacial Warm Interval deposits in the Oslofjord area, viz., in subzone F_{III} of boring no. 5, Sandefjord, in subzone F_{II} of boring no. 2, profile C, Fredrikstad, in subzone F_{II} of borings at Onsøy, in the same subzone of boring no. 297 at Nesset, and in subzone F_{I} of boring no. 5, Majorstuen, Oslo. It was very rare.

Remarks. – Millett (1901, pl. 8, fig. 9) figured a long and slender form "having at the aboral end a cup-shaped indentation surrounded by a circle of setae" (l.c., p. 491), whereas the specimens figured by Loeblich and Tappan are short and globose. Their identification is therefore questioned here. On the other hand Loeblich and Tappan on plate 11, figure 3, figured a slender specimen with apical denticulation much resembling that of *L. setigera*. Cushman and McCulloch (1950, p. 343, pl. 46, figs. 3 and 4) figured two specimens of *L. setigera* under the name of *L. perlucida* (Montagu), a record which Loeblich and Tappan placed in the synonymy of *L. setigera*.

Together with the two above-mentioned, figures 3 and 4, Cushman and McCulloch (1950, pl. 46) figured two other specimens, figures 1 and 2, as *Lagena perlucida.* Similar figures are scattered through the literature of Foraminifera, quite constantly referred to *Lagena perlucida* (Montagu). They have very little in common with Montagu's original description of *Vermiculum perlucidum* (1803, p. 525) or his drawing of the same (pl. 14, fig. 3), which shows a globose *Lagena* with few (probably only 6) equidistant longitudinal costae extending over the whole inflated part of the test, from the basal knob to the base of the apertural neck. Williamson (1848, pl. 1, fig. 11) under the name *Lagena striata*, var. *perlucida* figured a specimen very similar to Montagu's figure (he observes, by the way, that Montagu had never seen the specimen which he described, only copied a drawing sent to him by Mr. Boys), but later on most of the specimens figured as *L. perlucida* would better belong with *L. semistriata* Williamson (1848, p. 14, figs. 9 and 10), or *L. setigera* Millett.

Lagena striata (d'Orbigny), forma **typica**

Plate 12, figures 4, 5

1839b. *Oolina striata* d'Orbigny, p. 21, pl. 5, fig. 12.
1863a. *Lagena striata* (d'Orbigny) – Reuss, p. 327, pl. 3, fig. 44 (not fig. 45); pl. 4, figs. 46, 47.
1884. *Lagena striata* (d'Orbigny) – Brady, p. 460, pl. 57, figs. 22, 24 (not 19, 23, 28, 29, 30).
1923. *Lagena striata* (d'Orbigny) ? – Cushman, Bull. 104, pt. 4, p. 54, pl. 10, fig. 9.
1940. *Lagena striata* (d'Orbigny) – Buchner, p. 424, pl. 4, figs. 58–61 (not figs. 54–57).
1951. *Lagena striata* (d'Orbigny) – van Voorthuysen, pl. 1, fig. 11.

Some specimens of this globose and densely striated form occurred with the present material. Length of the specimen of figure 4, 0.76 mm, width 0.38 mm. Length of specimen of figure 5, 0.57 mm, width 0.27 mm.

Occurrence. – This typical form of *L. striata* was found only in Holocene deposits of the Oslofjord area. It was often met with in Post Glacial Warm Interval deposits, zone F, a few specimens per sample. It occurred also in zone E, but only occasionally in zone B and C.

Remarks. – Cushman (1923, pl. 10, fig. 9) figured a broad-costate specimen which seems to belong rather with *Lagena filicosta* Reuss (= *Lagena striata* Williamson, 1848, pl. 1, figs. 6 and 8).

Among the present specimens there are some in which the striae, or costae, over the main body of the test continue longitudinally along the apertural neck and a few in which they are spirally wound around it, as described by Williamson (1848, p. 14). Narrower transitional forms, leading over to *L. striata* forma *substriata* occurred.

Lagena striata (d'Orbigny), forma **substriata** Williamson
Plate 12, figure 6

1848. *Lagena substriata* Williamson, p. 15, pl. 2, fig. 12.
1858. *Lagena vulgaris* Williamson, var. *substriata* Williamson, p. 7, pl. 1, fig. 14.
1940. *Lagena striata* (d'Orbigny) – Buchner, p. 424, pl. 4, figs. 54–57.
1950b. *Lagena substriata* Williamson, – van Voorthuysen, p. 55, pl. 1, fig. 9.

This slender form was more common with the present material than the typical one. The specimen of figure 6 is a small one, its length was 0.35 mm, width 0.10 mm. They were otherwise of almost the same size as the typical form.

Occurrence. – This form was more frequently met with in the Late Quaternary of the Oslofjord area than the typical one. It extends backward into the Pleistocene subzone A_m and may occur through the whole sequence, quite commonly in the upper part of zone F and even with lower zone G-assemblages.

Lagena sulcata sulcata Walker and Jacob

1798. *Serpula (Lagena) sulcata* Walker and Jacob, p. 634, pl. 14, fig. 5.
1899. *Lagena sulcata* Walker and Jacob – Flint, p. 307, pl. 53, fig. 7.
1923. *Lagena sulcata* Walker and Wright – Cushman, Bull. 104, pt. 4, p. 57, pl. 11, fig. 1 (with extensive synonymy).

A single specimen of this species was found in the Post Glacial subzone F_u of boring no. 2, profile B, Fredrikstad. It was 0.30 mm long and 0.14 mm wide.

Remarks. – Matthes (1939, p. 54), because of great variability in form and striation, united *L. sulcata* and *L. striata*, whereas Buchner (1940, p. 418) for similar reasons incorporated *L. sulcata* in *L. laevis*.

Lagena sulcata laevicostata Cushman and Gray
Plate 12, figure 7

1946a. *Lagena sulcata* (Walker and Jacob), var. *laevicostata* Cushman and Gray, p. 68, pl. 12, figs. 13, 14.
1946b. *Lagena sulcata* (Walker and Jacob), var. *laevicostata* Cushman and Gray – Cushman and Gray, p. 20, pl. 3, figs. 47, 48.
1950. *Lagena sulcata* (Walker and Jacob), var. *laevicostata* Cushman and Gray – Cushman and McCulloch, p. 361, pl. 48, figs. 8–10.

Length of specimen of figure 7, 0.47 mm, width 0.20 mm. Length of unfigured specimen from subzone F_u of boring no. 2, Lodalen, Oslo (F 45), 0.46 mm, width 0.21 mm. A long-necked specimen from the same sample had a length of 0.48 mm, width 0.17 mm.

Occurrence. – This subspecies was found only in younger Holocene deposits, viz., in zone F, occasionally even in shallow-water assemblages of zone G, of low-lying localities. It was rare.

Remarks. – This subspecies was originally described from the Pliocene of Timms Point, California, as a variety of *Lagena sulcata*, from which it differs in the elongate, tapering neck and the much higher plate-like costae, especially high over the base of the apertural neck. With the present material this form is very distinct, no transitional form between it and the typical *L. sulcata* was observed. With more specimens at hand for examination it should probably have been raised to specific rank.

Recent records of *L. sulcata laevicostata* are from tropical to temperate waters (Cushman and McCulloch, 1950, p. 361).

Genus Amphicoryna Schlumberger, 1881

Amphicoryna cf. **perversa** (Schwager)
Plate 12, figure 8

1866. *Nodosaria perversa* Schwager, p. 212, pl. 5, fig. 29.
1950. *Nodosaria* cf. *perversa* Schwager – Cushman and McCulloch, p. 318, pl. 41, figs. 26–32.

Test small, circular in section, slightly tapering towards the initial end, no distinct basal spine; chambers 3–5, uniserially, but somewhat irregularly arranged, inflated with broadly rounded, nearly flattened, basal parts; sutures distinct, depressed; wall calcareous hyaline with radiate structure, surface ornamented by longitudinal costae, less numerous on the last-formed chamber, the distal part of which is almost smooth; aperture terminal, at the end of a smooth, cylindrical neck.

Length of specimen of figure 8, 0.46 mm, greatest diameter 0.17 mm; the apertural end of the neck was broken off. A five-chambered specimen from the lowest part of subzone F_u of boring no. 2, profile C, Fredrikstad had a length of 0.53 mm, greatest diameter 0.16 mm.

Occurrence. – This species was found only in subzone F_u of two borings in Fredrikstad, vis., boring no. 3 at Glemmen Church and boring no. 2, profile C, at two levels.

Remark. – The specimen figured by Schwager (1866, pl. 5, fig. 29) had 6 chambers.

Amphicoryna scalaris (Batsch), forma **compacta** Parr
Plate 12, figure 9

1950. *Amphicoryna scalaris* (Batsch), var. *compacta* Parr, p. 328, pl. 11, fig. 24.

The test of the figured specimen is short and relatively thick, circular in section, with three chambers of approximately equal diameter. The surface is ornamented with numerous costae, most of which extend the full length of the test, slightly overhanging the base as a ring of spinous processes. The apertural neck is provided with horizontal costae and a distinct apertural lip.

Length of hypotype of figure 9, 0.57 mm, diameter 0.20 mm.

Occurrence. – This form was rare in the Holocene of the Oslofjord area. One specimen occurred in the uppermost part of zone D of boring no. 5 at Majorstuen, Oslo, and a small specimen, probably referable to this form, in the upper part of zone F of boring 297, Nesset.

Remarks. – The present variety differs from the typical *Amphicoryna scalaris* (= *Nodosaria scalaris*) in that it does not broaden in the later chambers and in that the longitudinal costae form a series of small, irregular spines at the base. The present variety has also no distinct basal spine, which is quite characteristic of the typical form (Cp. Buchner, 1940, pl. 1).

Parr (1950) described *A. scalaris*, var. *compacta* from the east and south coasts of Australia.

Family **POLYMORPHINIDAE** d'Orbigny, 1839
Genus Guttulina d'Orbigny, 1826
Guttulina dawsoni Cushman and Ozawa
Plate 12, figures 10, 11

1930. *Guttulina dawsoni* Cushman and Ozawa, p. 47, pl. 12, figs. 1, 2.
1960. *Guttulina dawsoni* Cushman and Ozawa – Barker, pl. 72, fig. 18.

Length of hypotype of figure 10, 0.98 mm, breadth 0.46 mm, thickness 0.35 mm. Length of hypotype of figure 11, 0.96 mm, breadth 0.38 mm, thickness 0.32 mm.

Occurrence. – This species was found in deposits of Pleistocene and earliest Holocene age. The figured specimens are from a sample collected 5 m below a terrace surface which was situated 40 m above present-day sea level at Tingsager Church, near Lillesand, southwest of the Oslofjord area. That deposit was of Late Pleistocene age. Other specimens occurred in subzone A_m of boring no. 3b at Borregaard and in subzone A_u of boring no. 22 at Valle. One specimen occurred also in zone D, boring no. 18 at Bryn, Oslo. The species was extremely rare.

Remarks. – *Guttulina dawsoni* seems to be a cold-water species (Cushman and Ozawa, p. 47). The present author found it in Recent bottom samples both in Spitsbergen and in East Greenland, at depths of 8 m–28 m. It occurred also in Holocene deposits in Spitsbergen.

Guttulina lactea (Walker and Jacob)
Plate 12, figures 12–14

1798. *Serpula lactea* Walker and Jacob, p. 634, pl. 14, fig. 4.
1858. *Polymorphina lactea* (Walker and Jacob) – Williamson, p. 70, pl. 6, figs. 145–152.
1930. *Guttulina lactea* (Walker and Jacob) – Cushman and Ozawa, p. 43, pl. 10, figs. 1–4.
1944. *Guttulina lactea* (Walker and Jacob) – Cushman, p. 22, pl. 3, figs. 10, 11.

Length of hypotype of figures 12–14, 0.73 mm, breadth 0.40 mm, thickness 0.30 mm. A specimen from subzone F_u of a boring at Onsøy, Østfold, had a length of 0.68 mm, breadth 0.28 mm, thickness 0.21 mm.

Occurrence. - This species occurred in Holocene deposits of the Oslofjord area, viz., in subzone A_u, zone E, F and a single specimen also in zone G. It was rare.

Genus Globulina d'Orbigny, 1826

Globulina inaequalis Reuss

Plate 12, figure 17; plate 13, figures 1, 2; text figures 42–44

1850. *Globulina inaequalis* Reuss, p. 377, pl. 48, fig. 9.
1884. *Polymorphina amygdaloides* (Reuss) – Brady, p. 560, pl. 71, fig. 13.
1894. *Polymorphina gibba* d'Orbigny – Goës, p. 55, pl. 9, figs. 520–522 and 525 and 526.
1930. *Globulina inaequalis* Reuss – Cushman and Ozawa, p. 73, pl. 18, figs. 2–4 (with extensive synonymy).
1946. *Globulina inaequalis* Reuss – van Bellen, p. 39, pl. 3, fig. 8.
1948. *Globulina inaequalis* Reuss – F. L. Parker, p. 222, pl. 1, fig. 8.
1954b. *Globulina caribaea* d'Orbigny – Boltovskoy (not *Globulina caribaea* d'Orbigny, 1839a), p. 271, pl. 23, fig. 7.
1957. *Globulina caribaea* d'Orbigny – Boltovskoy (part., not *Globulina caribaea* d'Orbigny, 1839a), p. 38, pl. 7, figs. 9, 10.
1960. *Globulina inaequalis* Reuss – Barker, p. 148, pl. 71, fig. 13.

The present specimens agree well with the original description and figures. Many fistulose forms occurred.

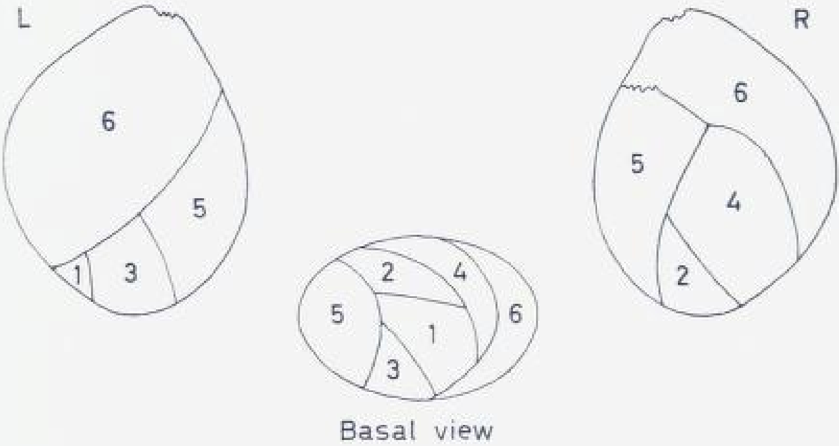
Length of the hypotype of figure 17, 0.89 mm, breadth 0.76 mm, thickness 0.54 mm. Length of hypotype of plate 13, figure 1, 0.96 mm, and length of the fistulose form (outgrowths not measured) of figure 2, 0.97 mm.

Occurrence. – The present species occurred in Münster's collection from Tapes beds at Brevik (Cp. p. 30) recorded by Brøgger (1900–1901, p. 436 and 520), who listed the smooth forms without outgrowths as *Polymorphina lactea*, and the fistulose forms as *Polymorphina horrida*. The Tapes beds are assumed to represent the littoral, or beach, equivalent to the clay sediments of zone F. *Globulina inaequalis* furthermore occurred in the upper part of zone F in boring no. 2, Fredrikstad, profile C.

Remarks. – The sutures of the present specimens are quite indistinct. The succession of chambers are therefore illustrated in text figures 42–44 with the chambers numbered, the figured specimen is the same as that of plate 12, figure 17.

Boltovskoy (1954b, p. 271; 1957, p. 33) suppressed *Globulina inaequalis* as a junior synonym of *Globulina caribaea* d'Orbigny. The latter species has its surface covered with a spiny ornamentation and its sutures considerably depressed. Cushman and Ozawa (1930, p. 75) considered *G. caribaea* as a variety of *G. inaequalis*.

G. inaequalis was originally described from the Tertiary of Austria. Its Recent distribution seems to be concentrated in temperate waters (Cp. Cushman and Ozawa, 1930, p. 74). Madsen (1895 a, p. 201) recorded



Figs. 42–44. *Globulina inaequalis*, side views and basal view, showing succession of chambers. × 46.

compressed forms of *Polymorphina lactea* Walker and Jacob from the Quaternary of Denmark and Holstein. He supposed that they were conspecific with *Polymorphina amygdaloides* Reuss and referred to Brady's Challenger record (1884, p. 560, pl. 71, fig. 13), but he did not distinguish them from more spherical forms.

Globulina landesi (G. D. Hanna and M. A. Hanna)
Plate 12, figures 15, 16

1924. *Polymorphina landesi* G. D. Hanna and M. A. Hanna, p. 60, pl. 13, figs. 16,17.
1930. *Globulina landesi* (G. D. Hanna and M. A. Hanna) – Cushman and Ozawa, p. 71.

The figured specimen had a length of 0.39 mm, breadth 0.30 mm, thickness 0.26 mm. Another specimen from the same sample measured: length 0.22 mm, breadth 0.21 mm, thickness 0.17 mm.

Occurrence. – This species was found only in Fredrikstad, three specimens at core level 14.2 m and one specimen at 15.7 m, of boring no. 2, profile B both samples within the upper part of the Post Glacial zone F of the Holocene. Another specimen occurred in subzone F_u of boring no. 2, profile C.

Remarks. – The two measured specimens were from the sample at core level 14.2 m. A third specimen from this sample was broken and revealed a rather thick wall, 0.024 mm in section. This specimen was not as long as the largest of the two measured ones, but considerably longer than the smallest. The inner 1/5 of the wall section was white to yellowish white, and of a dense structure, the median, and major, part was grayish white with radial structure, and exterially there was a thin, again more whitish, coating.

G. landesi was described from the Eocene of Lewis County, Washington, and was recorded also from Recent shore sand of the Sea of Japan (Cushman and Ozawa, 1930, p. 72).

Genus Pseudopolymorphina Cushman and Ozawa, 1928
Pseudopolymorphina novangliae (Cushman)
Plate 13, figure 3

1923. *Polymorphina lactea* (Walker and Jacob), var. *novangliae* Cushman, Bull. 104, pt. 4, p. 146, pl. 39, figs. 6–8.
1930. *Pseudopolymorphina novangliae* (Cushman) – Cushman and Ozawa, p. 90, pl. 23, figs. 1, 2.
1952a. *Pseudopolymorphina novangliae* (Cushman) – F. L. Parker, p. 410, pl. 5, fig. 1.

Length of hypotype of figure 3, 0.63 mm, greatest breadth 0.26 mm. Unfigured specimen from zone A at Moss, most probably upper part of the zone, had a length of 0.63 mm, breadth 0.25 mm.

Occurrence. – This species was rare. It occurred in subzone A_{II} of a boring at Moss, in the Late Pleistocene part of the boring at Halden, and in a Late Pleistocene raised marine terrace at Tingsager by Lillesand, southwest of the Oslofjord area.

Remarks. – Cushman and Ozawa (1930, p. 90) gave lengths from 1.15 mm to 1.95 mm for this species. F.L. Parker (1952 a, pl. 5, fig. 1) figured a 0.84 mm long specimen from New Hampshire, and (1952 b, pl. 3, fig. 11) a 0.74 mm long specimen from the Buzzards Bay.

Pseudopolymorphina suboblonga Cushman and Ozawa
Plate 13, figure 4

1930. *Pseudopolymorphina suboblonga* Cushman and Ozawa, p. 91, pl. 23, fig. 3.

Length of specimen of figure 4, 2.20 mm, breadth 0.68 mm, thickness 0.48 mm.

Occurrence. – A single specimen of this species was found in Münster's collection from an Upper Tapes bed, Jettegryten, at Brevik, a Post Glacial Warm Interval deposit.

Remarks. – The present specimen was twisted, the illustration gives an oblique edge-side view. It was recorded as *Polymorphina thoini* d'Orbigny.

Genus Sigmomorphina Cushman and Ozawa, 1928

Sigmomorphina undulosa (Terquem)

Plate 13, figures 5–8

1878. *Polymorphina undulosa* Terquem, p. 41, pl. 3, fig. 35.
1930. *Sigmomorphina undulosa* (Terquem) – Cushman and Ozawa, p. 131, pl. 34, figs. 4, 5.

The present specimens agree well with the original description and figures and with the specimens figured by Cushman and Ozawa (l.c.), but they are larger.

Length of hypotype of figures 7 and 8, 0.89 mm, breadth 0.62 mm, thickness 0.38 mm. Length of hypotype of figures 5 and 6, 0.77 mm, breadth 0.46 mm, thickness 0.27 mm. A third specimen, from the same sample as the two mentioned (Lower Tapes bed at Smedholmen), had a length of 0.99 mm, breadth 0.51 mm and thickness 0.35 mm. A specimen from Jettegryten measured: length 0.79 mm, breadth 0.38 mm, thickness 0.24 mm. Cushman and Ozawa gave 0.60 mm as maximum length for the species.

Occurrence. – This species occurred in a shell bed sample from Upper Tapes beds at Jettegryten by Brevik and in a Lower Tapes bed at Smedholmen, also at Brevik. The Tapes beds comprise littoral formations corresponding to sediments of zone F. It was found also in subzone F_u of boring no. 2, profile C, Fredrikstad.

Remarks. – The figured specimens were all collected by E. B. Münster and in a posthumous manuscript recorded as *Polymorphina compressa* d'Orbigny (Cp. p. 30 of the present paper and p. 436 and 520 in Brøgger's paper on the Late Glacial and Post Glacial changes of level, 1900–1901).

Sigmomorphina undulosa was dredged at the coast of Ireland, at Florida and at the coast of Brazil. It also occurred in Pliocene beds of Sutton, England (Cushman and Ozawa).

Genus Laryngosigma Loeblich and Tappan, 1953
Laryngosigma hyalascidia Loeblich and Tappan

1953. *Laryngosigma hyalascidia* Loeblich and Tappan, p. 83, pl. 15, figs. 6–8.

A specimen from zone G of boring no. 5 at Majorstuen, Oslo, had a length of 0.35 mm, breadth 0.17 mm, thickness 0.15 mm. Another specimen occurred in subzone A_1 of boring no. 13, Borregaard.

Genus Esosyrinx Loeblich and Tappan, 1953
Esosyrinx curta (Cushman and Ozawa

1930. *Pseudopolymorphina curta* Cushman and Ozawa, p. 105, pl. 27, fig. 3.
1953. *Esosyrinx curta* (Cushman and Ozawa) – Loeblich and Tappan, p. 85, pl. 15, figs. 1–5.

Like *Laryngosigma hyalascidia* this species was very rare in the Late Quaternary of the Oslofjord area. A few specimens occurred in zone G of boring no. 5 at Majorstuen, Oslo, and two specimens in zone E of boring no. 3, Risløkkveien, Ulvenveien, Oslo. The latter locality is situated 93 m above present-day sea level. One of the specimens from Majorstuen had a length of 0.36 mm, breadth 0.19 mm, thickness 0.12 mm.

Superfamily BULIMINOIDEA Jones, 1875
Family **BULIMINIDAE** Jones, 1875
Subfamily **Turrilininae** Cushman, 1927
Genus Buliminella Cushman, 1911
Buliminella elegantissima (d'Orbigny)
Plate 14, figure 1

1839b. *Bulimina elegantissima* d'Orbigny, p. 51, pl. 7, figs. 13, 14.
1884. *Bulimina elegantissima* d'Orbigny – Brady, p. 402, pl. 50, figs. 20–22.
1931. *Buliminella elegantissima* (d'Orbigny) – Cushman and Parker, p. 13, pl. 3, figs. 12, 13.
1947. *Buliminella elegantissima* (d'Orbigny) – Höglund, p. 215, pl. 18, fig. 1; text figs. 196, 197.
1954a. *Buliminella elegantissima* (d'Orbigny) – Boltovskoy, p. 173, pl. 8, figs. 9, 10.
1957. *Buliminella elegantissima* (d'Orbigny) – Todd and Bronnimann, p. 32, pl. 8, figs. 1, 2.
1960. *Buliminella elegantissima* (d'Orbigny) – van Voorthuysen, p. 250, pl. 11, fig. 10.

Length of hypotype of figure 1, 0.32 mm, breadth 0.14 mm.

Occurrence. – This very characteristic species was found in zone F and zone G of a few borings in the southern as well as in the northern part of the Oslofjord area. It was very rare.

Remarks. – *B. elegantissima* seems to be widely distributed in temperate to tropical coastal parts of Recent oceans. Höglund (1947, p. 215–218) found it in the Gullmarfjord on the Swedish west coast at depths between 8 m and 80 m, it seemed to prefer the shallowest areas and was entirely absent at depths exceeding 80 m. In the Skagerrak, however, it was obtained in bottom samples from depths between 66 m and 626 m. Buch (1955, p. 614) recorded this species from the uppermost part of the Esbjerg Yoldialer (Riss/Mindel Interglacial) of a boring at Inder Bjergum, Jutland in Denmark.

Subfamily **Buliminінae** Jones, 1875

Genus Bulimina d'Orbigny, 1826

Bulimina marginata d'Orbigny

Plate 14, figures 2–5

1826. *Bulimina marginata* d'Orbigny, p. 269, pl. 12, figs. 10–12.
1826. *Bulimina aculeata* d'Orbigny, p. 269.
1884. *Bulimina marginata* d'Orbigny – Brady, p. 405, pl. 51, figs. 3–5.
1884. *Bulimina aculeata* d'Orbigny – Brady, p. 406, pl. 51, figs. 7–9.
1947. *Bulimina marginata* d'Orbigny – Höglund, p. 227, pl. 20, figs. 1, 2; pl. 22, fig. 1; text figs. 205–218.
1959. *Bulimina marginata* d'Orbigny, forma *typica*, *echinata*, *aculeata*, and *subulata* – Boltovskoy, p. 77–79, pl. 10, figs. 3–17.

Length of hypotype of figure 2, 0.49 mm, breadth 0.29 mm. Length of hypotype of figure 3, 0.46 mm, breadth 0.27 mm. Length of hypotype of figure 4, 0.62 mm, breadth 0.36 mm. Length of hypotype of figure 5, 0.51 mm, breadth 0.37 mm. Unfigured specimens from subzone F_{II} of boring no. 1, Fornebo, had lengths from 0.62 mm to 0.65 mm.

Occurrence. – This species characterized and predominated Holocene, Post Glacial Warm Interval sediments of the Oslofjord area, zone F, acounting for 40 to 70 % of the fauna. It was quite frequent also in zone E. In zone D it was absent or occasionally represented by a single specimen. A few specimens occurred in zone C, in and around the city of Oslo. In zone B it occurred, sparsely, in the upper as well as in the lower part, being less rare in subzone B_{u} than in subzone B_{l}. Single specimens occurred even in some samples from the middle part of zone A.

Remarks. – Höglund (1947, p. 227–231), after detailed statistical investigation of *Bulimina marginata* concluded that this species displays great variation from very spiny specimens to such with only slight crenulation on the undercutting margins. Even individuals in which undercuttings were hardly observable occurred. *B. marginata* thus comprise many forms previously listed as distinct species, e. g. *B. aculeata*, *B. echinata*, *B. elongata*. Boltovskoy (1959, p. 77–79) reached a similar conclusion, but separated some of the older species as forms of *B. marginata*: *B. marginata* d'Orbigny, forma *typica* d'Orbigny, *B. marginata* d'Orbigny, forma *aculeata* d'Orbigny, *B. marginata* d'Orbigny, forma *echinata* d'Orbigny, *B. marginata* d'Orbigny, forma *subulata* Cushman and Parker (= *B. elongata* d'Orbigny, var. *subulata* Cushman and Parker).

Great variations occur in *Bulimina marginata* also among specimens from the very rich material from the Late Quaternary of the Oslofjord area. Most of the specimens are, however, quite close to *B. marginata*, forma *aculeata*, whereas *B. marginata*, forma *typica* was rare. In subzone F_{u} of boring F 1 at Fornebo an elongated, almost spineless, form occurred, referable to *Bulimina elongata* d'Orbigny or *B. elongata*, var. *subulata* (= *B. marginata*, forma *subulata* Cushman and Parker). Samples with this form of *B. marginata* contained many specimens of *Nonion labradoricum* and were thus probably of Recent (Sub-Atlantic) age. A similar tendency was found in the lowest part of zone G and uppermost part of subzone F_{u} of boring no. 2, profile B, in Fredrikstad. In both examples, however, broader and spinier forms occurred along with the elongated ones. Elongated forms also occurred in the deepest part of boring F 1, Fornebo, that part which was classified as subzone B_{u}, the very latest part of that subzone. Any general conclusion is here not drawn from these observation, as it is not known in detail what ecological factors affect development of spines and elongation of tests.

Bulimina marginata was particularly frequent in Recent bottom samples from the Gullmarfjord at depths exceeding 20 m, most numerous between 40 m and 50 m. In the Skagerrak it was most common at depths between 66 m and 250 m (Höglund, 1947, p. 228). It seems to be a form preferring temperate waters (Nørvang, 1945, p. 32). *B. marginata* has been recorded in Late Quaternary deposits from Norway (Sars, 1865, recorded as *Bulimina presli*; Kiær, 1900; Feyling-Hanssen, 1954 a, as characteristic of the Isocardia clay), Sweden (Brotzen, 1951), and Denmark (Madsen, 1895 a; Buch, 1955, who referred its occurrence also in Pleistocene and Pliocene deposits of some other countries).

Genus Globobulimina Cushman, 1927
Globobulimina auriculata arctica Höglund
Plate 14, figure 6

1947. *Globobulimina auriculata* (Bailey), forma *arctica* Höglund, p. 254, text figs. 266, 267, 270, 271.
1952b. *Globobulimina (Desinobulimina) auriculata* (Bailey), var. *arctica* Höglund – Phleger, p. 85, pl. 14, fig. 13.
1953. *Globobulimina auriculata* subsp. *arctica* Höglund – Loeblich and Tappan, p. 110, pl. 20, figs. 8, 9.

Length of the figured specimen from subzone B_l of boring no. 1, Sandefjord, 0.97 mm, breadth 0.59 mm. An unfigured specimen from the same sample had a length of 1.00 mm, breadth 0.58 mm. Another unfigured specimen from this sample had length 1.08 mm, breadth 0.62 mm, and a third one had length 1.13 mm, breadth 0.68 mm.

Occurrence. – This subspecies occurred i.a., in subzone B_l also of boring no. 5 in Sandefjord, in subzone A_m of boring no. 2, profile B, Fredrikstad, and in subzone A_m of boring no. 22, Valle. It was rare and seems to be restricted to Pleistocene and Early Holocene deposits in the Oslofjord area.

Remarks. – *Globobulimina auriculata arctica* has an abruptly and broadly rounded basal end with no spines or denticles. There is no suture immediately below the aperture in adult specimens. It is still there in young individuals, but disappears, little by little, so that in adult specimens it is usually not discernible. Höglund (1947, p. 237–254) made a very detailed investigation of the genus *Globobulimina.* The present subspecies was recorded in Recent bottom samples from Spitsbergen, Greenland, Arctic Canada and Alaska. Höglund (l.c., p. 254) observed that all Arctic specimens referred by Goës (1894) to *Bulimina ellipsoides*, belong to this form.

Globobulimina auriculata gullmarensis Höglund
Plate 14, figures 7, 8

1947. *Globobulimina auriculata* (Bailey), forma *gullmarensis* Höglund, p. 252 (p. 237–254) pl. 20, fig. 6; pl. 21, fig. 5; pl. 22, fig. 6; text figs. 258–265, 268, 269, 271.

The specimen on figure 7, from subzone F_m of boring no. 5, Sandefjord, had a length of 0.78 mm, breadth 0.46 mm. The specimen of figure 8, zone E of boring no. 297, Nesset, had a length of 0.81 mm, breadth 0.52 mm.

Occurrence. – This form occurred in many samples of Post Glacial age, usually represented by one or a few specimens per sample. A single specimen was found in subzone B_l of boring no. 22, Valle. Otherwise it seems to be restricted to zone E and F of the Holocene in the Oslofjord area.

Remarks. – *Globobulimina auriculata gullmarensis* has slightly to distinctly pointed apical end, no spines or denticles. For further differences the reader is referred to Höglund's description. He found it abundantly in Recent bottom samples from the deepest part of the Gullmarfjord on the Swedish west coast.

Globobulimina turgida (Bailey)

1851. *Bulimina turgida* Bailey, p. 12, figs. 28–31.
1947. *Globobulimina turgida* (Bailey) – Höglund p. 248, pl. 20, fig. 5; pl. 21, figs. 4, 8; pl. 22, fig. 5; text figs. 247–257, 271.
1953. *Globobulimina* (*Desinobulimina*) cf. *turgida* (Bailey) – Phleger, Parker, and Peirson, p. 34, pl. 6, figs. 33, 34.
1954a. *Globobulimina turgida* (Bailey) – Feyling-Hanssen, p. 132, pl. 1, fig. 11.
1958. *Globobulimina turgida* (Bailey) – Asano, p. 13, pl. 2, figs. 7–9.

A specimen from zone F of boring no. 22, Valle, had a length of 0.76 mm, breadth 0.55 mm. A specimen from subzone B_u of boring F 1, Fornebo, had a length of 0.84 mm, breadth 0.59 mm. Larger specimens occurred.

Occurrence. – Except for a single specimen which occurred in the lowest sample of boring F 1 at Fornebo, classified as subzone B_u, *Globobulimina turgida* was observed only in Post Glacial assemblages referable to zone F and E. It was never numerous, but it was more common in the middle and lower part of zone F than in the upper part of that zone.

Remark. – This species is not recorded from Recent Arctic faunas.

Genus Virgulina d'Orbigny, 1826

Virgulina concava Höglund

Plate 14, figures 9–11

1947. *Virgulina concava* Höglund, p. 257, pl. 23, figs. 3, 4; pl. 32, figs. 4–7; text figs. 273–275.

This species is characterized by its well-developed apical spine; its wall is calcareous perforate with radiate structure.

Length of hypotype of figure 9, 0.43 mm, breadth 0.13 mm. Length of hypotype of figure 10, 0.40 mm, breadth 0.13 mm. Length of hypotype of figure 11, 0.35 mm, breadth 0.11 mm. An unfigured specimen from subzone F_u of boring no. 5 in Sandefjord had a length of 0.48 mm.

Occurrence. – *Virgulina concava* was rare in the investigated samples from the Late Quaternary borings of the Oslofjord area. A few specimens occurred in F_u-assemblages, and two specimens were found with an E-assemblage from boring no. 1 (F 226) at Skøyen in the city of Oslo.

Remarks. – Because of its radiate wall structure Hofker (1956, p. 908) made *Virgulina concava* Höglund the type species of his new genus *Stainforthia*. All the species of *Virgulina* in the present material seem to possess radiate wall structure and would thus have to be transferred to *Stainforthia*. There are, however, a good many factors involved in the question of wall structure as basis for generic classification. Until they are further settled the writer prefers to keep the old name *Virgulina*.

Virgulina fusiformis (Williamson)
Plate 14, figures 15–18

1858. *Bulimina pupoides*, var. *fusiformis* Williamson, p. 63, pl. 5, figs. 129, 130.
1947. "*Bulimina*" *fusiformis* Williamson – Höglund, p. 232, pl. 20, fig. 3; text figs. 219–233.
1954a. *Virgulina fusiformis* (Williamson) – Feyling-Hanssen, p. 132, pl. 1, fig. 13.

Length of hypotype of figure 15, 0.39 mm, greatest breadth 0.16 mm. Length of hypotype of figure 16, 0.30 mm, breadth 0.13 mm. 44 unfigured specimens from zone F of boring no. 1 in Sandefjord had lengths from 0.24 mm to 0.38 mm.

Occurrence. – Next to *Bulimina marginata* this species was the most abundant one in subzone F_m, which subzone it thus characterized at least in sediments of the southern part of the Oslofjord area. In some samples of the said subzone it even predominated. In Post Glacial sediments around the city of Oslo *Virgulina fusiformis* was frequent in the upper half of zone F. It was not rare in zone G nor in zone E, but occurred only occasionally in the zones D, C, and B. It was twice observed in subzone A_m.

Remarks. – In the Recent fauna of the Gullmarfjord this species was most numerous at depths between 40 m and 50 m. It was present in most of the samples from depths exceeding 20 m.

Virgulina loeblichi Feyling-Hanssen

Plate 14, figures 12–14

1952a. *Virgulina complanata* Egger – F. L. Parker (not *V. complanata* Egger, 1893), p. 417, pl. 6, fig. 2.

1953. *Bulimina exilis* Brady – Loeblich and Tappan (not *B. elegans* var. *exilis* Brady, 1884), p. 110, pl. 20, figs. 4, 5.

1954b. *Virgulina loeblichi* Feyling-Hanssen, p. 191, pl. 1, figs. 14–18; text fig. 3.

1958b. *Virgulina loeblichi* Feyling-Hanssen, p. 9, pl. 1, figs. 7, 8.

The present species differs from *Virgulina concava* by being somewhat larger and by the lack of a distinct apical spine.

Length of the specimen of figure 12, 0.54 mm, greatest breadth 0.19 mm. Length of specimen of figure 13, 0.52 mm, greatest breadth 0.17 mm. Length of unfigured specimen from subzone B_l of boring no. 1 in Sandefjord, 0.62 mm, greatest breadth 0.19 mm. The slender form of figure 14, from subzone F_m of boring no. 28, profile A, Fredrikstad, had a length of 0.56 mm, breadth 0.15 mm. Other specimens from the Late Quaternary of the Oslofjord area usually ranged from 0.50 mm to 0.60 mm.

Occurrence. – *Virgulina loeblichi* is the primary diagnostic form of subzone B_l and zone C of the foraminiferal zonation in the Late Quaternary deposits of the Oslofjord area. Outside these assemblages it is usually sparingly represented in zone A and zone D, and has only a casual occurence in zone E and F. It is less scarce in the middle part of zone A than in other parts of that zone.

Remarks. – The initial end of *Virgulina loeblichi* may be slightly apiculate but does not possess a strong, long and distinct spine like that of Höglund's figured specimens of *V. concava*. In the author's present material there occur a few forms which seem probably to be transitional between *V. loeblichi* and *V. concava*. If by future investigation this turns out to be the case, the two belong to the same species, viz., *V. concava* which takes the priority. *V. loeblichi* should then have to be segregated as a subspecies or a form of Höglund's species.

The present species has frequently been referred to *Virgulina complanata* Egger (1893, p. 292, pl. 8, figs. 91, 92) from western Australia, taken at 359 m depth by the Gazelle Expedition. However, *Virgulina* *schreibersiana* Czjzek, variatio *complanata* Egger is characterized by being strongly laterally compressed, almost completely flat. Egger wrote (l.c., p. 292): "Das Gehäuse — — — weicht von der normalen Form (viz., of *V. schreibersiana*) dadurch ab, dass die Schale ganz flach gedrückt ist." It is also smaller than the present species, length 0.30 mm, breadth 0.08 mm, and hyaline. *Virgulina davisi* Chapman and Parr (1937, p. 88, pl. 8, fig. 15), according to figure and indicated magnification, is also smaller than the present species, it is more slender, less lobulate and has fewer chambers. *Bulimina exilis* Brady (1884, p. 399, pl. 50, figs. 5, 6) is a longer, more regularly tapering form. Brady gave 0.75 mm as length. It has more chambers, and its aperture is different from that of the present species.

Loeblich and Tappan (1953, p. 110) recorded the present species in Recent samples from Alaska and East Greenland. F.L. Parker (1952 a, p. 417) found it off Portsmouth, New Hampshire. I have taken it in bottom samples in Spitsbergen as well as in East Greenland.

The slender form of figure 14, from subzone F_{III} at Fredrikstad, is with some hesitation referred to *Virgulina loeblichi*.

Virgulina schreibersiana Czjzek
Plate 14, figures 19–21

1848. *Virgulina schreibersiana* Czjzek, p. 11, pl. 13, figs. 18–21.
1937c. *Virgulina schreibersiana* Czjzek – Cushman, p. 13, pl. 2, figs. 11–20 (with extensive synonymy).
1954b. *Virgulina* species Feyling-Hanssen, p. 193, pl. 1, figs. 23, 24.

Length of hypotype of figure 19, 0.48 mm, greatest breadth 0.16 mm. Length of hypotype of figure 21, 0.48 mm, breadth 0.15 mm. The specimen of figure 20 was broken when replaced to the slide after photographing.

Occurrence. – This species was never frequent in Late Quaternary sediments of the Oslofjord area. It was less rare in Late Glacial assemblages, zone A–D, than in Post Glacial ones. Its occurrence in subzone A_{II} and zone D was quite consistent.

Virgulina skagerakensis Höglund
Plate 15, figures 1, 2

1947. *Virgulina skagerakensis* Höglund, p. 255, pl. 23, figs. 1, 2; pl. 32, figs. 1–3; text fig. 272.

Length of hypotype of figure 1, 0.81 mm, greatest breadth 0.21 mm, thickness 0.17 mm. Length of hypotype of figure 2, 0.81 mm, greatest breadth 0.22 mm, thickness 0.18 mm. Unfigured specimens of the present material had lengths from 0.48 mm to 0.84 mm.

Occurrence. – This species was found only in Post Glacial deposits of the Oslofjord area. It was never frequent, but fairly common though, in the lower part of subzone F_{II}. Occasionally it occurred at the transition between zone F and zone E, and a few specimens were found in zone G-assemblages.

Genus Oolina d'Orbigny, 1839
Oolina borealis Loeblich and Tappan

1858. *Entosolenia costata* Williamson (not *Oolina costata* Egger, 1857), p. 9, pl. 1, fig. 18.
1953. *Oolina costata* (Williamson) – Loeblich and Tappan, p. 68, pl. 13, figs. 4–6.
1954. *Oolina borealis* Loeblich and Tappan, new name, no. 12.

An unfigured specimen from subzone A_{III} of boring no. 22 at Valle by Sarpsborg, had a length of 0.35 mm, breadth 0.29 mm.

Occurrence. – Very few specimens of this species occurred in subzone A_{III} of the Pleistocene of the Oslofjord area.

Oolina caudigera (Wiesner)
Plate 15, figure 3

1931. *Lagena (Entosolenia) globosa* (Montagu), var. *caudigera* Wiesner, p. 119, pl. 18, fig. 214.
1953. *Oolina caudigera* (Wiesner) – Loeblich and Tappan, p. 67, pl. 13, figs. 1–3.
1963. *Oolina caudigera* (Wiesner) – Boltovskoy, p. 63, pl. 7, fig. 7.

Length of hypotype of figure 3, 0.35 mm, width 0.30 mm.

Occurence. – This species occurred in boring no. 1 at Sauøya, Halden, in an assemblage fairly comparable with the middle part of zone A. It was extremely rare.

Oolina caudigera was originally described from Antarctic waters. Cushman (1948, p. 64) found it in Recent Arctic bottom samples (recorded as *Entosolenia lineata* Williamson) and so did Loeblich and Tappan. The present author observed it in Post Glacial samples from the Barents Island in Spitsbergen.

Oolina hexagona (Williamson)
Plate 15, figure 4

1848. *Entosolenia squamosa* (Montagu) var. *hexagona* Williamson, p. 20, pl. 2, fig. 23.
1884. *Lagena hexagona* (Williamson) – Brady, p. 472, pl. 58, figs. 32, 33.
1943. *Lagena hexagona* (Williamson) – Hessland, p. 262, pl. 3, fig. 34.
1950b. *Oolina hexagona* (Williamson) – van Voorthuysen, p. 56, pl. 1, fig. 12.
1953. *Oolina hexagona* (Williamson) – Loeblich and Tappan, p. 69, pl. 14, figs. 1, 2.

The figured specimen, from the Post Glacial subzone F_{II} of boring no. 1 (F 175) at Skøyen, Oslo, had a length of 0.20 mm, width 0.17 mm.

Occurence. – A few specimens of this species occurred in subzone F_{II} of some borings in Holocene deposits in the Oslofjord area. It was occasionally observed in other parts of zone F and also in zone E.

Remarks. – Kiær (1900, p. 52) recorded this species from Münster's collection, probably from a Post Glacial shell bed near Skien. Madsen (1895 a, p. 194) found it in Quaternary deposits (De ældre Yoldialer-lag) in Denmark, and Buch (1955, p. 609) recorded it from the penultimate interglacial period in Jutland.

Oolina lineato-punctata (Heron-Allen and Earland)
Plate 15, figure 5

1922. *Lagena globosa* (Montagu) var., *lineato-punctata* Heron-Allen and Earland, p. 142, pl. 5, figs. 12–14.
1953. *Oolina lineato-punctata* (Heron-Allen and Earland) – Loeblich and Tappan, p. 70, pl. 13, fig. 8.

Length of hypotype of figure 5, 0.21 mm, width 0.16 mm.

Occurrence. – This species was as rare as the previous in Late Quaternary deposits of the Oslofjord area. It occurred in zone E of a boring at Bekkelaget, Oslo, and at Valle, in zone D of a boring at Bryn, also in Oslo, and in zone C of boring no. 5 at Majorstuen, Oslo.

Oolina melo d'Orbigny
Plate 15, figures 6, 7

1839b. *Oolina melo* d'Orbigny, p. 20, pl. 5, fig. 9.
1884. *Lagena squamosa* (Montagu) – Brady, p. 471, pl. 58, figs. 28–31.
1953. *Oolina melo* d'Orbigny – Loeblich and Tappan, p. 71, pl. 12, figs. 8–15.
1960. *Oolina melo* d'Orbigny – van Voorthuysen, p. 247, pl. 10, fig. 16.

The specimen of figure 6, from zone F of boring no. 5 in Sandefjord, had a length of 0.24 mm, width 0.19 mm. The number of axial ridges was 14 in that specimen. The specimen of figure 7, from subzone A_m of boring no. 27 at Valle, had a length of 0.46 mm, width 0.40 mm. Its number of axial ridges was 17.

Occurrence. – This species was found mainly in borings from the southern part of the Oslofjord area. It occurred in subzone A_m and in the Post Glacial zones E and F. It was never frequent.

Oolina squamoso-sulcata (Heron-Allen and Earland)

1888. *Lagena melo* (d'Orbigny) (intermediate var.) Brady, Parker and Jones, p. 237, pl. 44, fig. 25.
1922. *Lagena squamoso-sulcata* Heron-Allen and Earland, p. 151, pl. 5, figs. 15, 19.
1953. *Oolina squamoso-sulcata* (Heron-Allen and Earland) – Loeblich and Tappan, p. 74, pl. 12, figs. 6, 7.

One specimen of this species was found in subzone F_u of boring no. 2, profile C, Fredrikstad. Its length was 0.38 mm, width 0.30 mm.

Oolina williamsoni (Alcock)
Plate 15, figure 8

1865. *Entosolenia williamsoni* Alcock, p. 193.
1923. *Lagena williamsoni* (Alcock) – Cushman, Bull. 104, pt. 4, p. 61, pl. 11, figs. 8, 9.
1950. *Lagena williamsoni* (Alcock) – Cushman and McCulloch, p. 362, pl. 48, figs. 14, 15.
1960. *Oolina williamsoni* (Alcock) – van Voorthuysen, p. 247, pl. 10, fig. 18.

The hypotype of figure 8, from subzone A_m of boring no. 27, Valle, had a length of 0.38 mm, width 0.30 mm. An unfigured specimen from the same sample measured: length 0.40 mm, width 0.28 mm.

Occurrence. – This characteristic species occurred in many of the borings through Late Quaternary deposits in the Oslofjord area. It was found in the Pleistocene subzones A_m and A_u and through the whole Post Glacial zone F. It was never frequent.

Genus Fissurina Reuss, 1850

Fissurina castanea (Flint)

Plate 15, figures 9–14

1899. *Lagena castanea* Flint, p. 307, pl. 54, fig. 3.
1923. *Lagena castanea* Flint – Cushman, Bull. 104, pt. 4, p. 9, pl. 1, figs. 12, 13.
1950a. *Fissurina castanea* (Flint) – van Voorthuysen, p. 36, pl. 1, fig. 7, text fig. 2.

Length of hypotype of figures 9 and 10, 0.20 mm, breadth 0.18 mm, thickness 0.14 mm. Length of hypotype of figures 11 and 12, 0.18 mm, breadth 0.16 mm, thickness 0.13 mm. Length of hypotype of figures 13 and 14, 0.18 mm, breadth 0.16 mm, thickness 0.14 mm.

All specimens of the present material had short entosolenian tube, no cases of twisted tube were observed.

Occurrence. – This species was rare. It was observed only in the Post Glacial part of the Holocene in the Oslofjord area, viz., in zone E of boring no. 1 in Sandefjord and in subzone F_u of boring no. 2, profile C, in Fredrikstad, and in boring no. 2, profile B, in the same town.

Remarks. – Van Voorthuysen recorded *F. castanea* from a boring through Plio – Pleistocene deposits at the Hague, the Netherlands. He called attention to the close resemblance between that species and *Lagena danica* Madsen (1895 a, p. 196, pl. 1, fig. 4) from the Older Yoldia clay of Vendsyssel, Denmark.

Fissurina cf. **fasciata** (Egger)

Plate 15, figures 15, 16

1857. *Oölina fasciata* Egger, p. 270, pl. 5, figs. 12–15.

The present form is elongate with very narrow and rather short marginal bands. The wall is thin and glassy.

The length of the figured specimen was 0.27 mm, breadth 0.13 mm, thickness 0.11 mm. A specimen from subzone F_u of boring no. 31 (O 1–33) at the river of Akerselva, Oslo, had a length of 0.22 mm, breadth 0.14 mm, thickness 0.13 mm. A specimen from the transition between zone F and G of boring no. 5 in Bjørvika, Oslo, had a length of 0.24 mm.

Occurrence. – This species was very rare in the Late Quaternary of the Oslofjord area. Except the figured specimen which was found in a Late Glacial but Holocene (probably zone C) sample from boring no. 2 at Naddum bridge (O 708), the other few specimens observed were from from Post Glacial deposits, subzone F_{II} and the transition F/G.

Remarks. – As mentioned by Heron-Allen and Earland (1916, p. 250) about *Fissurina fasciata*, the present form has probably been included in many records of *Fissurina quadricostulata* Reuss.

Fissurina laevigata Reuss
Plate 15, figures 17, 18

1850. *Fissurina laevigata* Reuss, p. 366 pl. 46 fig. 1.
1863a. *Fissurina laevigata* Reuss – Reuss, p. 338, pl. 6, fig. 84.
1884. *Lagena laevigata* (Reuss) – Brady, p. 473, pl. 114, fig. 8.
1923. *Lagena laevigata* (Reuss) – Cushman, Bull. 104, pt. 4, p. 28, pl. 5, figs. 1, 2.
1954a. *Fissurina laevigata* Reuss – Boltovskoy, p. 157, pl. 11, fig. 5.

Length of the specimen of figures 17 and 18, 0.35 mm, breadth 0.26 mm, thickness 0.22 mm.

Occurrence. – This species was rare in the Late Quaternary of the Oslofjord area. Scattered specimens were observed in samples from subzone B_I and in the zones D, E, F, and once even in a zone G-assemblage, i. e., almost throughout the Holocene sequence.

Remarks. – The figured specimen carried a very fine and dense longitudinal striation. The entosolenian tube was short and not attached to the wall. Such forms were found in zone E and F in Sandefjord and Fredrikstad.

Fissurina lagenoides (Williamson), forma **tenuistriata** Brady
Plate 15, figures 19, 20

1881. *Lagena tubulifera* Brady, var. *tenuistriata* Brady, p. 61.
1884. *Lagena lagenoides* Williamson, var. *tenuistriata* Brady – Brady, p. 479, pl. 60, fig. 11.
1923. *Lagena lagenoides* (Williamson), var. *tenuistriata* Brady – Cushman, Bull. 104, pt. 4, p. 31, pl. 5, fig. 9.

Length of the specimen of figure 19, 0.24 mm, breadth 0.16 mm. Length of the specimen of figure 20, a trihedral specimen, 0.27 mm, breadth 0.13 mm.

Occurrence. – Two specimens of this form were found in subzone A_m of boring no. 2, profile B, in Fredrikstad.

Fissurina lucida (Williamson)
Plate 15, figure 21

1848. *Entosolenia marginata* (Montagu) var. *lucida* Williamson, p. 17, pl. 2, fig. 17.
1953. *Fissurina lucida* (Williamson) – Loeblich and Tappan, p. 76, pl. 14, fig. 4.

Length of hypotype of figure 21, 0.25 mm, breadth 0.19 mm, thickness 0.14 mm. Three unfigured specimens from the same sample (zone E of boring no. 5, Sandefjord) had lengths from 0.16 to 0.22 mm. A specimen from zone D, depth 17.2 m, of boring no. 2, Lodalen, Oslo, was 0.25 mm long.

Occurrence. – *Fissurina lucida* occurred never frequently in Late Quaternary deposits of the Oslofjord area, it was, however, the most common species of *Fissurina*. It was observed in most samples of zone C, D, and E, and occurred also in zone F, zone B and subzone A_m.

Fissurina marginata (Walker and Boys)
Plate 15, figure 22

1784. *Serpula (Lagena) marginata* Walker and Boys, p. 2, pl. 1, fig. 7.
1803. *Serpula (Lagena) marginata* Walk. – Montagu, p. 524.
1865. *Lagena sulcata* Walker and Jacob, var. (*Entosolenia*) *marginata* (Montagu) – Parker and Jones, p. 355, pl. 13, figs. 42, 43.
1953. *Fissurina marginata* (Montagu) – Loeblich and Tappan, p. 77, pl. 14, figs. 6–9.
1959. *Fissurina marginata* (Walker and Boys) – Boltovskoy, p. 69, pl. 9, fig. 18.

Length of hypotype of figure 22, 0.19 mm, breadth 0.17 mm, thickness 0.11 mm. An unfigured specimen from subzone F_u of boring no. 2, profile B, Fredrikstad, had a length of 0.23 mm, breadth 0.20 mm, thickness 0.09 mm.

Occurrence. – This species was extremely rare in Late Quaternary deposits of the Oslofjord area. It was observed in zone E of boring no. 5 in Sandefjord and in subzone F_u of the above-mentioned boring from Fredrikstad. One specimen occurred in the lower zone D of boring F 1, Storøymyr, Fornebo.

Remarks. – Parker and Jones (l.c.) recorded this species i. a., from the Norwegian coast, at Trondheim and at North Cape.

Loeblich and Tappan (1954) proposed the new name *Fissurina siciliensis* for the species *Fissurina* (*Fissurine*) *marginata* Seguenza (1862, p. 66).

Genus Parafissurina Parr, 1947

Parafissurina lateralis (Cushman), forma **simplex** (Buchner)

Plate 15, figures 23, 24

1940. *Lagena lateralis* Cushman, forma *simplex* Buchner, p. 520, pl. 23, figs. 487–492.

Length of the specimen of figures 23 and 24, 0.29 mm, breadth 0.17 mm, thickness 0.12 mm. An unfigured specimen from subzone F_u of boring no. 2, profile C, Fredrikstad, had a length of 0.33 mm, breadth 0.19 mm, thickness 0.12 mm.

Occurrence. – A few specimens of this form occurred in Holocene deposits of the Oslofjord area, viz., in zone D, zone E, and zone F.

Parafissurina lateralis (Cushman), forma **carinata** (Buchner)

Plate 15, figures 25, 26

1940. *Lagena lateralis* Cushman, forma *carinata* Buchner, 521, pl. 23, figs. 497–500.

Length of the specimen of figures 25 and 26, 0.26 mm, breadth 0.21 mm, thickness 0.13 mm.

Occurrence. – This form had a similar occurrence as forma *simplex*. It was observed in the Post Glacial zones E and F and also in the Late Glacial zone C (Nesset), but it was not met with in deposits older than Holocene in the Oslofjord area. It occurred also in the deepest part of boring F 1, Storøymyr, Fornebo, classified as B_u.

Subfamily **Uvigerininae** Cushman, 1913

Genus Uvigerina d'Orbigny, 1826

Uvigerina peregrina Cushman

Plate 15, figures 27–29

1923. *Uvigerina peregrina* Cushman, Bull. 104, pt. 4, p. 166, pl. 42, figs. 7–10.
1947. *Uvigerina peregrina* Cushman – Höglund, p. 279, pl. 23, fig. 9; text figs. 291–304.
1954. *Uvigerina peregrina* Cushman – Parker, p. 521, pl. 8, fig. 5.
1954a. *Uvigerina peregrina* Cushman – Feyling-Hanssen, p. 132, pl. 1, fig. 14.
1958. *Uvigerina peregrina* Cushman – F. Parker, p. 263, pl. 2, figs. 37, 38.
?1960. *Euuvigerina peregrina* (Cushman) – Barker, pl. 74, figs. 11, 12

Length of hypotype of figure 27, 0.78 mm, greatest breadth 0.35 mm. Length of hypotype of figure 28, 0.76 mm, greatest breadth 0.36 mm. Length of hypotype of figure 29, 0.69 mm, greatest breadth 0.35 mm.

Unfigured hypotypes from subzone F_{II} of boring no. 3 (O 343) at Glemmen Church by Fredrikstad, had lengths from 0.46 mm to 1.00 mm.

Occurrence. – This species was quite frequent in subzone F_{II} of Post Glacial deposits in the Oslofjord area, it was especially characteristic of the lower part of that subzone. It occurred also in subzone F_{III}, and was observed even in subzone F_{I} and in zone E. It was more common in southern parts of the area than in northern.

Remarks. – The specimens from the Holocene of the Oslofjord area seem in all respect to agree with the description and figures given by Cushman and with Höglund's material of Recent specimens from the Gullmarfjord. Spino-costate specimens intermingle with more or less purely costate forms. The present writer can therefore not follow Hofker (1951, p. 187, 224) in referring Höglund's specimens to the much smaller *Uvigerina pigmaea* d'Orbigny (= *Aluvigerina pigmaea*). The specimens from the West Indies referred by Brady (1884, pl. 74, figs. 11, 12) to *Uvigerina pygmaea* and by Barker (1960, p. 154) to *Euuvigerina peregrina* (Cushman) are considerably stouter than normal *Uvigerina peregrina* specimens, the costae seem to be lower and their spacing greater.

Nørvang (1945, p. 36) found the main Recent distribution of *U. peregrina* to be the Lusitanian and Boreal parts of the Atlantic and the Pacific, its vertical range being from 30 m down to 4350 m.

Madsen (1895 a, p. 207) recorded *Uvigerina pygmaea* from the youngest Yoldia clay at Vendsyssel, Denmark. Those specimens may probably be referable to *U. peregrina*.

Genus Angulogerina Cushman, 1927
Angulogerina angulosa (Williamson)
Plate 16, figures 1–3

1857. *Uvigerina pygmaea* d'Orbigny – Parker and Jones (part., not *Uvigerina pygmaea* d'Orbigny, 1826), p. 297, pl. 11, fig. 41.
1858. *Uvigerina angulosa* Williamson, p. 67, pl. 5, fig. 140.
1884. *Uvigerina angulosa* Williamson – Brady, p. 576, pl. 74, figs. 15, 16.
1923. *Uvigerina angulosa* Williamson – Cushman, Bull. 104, pt. 4, p. 170, pl. 41, figs. 17–20 (with extensive synonymy).
1927. *Angulogerina angulosa* (Williamson) – Cushman, p. 69.
1947. *Angulogerina angulosa* (Williamson) – Höglund, p. 283, pl. 23, fig. 8; text figs. 305–308.
1950a. *Angulogerina angulosa* (Williamson) – van Voorthuysen, p. 38, pl. 1, fig. 13.
1958. *Angulogerina angulosa* (Williamson) – F. Parker, p. 259, pl. 2, figs. 1, 2.

Length of hypotype of figure 1, 0.30 mm, breadth 0.21 mm. Length of hypotype of figure 2, 0.48 mm, breadth 0.24 mm. Length of hypotype of figure 3, 0.30 mm, breadth 0.22 mm.

Occurrence. – This species occurred only in the Post Glacial zone F of the Holocene of the Oslofjord area. It was never frequent, but more common in the upper part of the zone than in the lower.

Remarks. – According to Nørvang (1945, p. 37) this species is in Recent time mainly distributed in Boreal and Lusitanian parts of the Atlantic and the Pacific, which is in good keeping with its occurrence in the Holocene deposits of the Oslofjord area.

Van Voorthuysen (1950 a, p. 38) recorded *A. angulosa* from the Icenian (Early Pleistocene) of a boring at the Hague, the Netherlands, and Madsen (1895 a, p. 208) found it in the Older Yoldia clay of Vendsyssel, Denmark.

Angulogerina fluens Todd
Plate 16, figures 4, 5

1947. *Angulogerina fluens* Todd, in Cushman and Todd, p. 67, pl. 16, figs. 6, 7.
1953. *Angulogerina fluens* Todd – Loeblich and Tappan, p. 112, pl. 20, figs. 10–12.

Length of hypotype of figure 4, 0.45 mm, breadth 0.17 mm. Length of hypotype of figure 5, 0.36 mm, breadth 0.16 mm. The two figured specimens are from a Late Glacial deposit in Rotsund, Troms, in North Norway (collected 7/8–1957).

Occurrence. – This species occurred at 32.8 and 33.2 m depth in boring no. 1 (O 953) at Sauoya, Halden, in Late Pleistocene deposits. It was very rare.

Remarks. – Many Arctic specimens previously referred to *Angulogerina angulosa* may belong with the present species.

Subfamily **Bolivininae** Glaessner, 1937
Genus Bolivina d'Orbigny, 1839
Bolivina albatrossi Cushman
Plate 16, figure 6

1922. *Bolivina albatrossi* Cushman, Bull. 104, pt. 3, p. 31, pi. 6, fig. 4.
1947. *Bolivina albatrossi* Cushman – Höglund, p. 264, pl. 24, fig. 1; pl. 32, figs. 19, 20.
1958. *Bolivina albatrossi* Cushman – F. L. Parker, p. 259, pl. 2, figs. 3, 4.

Length of hypotype of figure 6, 0.30 mm, breadth 0.12 mm, thickness 0.07 mm.

Occurrence. – This species was observed in the Post Glacial zones E and F and once also in the Late Glacial subzone B_u of the Holocene in the Oslofjord area. It was rare.

Remarks. – Recent specimens from the Gullmarfjord were 0.19 mm to 0.40 mm long and 0.10 mm to 0.15 mm broad (Höglund, 1947, p. 265).

Bolivina pseudoplicata Heron-Allen and Earland

1930b. *Bolivina pseudoplicata* Heron-Allen and Earland, p. 81, pl. 3, figs. 36–40.
1937c. *Bolivina pseudoplicata* Heron-Allen and Earland – Cushman, p. 166, pl. 19, figs. 12–20 (with extensive synonymy).
1947. *Bolivina pseudoplicata* Heron-Allen and Earland – Höglund, p. 263, pl. 24, fig. 2; pl. 32, figs. 8–11; text fig. 287.
1958. *Bolivina pseudoplicata* Heron-Allen and Earland – F. L. Parker, p. 261, pl. 2, fig. 8.

An unfigured specimen from subzone F_u of boring no. 2, profile C, Fredrikstad, had a length of 0.36 mm, breadth 0.14 mm, thickness 0.08 mm.

Occurrence. – This species occurred in the zones E and F and once also in subzone B_u of the Holocene in the Oslofjord area. It was rare, however, not as rare as *B. albatrossi.*

Remarks. – The main Recent distribution of this species seems to be Atlantic – Mediterranean. Höglund (1947, p. 263) found it in the Gullmarfjord at depths between 20 m and 93 m, in the Skagerrak at depths from 66 m to 700 m. Van Voorthuysen (1957, p. 36) recorded it from the Eemian at Amersfoort in the Netherlands.

Bolivina pseudopunctata Höglund
Plate 16, figure 7

1947. *Bolivina pseudopunctata* Höglund, p. 273, pl. 24, fig. 5; pl. 32, figs. 23, 24; text figs. 280, 281, 287.
1953. *Bolivina pseudopunctata* Höglund – Loeblich and Tappan, p. 111, pl. 20, figs. 13, 14.

Length of hypotype of figure 7, 0.44 mm, breadth 0.11 mm, thickness 0.08 mm. An unfigured hypotype from subzone B_l of boring no. 1 (O 341) in Rakkestad, had length 0.54 mm, breadth 0.14 mm, thickness 0.10 mm.

Occurrence. – This species was found mainly in the Late Glacial parts of the deposits in the Oslofjord area, viz., in the Pleistocene subzone A_m, the Holocene subzone B_l and in the Holocene zones C and E. It was never frequent.

Remarks. – The Recent distribution of this species seems to be mainly Arctic – Boreal (Höglund, l.c.; F. L. Parker, 1952, p. 414; Phleger, 1952b, p. 83; Loeblich and Tappan, l.c.), which is in good agreement with its occurrence in the Late Quaternary of the Oslofjord area. *Bolivina pseudopunctata* is the only *Bolivina* species in the present material which occurred in Late Glacial deposits; the others seem to keep to the Post Glacial ones.

Bolivina pygmaea Brady
Plate 16, figure 8

1881. *Bolivina pygmaea* Brady, p. 27.
1884. *Bolivina pygmaea* Brady – Brady, p. 421, pl. 53, figs. 5, 6.
1937c. *Bolivina pygmaea* Brady – Cushman, p. 124, pl. 15, figs. 18, 19 (with extensive synonymy).

Length of hypotype of figure 7, 0.22 mm, breadth 0.14 mm, thickness 0.06 mm. Length of unfigured hypotype from the middle part of zone F of boring no. 22 (O 287) at Valle by Sarpsborg, 0.27 mm, breadth 0.16 mm, thickness 0.08 mm.

Occurrence. – This species occurred in the middle part of zone F of boring no. 5, Sandefjord and in the same subzone of the above-mentioned boring from Valle.

Remarks. – The specimens of *B. pygmaea* from the Holocene of the Oslofjord area differ from *Bolivina gramen* d'Orbigny, 1839, in having less oblique sutures and marginal points and in being translucent instead of white. According to variations in *B. gramen* demonstrated by Höglund (1947, p. 268) the two are probably conspecific. In that case *B. gramen* would take the priority. *Bolivina difformis* (Williamson, 1858) is a much more compressed species.

Bolivina cf. **robusta** Brady
Plate 16, figure 9

1947. *Bolivina* cf. *robusta* Brady – Höglund, p. 270, pl. 24, figs. 8, 9; pl. 32, figs. 16–18; text fig. 287.

Length of the figured specimen 0.43 mm, breadth 0.23 mm, thickness 0.14 mm.

Occurrence. – One specimen of this species was observed in the Late Glacial, Holocene, subzone B_u of boring no. 2 (O 962) at Ryen, Oslo. Another specimen occurred in the Post Glacial subzone F_m of boring no. 22 (O 287) at Valle by Sarpsborg.

Remarks. – Höglund (l.c.) found this form to be very frequent in the Recent fauna of the Skagerrak especially at depths between 300–500 m. In the Gullmarfjord, with depths not exceeding 120 m, he obtained only one single specimen. As previously mentioned (p. 51) the maximum depth at which any Late Glacial sediment, sampled for the present study, was deposited was 250 m. Most of the samples represent sediments deposited in shallower water, and that may constitute one reason why *Bolivina* cf. *robusta* is so rare in Late Quaternary deposits of the Oslofjord area. From micropaleontological investigation of core samples from the Skagerrak and the Kattegat (Lange, 1956) it seems that *Bolivina* cf. *robusta* flourished there in late times, being absent or only sparsely represented in older sediments.

Bolivina spathulata (Williamson)
Plate 16, figure 10

1858. *Textularia variabilis* Williamson, var. *spathulata* Williamson, p. 76, pl. 6, figs. 164, 165.

1937c. *Bolivina spathulata* (Williamson) – Cushman, p. 162, pl. 15, figs. 20–24 (with extensive synonymy).

1947. *Bolivina spathulata* (Williamson) – Höglund, p. 271, pl. 24, fig. 7; pl. 32, figs. 21, 22; text figs. 286, 287.

Length of hypotype of figure 10, 0.33 mm, breadth 0.16 mm, thickness 0.08 mm. An unfigured specimen from subzone F_m of boring no. 5 in Sandefjord had length 0.45 mm, breadth 0.17 mm. Another unfigured specimen from that sample was 0.44 mm long and 0.20 mm broad.

Occurrence. – A few specimens of this species were observed in the Post Glacial zone F of the Holocene of the Oslofjord area.

Family **CASSIDULINIDAE** d'Orbigny, 1839

Genus Cassidulina d'Orbigny, 1826

Cassidulina crassa d'Orbigny

Plate 16, figures 11–13

1839b. *Cassidulina crassa* d'Orbigny, p. 56, pl. 7, figs. 18–20.
1953. *Cassidulina islandica* Nørvang – Loeblich and Tappan (not *Islandiella islandica* (Nørvang, 1945) (= *Cassidulina islandica*)), p. 118, pl. 24, fig. 1.
1954a. *Cassidulina crassa* d'Orbigny – Boltovskoy, p. 208, pl. 18, fig. 3.
1954a. *Cassidulina crassa* d'Orbigny – Feyling-Hanssen, p. 133, pl. 2, fig. 1.
1954b. *Cassidulina crassa* d'Orbigny – Feyling-Hanssen, p. 193, pl. 1, figs. 19, 20.
1958. *Cassidulina crassa* d'Orbigny – Nørvang, p. 36, pl. 8, figs. 20–22; pl. 9, figs. 24, 25.

Length of hypotype of figures 11–13, 0.32 mm, breadth 0.29 mm, thickness 0.18 mm. Other specimens of the present material had lengths from 0.20 mm. to 0.39 mm.

Occurrence. – This species was characteristic of Late Glacial deposits from the Late Pleistocene and Holocene of the Oslofjord area. It was next to *Elphidium incertum clavatum* in frequency in most samples of that kind from zone A through zone D, in some of them even dominant. It was also met with in Post Glacial deposits, fairly commonly in zone E, rarely to very rarely in zone F. It was not observed in zone G.

Remarks. – In an emendation to d'Orbigny s description of the genus *Cassidulina*, Nørvang wrote (1958, p. 34): "– – – wall perforate, granulate; aperture narrow tripartite, but one or two of the narrow branches are normally closed, except in the most primitive species; often with one or two plate-like lips, situated on the normally inward-bent border of the test wall, partially closing the aperture." All specimens from the Late Quaternary of the Oslofjord area possess a granulate wall. The aperture is basal, rather long and narrow, an areal branch is lacking, even a rudimentary indentation in the upper edge of the basal aperture could not be observed. A well-developed tooth-like plate or plate-like lip partly covers the aperture.

Cassidulina islandica as described and figured by Loeblich and Tappan (1953, p. 118) seems to belong with the present species. It is provided with a tooth-like plate extending upward from the lower margin of the chamber, not a free tongue projecting out of the aperture as in the genus *Islandiella* of which *Cassidulina islandica* was made the type species (Nørvang, 1958, p. 26). *Islandiella islandica* is also more than twice the size of the species described by Loeblich and Tappan. The latter fits well into the size range of the Late Glacial *Cassidulina crassa* specimens from the Oslofjord area.

Recent specimens from Spitsbergen show the same characters as those from the present material, and Nørvang (l.c., p. 37) observed the same with Arctic material examined by him.

Cassidulina crassa was early recognized in Glacial deposits in Norway (Sars, 1865; Kiær, 1900; Brøgger, 1900–1901, in the Oslofjord area; Kiær, 1908 at Tromsø). Munthe (1896) recorded it from Yoldia clay in south-western Sweden and Madsen (1895 a, b) found it in Denmark and northern Germany. Hessland (1943) recorded it from Late Glacial deposits in Bohuslän, southwestern Sweden, and Brotzen (1951) found it frequently in the Late Glacial part of a boring at Surte by Gothenburg. Furthermore, Brotzen (1961, p. 144) found *C. crassa* in marine interstadial deposits with an Arctic fauna in borings in and near Gothenburg in southwestern Sweden. These beds were radiologically dated at 24 000 –30 000 years before the present. Buch (1955, p. 615) found *C. crassa* fairly frequently in the lower part of the Esbjerg Yoldia clay (Mindel/Riss Interglacial) at Inder Bjergum in Jutland. Van Voorthuysen (1950 b, 1958) recorded it from Upper and Middle Miocene at Kruisschans and Zaandam respectively.

Cassidulina laevigata laevigata d'Orbigny

Plate 16, figures 14–16

1826. *Cassidulina laevigata* d'Orbigny, p. 282, pl. 5, figs. 4–5.
1954b. *Cassidulina laevigata* d'Orbigny – Feyling-Hanssen (part.), p. 193, pl. 1, figs. 25, 26.
1958. *Cassidulina laevigata* d'Orbigny – Nørvang, p. 38, pl. 9, figs. 27–31.

Greatest diameter of the specimen of figure 14, 0.38 mm, thickness 0.16 mm. Greatest diameter of the specimen of figure 15, 0.35 mm, thickness 0.15 mm. Greatest diameter of the specimen of figure 16, 0.37 mm, thickness 0.16 mm. Unfigured specimens of the present material had diameters from 0.25 mm to 0.42 mm.

Occurrence. – This subspecies was characteristic of the Post Glacial subzone F_1 in the southern part of the Oslofjord area as well as in the northern. It was also quite frequent in zone E and was regularly met with in the other sub-units of zone F. Single specimens occurred occasionally with G-assemblages. It was usually very rare in the Late Glacial zones B and C, a few specimens occurred in zone D. It was not met with in the Late Pleistocene of the area.

Remarks. – The diagnostic characters of this subspecies is the lenticular shape, the angular periphery and the curved chambers which extend completely over the central portion of the test thus closing the umbilicus on both sides (Cp. Nørvang, l.c., p. 39). Most of the present specimens are grayish-white, nearly opaque, but many translucent specimens occur. Some of them are slightly carinate.

Many records of *Cassidulina laevigata* from Recent waters as well as in Quaternary deposits, comprise also the subsequent subspecies *Cassidulina laevigata carinata* Silvestri. In the Late Quaternary of the Oslofjord aera the two forms usually occur separated, the typical *laevigata* in Post Glacial strata of the Holocene, *carinata* in Late Glacial deposits. They are here tentatively regarded as subspecies.

Cassidulina laevigata carinata Silvestri

1896. *Cassidulina laevigata* d'Orbigny, var. *carinata* Silvestri, p. 104, pl. 2, fig. 10 (*C. laevigata* in explanation of plate).

1953. *Cassidulina carinata* Silvestri – Phleger, Parker, and Peirson, p. 44, pl. 9, figs. 32, 37.

1954. *Cassidulina carinata* Silvestri – F. L. Parker, p. 535, pl. 10, fig. 30.

1954b. *Cassidulina laevigata* d'Orbigny – Feyling-Hanssen (part.), p. 193, pl. 1, figs. 27–32.

Specimens of this subspecies in a sample of Arca clay from Bekkelaget, Oslo, had greatest diameters from 0.28 mm to 0.38 mm.

Occurrence. – This subspecies was especially frequent in the Holocene Late Glacial zone C, in a few samples from this zone it was even dominant. It was quite common in zone D and zone B, rare in zone A. It was usually met with in zone E, but only occasionally in zone F. Whereas *Cassidulina laevigata laevigata* on the whole belonged to the Post Glacial part of the Late Quaternary sequence in the Oslofjord area, *C. l. carinata* was characteristic of the Late Glacial part of it.

Remarks. – F. L. Parker (l.c.) wrote that her specimens from the Gulf of Mexico had a larger clear area in the centre of the test than those from the Pliocene of Siena, described by Silvestri. As described by the present writer (1954 b, p. 193) specimens from the Late Glacial of the Oslofjord area have such a clear area more conspicuously developed on one side than on the other. On the opposite side the chambers may extend almost completely over the central portion of the test. The test of the present specimens is usually provided with a thin peripheral keel, which may be milled like in *Cassidulina laevigata*, var. *pliocarinata* van Voorthuysen (1950 b, p. 62). The test is translucent to hyaline.

Cassidulina laevigata carinata is one of the guide forms of the Calabrian (Earliest Pleistocene) in Italy where it indicates the Post Pliocene deterioration of water temperature in the Mediterranean (Selli, 1954, p. 245-247).

Genus Cassidulinoides Cushman, 1927

Cassidulinoides bradyi (Norman)

Plate 16, figures 18, 19

1880. *Cassidulina bradyi* Norman (Ms.) – Wright, p. 152.
1884. *Cassidulina bradyi* Norman – Brady, p. 431, pl. 54, figs. 6–9.
1922. *Cassidulina bradyi* Norman – Cushman, Bull. 104, pt. 3, p. 128, pl. 23, figs. 6, 7 (with extensive synonymy).
1950b. *Cassidulinoides bradyi* (Norman) – van Voorthuysen, p. 63, pl. 3, fig. 5.

Length of hypotype of figures 18, 19, 0.33 mm, breadth 0.13 mm, thickness 0.11 mm.

Occurrence. – One specimen of this species occurred in the Post Glacial subzone F_u of boring 297, Tohellinga, Nesset, south of Oslo.

Genus Islandiella Nørvang, 1958

Islandiella norcrossi (Cushman)

Plate 16, figure 20; plate 17, figure 1

1933. *Cassidulina norcrossi* Cushman, p. 7, pl. 2, fig. 7.
1953. *Cassidulina norcrossi* Cushman – Loeblich and Tappan, p. 120, pl. 24, fig. 12 (with extensive synonymy).
1958. *Islandiella norcrossi* (Cushman) – Nørvang, p. 32, pl. 7, figs. 8–13; pl. 8, fig. 14.

Greatest diameter of hypotype of figure 20, 0.49 mm, thickness 0.19 mm. Greatest diameter of hypotype of figure 1, 0.49 mm, thickness 0.21 mm. An unfigured specimen from subzone A_m of boring no. 3 b in the Ra ridge at Borregaard, Sarpsborg, had greatest diameter 0.46 mm. Other specimens from subzone A_m of the present material had greatest diameters from 0.28 mm to 0.50 mm. A specimen from the Post Glacial subzone F_m of boring no. 28, profile A, Fredrikstad, had a greatest diameter of 0.43 mm.

Occurrence. – This species was rather commonly met with in the Late

Glacial subzone A_m of the Pleistocene in the Oslofjord area, always represented only by one or a few specimens. It was rare in subzone A_l and very rare in subzone A_u. It was only occasionally met with in Holocene deposits, viz., in subzone F_m of boring no. 28, profile A, Fredrikstad, and in the lowest part of subzone F_u of boring no. 2, profile C in the same town. It is possible that the latter occurrences represent redeposited specimens.

Remarks. – There are usually 8 chambers visible on either side of the final whorl, and they appear more or less triangular in side view. The wall texture is radiate fibrous, and a true tooth with a free tongue is present. For the two latter reasons Nørvang (l.c.) transferred *Cassidulina norcrossi* to his new genus *Islandiella*. The main Recent distribution of *I. norcrossi* is Arctic (Nørvang, 1945, p. 44).

Islandiella teretis (Tappan)

Plate 16, figure 17

1951. *Cassidulina teretis* Tappan, p. 7, pl. 1, fig. 30.
1953. *Cassidulina teretis* Tappan – Loeblich and Tappan, p. 121, pl. 24, figs. 3, 4.
1954. *Cassidulina laevigata* d'Orbigny – Bowen, p. 741, text fig. 1, figs. 1, 2.
1954a. *Cassidulina laevigata* d'Orbigny – Feyling-Hanssen (part.), p. 133, pl. 2, fig. 2.
1958b. *Cassidulina teretis* Tappan – Feyling-Hanssen, p. 9, pl. 1, fig. 13.

Greatest diameter of hypotype of figure 17, 0.65 mm, smallest diameter 0.54 mm, thickness 0.27 mm.

Occurrence. – This species was met with in the Pleistocene subzone A_m of the Late Quaternary of the Oslofjord area, one or a few specimens per sample. It was also found in subzone A_u.

Remarks. – This species was originally described from the Pleistocene Gubik formation in northern Alaska. Its Recent distribution seems to be Arctic. The present writer has collected it in Recent bottom samples from Spitsbergen as well as from East Greenland.

Nørvang, who in his paper on *Islandiella* (1958, p. 32) maintained *Cassidulina teretis* in the genus *Cassidulina*, later (personal information during the printing of the present paper) studied topotype material of this species and found that its wall texture was radiate fibrous and that it possessed a free apertural tongue. After having received this information from Nørvang, the present writer examined some Recent specimens of *C. teretis* from East Greenland and found Nørvang's observations to apply also to them, as well as to the few representatives of this species from the Late Quaternary of the Oslofjord area. Consequently the present specimens, originally referred to *Cassidulina*, were transferred to the genus *Islandiella*. However, as the clichés for the illustrations were finished by that time, the species occurs as *Cassidulina teretis* in the range chart of fig. 17.

Family **NONIONIDAE** Schultze, 1854
Genus Nonionella Cushman, 1926
Nonionella auricula Heron-Allen and Earland
Plate 16, figures 21–23

1930b. *Nonionella auricula* Heron-Allen and Earland, p. 192, pl. 5, figs. 68–70.
1943. *Nonionella turgida* (Williamson) – Hessland (not *Rotalina turgida* Williamson, 1858), pl. 3, fig. 36.
1953. *Nonionella auricula* Heron-Allen and Earland – Loeblich and Tappan, p. 92, pl. 16, figs. 6–10.

Greatest diameter of the figured specimen 0.24 mm, thickness 0.11 mm. An unfigured specimen from subzone F_{II} of boring no. 2, profile C, Fredrikstad, had a greatest diameter of 0.29 mm, and one from the same subzone of boring no. 297 at Tohellinga, Nesset, had a greatest diameter of 0.27 mm.

Occurrence. – This species was very rare in the Late Quaternary of the Oslofjord area. The three measured specimens occurred in the Post Glacial subzone F_{II}. Other specimens were observed in the lower part of zone F. One specimen was observed in the Late Glacial of boring no. 1, Halden.

Remarks. – The size of the present specimens agrees well with that of the specimens from the Plymoth district described by Heron-Allen and Earland (l.c.). The Arctic specimens recorded by Loeblich and Tappan (l.c.) are, however, more than twice as large. Hessland (l.c.) recorded the present species from a Pre-Boreal sample from Bohuslän in Sweden.

Nonionella iridea Heron-Allen and Earland
Plate 16, figures 24–26

1932a. *Nonionella iridea* Heron-Allen and Earland, p. 438, pl. 16, figs. 14–16.

Greatest diameter of the figured hypotype, 0.19 mm, least diameter 0.15 mm, thickness 0.11 mm. Unfigured specimens from subzone F_I of boring no. 1 in the lakelet of Årungen (C 63) had greatest diameters from 0.16 mm to 0.20 mm.

Occurrence. – This species was rare in the Late Quaternary of the Oslofjord area. A few specimens occurred in the different parts of zone F in some borings, some specimens in an interbedded G – layer of boring no. 2, profile C, Fredrikstad. It was observed also in the deepest part of boring F 1, Storøymyr at Fornebo, classified as subzone B_u.

Remarks. – The present specimens are of similar size as those described from the ice-free area of the Falkland Islands and adjacent seas by Heron-Allen and Earland.

Nonionella turgida (Williamson)
Plate 17, figures 2–6

1858. *Rotalina turgida* Williamson, p. 50, pl. 4, figs. 95–97.
1884. *Nonionina turgida* (Williamson) – Brady, p. 731, pl. 109, figs. 17–19.
1930. *Nonionella turgida* (Williamson) – Cushmann, Bull. 104, pt. 7, p. 15, pl. 6, figs. 1–4.
1939. *Nonionella turgida* (Williamson) – Cushman, p. 32, pl. 9, figs. 2, 3.
1954a. *Nonionella turgida* (Williamson) – Feyling-Hanssen, p. 137, pl. 2, fig. 6.
1959. *Nonionella turgida* (Williamson) – Boltovskoy, p. 76, pl. 10, fig. 12.

Greatest diameter of hypotype of figures 2 and 3, 0.28 mm, least diameter 0.19 mm, thickness 0.14 mm. Greatest diameter of hypotype of figures 4 and 5, 0.28 mm, least diameter 0.20 mm, thickness 0.15 mm. Greatest diameter of hypotype of figure 6 was 0.29 mm. 22 unfigured specimens from the same sample had greatest diameters from 0.22 mm to 0.28 mm.

Occurrence. – The present species was rather common in samples from the Post Glacial zone F in the Oslofjord area, it was rare in zone G and zone E, and occurred only occasionally in the Late Glacial, but Holocene, zones C and B. Two specimens occurred also in boring no. 1 at Sauøya, Halden, in layers which are Late Glacial and probably Pleistocene.

Remarks. – In Recent waters *N. turgida* seems to be mainly distributed in Boreal parts of the North Atlantic. It usually prefers shallow water (Nørvang, 1945, p. 29). Kiær (1899, p. 7) recorded *Nonionina turgida* from Iceland and Spitsbergen, but did not give any illustration.

Genus Nonion Montfort, 1808

Nonion barleeanum (Williamson)

Plate 17, figures 7–12

1858. *Nonionina barleeana* Williamson, p. 32, pl. 3, figs. 68, 69.
1952b. *Nonion* sp. cf. *N. barleeanum* (Williamson) – Phleger, p. 85, pl. 14, fig. 6.
1953. *Nonion zaandamae* (van Voorthuysen) – Loeblich and Tappan, p. 87, pl. 16, figs. 11, 12.
1954a. *Nonion pompilioides* (Fichtel and Moll) – Feyling-Hanssen, p. 137, pl. 2, fig. 7.
1958b. *Nonion barleeanum* (Williamson) – Feyling-Hanssen, p. 9, pl. 1, figs. 16, 17.

Greatest diameter of the specimen of figures 7 and 8, 0.57 mm, thickness 0.32 mm. Greatest diameter of the specimen of figures 9 and 10, 0.54 mm, thickness 0.33 mm. Greatest diameter of the specimen of figures 11 and 12, 0.52 mm, thickness 0.27 mm. Other specimens from the present material ranged from 0.38 mm to 0.63 mm.

Occurrence. – This species was common in Post Glacial deposits belonging to zone E and zone F, especially from the upper part of zone E through the lower part of subzone F_u. It occurred occasionally in zone C and in subzone B_u.

Remarks. – The specimens from the Holocene of the Oslofjord area have a broadly rounded periphery, some of them are translucent with circular outline, some almost white with a slightly lobulate outline towards the later chambers. There are 10–13 chambers in the last-formed whorl, the sutures are limbate and usually not depressed. The aperture is bordered above with a more or less distinct lip.

The present specimens are in good keeping with those described by Loeblich and Tappan (1953, p. 87) as *Nonion zaandamae* (van Voorthuysen) (= *Nonion barleeanum* (Williamson), var. *inflatum* van Voorthuysen, 1950 a, but not = *Anomalinoides barleeanum* (Williamson), var. *inflatum* van Voorthuysen, 1950 b).

Boltovskoy (1958, p. 193–200) discussed the probability that this species, like many others, e. g., *Nonionina formosa* and *Nonionina umbilicatula*, is synonymous with *Nonion affine* (Reuss) from the German Oligocene. This latter species is, however, considerably smaller than the present one, its greatest diameter being 0.28–0.30 mm. The number of chambers in the last-formed whorl is 10 (Boltovskoy found 10–11 in topotype material), whereas in the present species it is usually 12.

Nørvang (1959, p. 141–150), on the other hand, dealt with the probability of *N. barleeanum* being synonymous with the broad *Nonion pompilioides* (Fichtel and Moll) from Recent Mediterranean faunas and from the

Italian Pliocene. There are some thick forms among the specimens of *N. barleeanum* from the Holocene of the Oslofjord area which show affinity to *N. pompilioides*. However, Nørvang found that the apertural face and septal walls of the latter species are imperforate, whereas with the present specimens of *N. barleeanum* the apertural face is always perforate.

Cushman (1939, p. 13, Nonionidae) and van Voorthuysen (1950 a, p. 41) questioned the reference of *N. barleeanum*, among other species, to the genus *Nonion* and called attention to their affinity to *Anomalina* d'Orbigny or even to *Anomalinoides* Brotzen (van Voorthuysen, 1950 b). Nørvang (l. c., p. 142), however, was not convinced about such a relationship.

Barker (1960, p. 224) referred Brady's figures 8 and 9 (1884, pl. 109) to *Gavelinonion barleeanum* (Williamson). The present writer has not in any case observed double septal walls, one of the important characteristics of the genus *Gavelinonion* Hofker, 1951, with specimens of *Nonion barleeanum* from the Holocene of the Oslofjord area.

Hessland (1943) found this species (referred to *Nonion pompilioides*) in Post Glacial deposits in North Bohuslän, Southwest Sweden, and Brotzen (1951), p. 62) in the Upper Post Glacial of a boring at Surte near Gothenburg. Buch (1955, p. 625) observed *Nonion barleeanum* and also *N. barleeanum*, var. *inflata* van Voorthuysen in Esbjerg Yoldia clay (Mindel/Riss Interglacial) of Inder Bjergum in southwestern Jutland.

Nonion depressulus asterotuberculatus van Voorthuysen
Plate 17, figures 13, 14

1957. *Nonion depressulus* (Walker and Jacob), forma *asterotuberculatus* van Voorthuysen, p. 28, pl. 23, fig. 3.

1960. *Nonion depressulus* (Walker and Jacob), forma *asterotuberculatus* van Voorthuysen, p. 254, pl. 11, fig. 21.

Greatest diameter of the figured specimen 0.67 mm, thickness 0.32 mm. Unfigured specimens had greatest diameter ranging from 0.30 mm to 0.68 mm.

Occurrence. – This subspecies was frequent in many zone G-assemblages, it was quite frequent in some samples from subzone F_{u}, and was represented by a few specimens in other parts of zone F and in zone E.

It occurred also in the Late Glacial shallow-water deposits of boring no. 1 at the island of Sauøya, Halden.

Remarks. – The present specimens have their umbilical region depressed and often open, the sutures are more or less excavated towards the umbilicus forming a stellate figure at the umbilical region. This figure is usually filled with granular shell material which appears milky white. Chambers 7–9 in the last-formed whorl, usually 8. The aperture is a curved slit at the base of the apertural face, in many cases obliterated by a similar granular mass as in the central part of the test.

Van Voorthuysen (1957) originally described the form *asterotuberculatus* from Eemien strata in a boring at Amersfoort in the Netherlands. The holotype had a diameter of only 0.3 mm, the number of chambers was 5 to 7. In 1960 he recognized it among the Recent Foraminifera of the Dollart-Ems-Estuary, and figured a specimen with greatest diameter 0.42 mm and 9 chambers in the last-formed whorl. This form was rare both in the Eemien deposits and on the tide-water flats of the Dollart-Ems-Estuary, whereas the typical *Nonion depressulus* was one of the most frequent species in the latter locality.

In the Holocene shallow-water deposits of the Oslofjord area the typical form was not observed, *Nonion depressulus* was represented only by its asterotuberculate form, which is here considered a subspecies.

Nonion depressulus asterotuberculatus is probably identical with the form which Williamson (1858, p. 33, figs. 70, 71) referred to *Nautilus, crassus utrinque umbilicatus geniculis lineatis* of Walker and Boys.

Nonion labradoricum (Dawson)
Plate 17, figures 15–18

1860. *Nonionina labradorica* Dawson, p. 191, fig. 4.
1939. *Nonion labradoricum* (Dawson) – Cushman, p. 23, pl. 6, figs. 13–16.
1953. *Nonion labradoricum* (Dawson) – Loeblich and Tappan, p. 86, pl. 17, figs. 1, 2.
1954a. *Nonion labradoricum* (Dawson) – Feyling-Hanssen, p. 139, pl. 2, fig. 8.

Greatest diameter of hypotype of figures 15 and 16, 0.68 mm, least diameter 0.54 mm, thickness 0.41 mm. Greatest diameter of hypotype of figures 17 and 18, 0.67 mm, least diameter 0.50 mm, thickness 0.43 mm. An unfigured specimen from subzone F_m of boring no. 5, Sandefjord, had greatest diameter 0.59 mm, least diameter 0.44 mm, thickness 0.35 mm, whereas unfigured specimens from the subzones A_m and B_l had greatest diameter ranging from 0.54 mm to 0.81 mm.

Occurrence. – *Nonion labradoricum* is characteristic of the Late Pleistocene subzone A_m, i.e., in clay sediments deposited during the stagnation of the land ice margin along the Ra position, and of the Early Holocene subzone B_l, i.e., in sediments assumed to have been deposited as the ice margin paused at the Ås–Ski ridges. In samples from these subzones it attained considerable frequency. Otherwise it occurred sparsely in all units of the Late Quaternary foraminiferal zonation in the Oslofjord area. It seems to have flourished anew in F_u- and low G-assemblages in low-lying sediments supposed to be of Sub-Atlantic (Recent) age.

Remarks. – Hessland (1943) recorded this species in Late Glacial as well as Post Glacial samples from Bohuslän in southwestern Sweden. It was most frequent in sediments supposed to be 10 000–12 000 years old. Brotzen (1951) found it in the Late Glacial part of a boring at Surte near Gothenburg, Sweden. Madsen (1895a) recorded *Nonionina scapha*, var. *labradorica* Dawson from the Older Yoldia clay and from the Youngest Yoldia clay in Denmark. Jones, Parker, and Brady (1866–1897) recorded it from the Crag.

In Recent waters *N. labradoricum* is mainly distributed in the Arctic parts of the Atlantic, but it occurs also in the Boreal ones (Nørvang, 1945, p. 28).

Genus Astrononion Cushman and Edwards, 1937

Astrononion gallowayi Loeblich and Tappan

Plate 18, figure 4

1953. *Astrononion gallowayi* Loeblich and Tappan, p. 90, pl. 17, figs. 4–7.
1954a. *Astrononion gallowayi* Loeblich and Tappan – Feyling-Hanssen, p. 139, pl. 2, fig. 9.

Greatest diameter of hypotype of figure 4, 0.65 mm, greatest thickness 0.19 mm. Greatest diameter of unfigured hypotype from zone A of boring no. 27 at Valle by Sarpsborg, 0.49 mm, thickness 0.17 mm.

Occurrence. – This species was common in the Late Pleistocene zone A in the Oslofjord area, about 1–20 specimens occurring per sample. It had an intermittent occurrence in the other units of the foraminiferal zonation, Post Glacial as well as Late Glacial.

Remarks. – This species has probably often been recorded as *Nonionina stelligera* d'Orbigny.

Astrononion tumidum Cushman and Edwards
Plate 18, figure 3

1937. *Astrononion tumidum* Cushman and Edwards, p. 33, pl. 3, fig. 17.
1954a. *Astrononion tumidum* Cushman and Edwards – Boltovskoy, p. 166, pl. 7, fig. 7.
1960. *Astrononion tumidum* Cushman and Edwards – Barker, p. 224, pl. 109, fig. 5.

The figured specimen had lost its two latest chambers. Its greatest diameter was 0.32 mm, least diameter 0.26 mm, thickness 0.18 mm. An unfigured specimen from subzone F_{II} of boring no. 31 (O 1–33) at Akerselva, Oslo, had greatest diameter 0.41 mm, least diameter 0.32 mm, thickness 0.16 mm.

Occurrence. – A few specimens of this species occurred in the Post Glacial subzone F_{II} of borings in Fredrikstad, at Nesset and in the city of Oslo. In boring no. 48 at Grønlandsleret, Oslo, it was found in subzone F_{I}. It was rare.

Remarks. – Cushman and Edwards (l.c.) gave 0.6 mm as greatest diameter, Boltovskoy (l.c.) recorded 0.25 mm as greatest diameter of his specimens from the Gulf of San Jorge, Argentina.

Genus Pullenia Parker and Jones, 1862
Pullenia bulloides (d'Orbigny)
Plate 18, figures 1, 2

1826. *Nonionina bulloides* d'Orbigny, p. 293, No. 2.
1826. *Nonionina sphaeroides* d'Orbigny, p. 293, No. 1; Modèles No. 43.
1846. *Nonionina bulloides* d'Orbigny, p. 107, pl. 5, figs. 9, 10.
1924. *Pullenia sphaeroides* (d'Orbigny) – Cushman, Bull. 104, pt. 5, p. 40, pl. 8, figs. 3, 4.
1943. *Pullenia bulloides* (d'Orbigny) – Cushman and Todd, p. 13, pl. 2, figs. 15–18.
1958. *Pullenia bulloides* (d'Orbigny) – Batjes, p. 139, pl. 6, fig. 9.
1960. *Pullenia bulloides* (d'Orbigny) – Barker, p. 174, pl. 84, figs. 12, 13.

The figured specimen was broken. Its greatest diameter was 0.38 mm, least diameter 0.32 mm, thickness 0.30 mm.

Occurrence. – This species was observed in a few samples from zone F of the Post Glacial in the Oslofjord area. It was very rare.

Remarks. – The present specimens were almost globular with very broadly rounded periphery, not lobulate in outline. The sutures were flush with the surface and the apertural face extremely low.

Pullenia osloensis Feyling-Hanssen
Plate 18, figures 5, 6

1954a. *Pullenia quinqueloba minuta* Feyling-Hanssen, p. 133, pl. 2, fig. 3.
1954b. *Pullenia osloensis*, new name, Feyling-Hanssen, p. 194, pl. 1, figs. 33–35.

Greatest diameter of the figured specimen, 0.19 mm, least diameter 0.17 mm, thickness 0.13 mm. An unfigured specimen from subzone B_l of boring no. 22, Valle by Sarpsborg, had greatest diameter 0.17 mm.

Occurrence. – This species was most common in the Early Holocene of the Oslofjord area, especially in zone C, but also in subzone B_l, zone D and zone E. It was usually rare in the Post Glacial zone F, and occurred intermittently in the Late Pleistocene subzones A_u and A_m.

Remarks. - This small, five-chambered, lobulate, and translucent *Pullenia* is the only common representative of this genus in the Late Quaternary of the Oslofjord area.

Pullenia subcarinata (d'Orbigny)
Plate 18, figures 7, 8

1839b. *Nonionina subcarinata* d'Orbigny, p. 28, pl. 5, figs. 23, 24.
1851. *Nonionina quinqueloba* Reuss, p. 71, pl. 5, fig. 31.
1932a. *Pullenia subcarinata* (d'Orbigny) – Heron-Allen and Earland, p. 403, pl. 13, figs. 14–18.
1958. *Pullenia quinqueloba* (Reuss) – Batjes, p. 139, pl. 6, fig. 8.
1960. *Pullenia subcarinata* (d'Orbigny) – Barker, p. 174, pl. 84, figs. 14, 15.

The figured specimen had greatest diameter 0.24 mm, thickness 0.13 mm. Unfigured specimens from subzone F_u of boring no. 31 (O 1–33)at the river Akerselva, had greatest diameter ranging from 0.38 mm to 0.43 mm.

Occurrence. – This species occurred in the Post Glacial subzone F_u of some of the borings in the northern part of the Oslofjord area (Nesset, Drammen, Skøyen and Akerselva in Oslo). It was usually rare.

Remarks. – The specimens of the present material were all five-chambered.

Superfamily SPIRILLINOIDEA Reuss, 1862
Family **SPIRILLINIDAE** Reuss, 1862
Subfamily **Patellininae** Rhumbler, 1906
Genus Patellina Williamson, 1858
Patellina corrugata Williamson
Plate 18, figure 9

1858. *Patellina corrugata* Williamson, p. 46, pl. 3, figs. 86–89.
1953. *Patellina corrugata* Williamson – Loeblich and Tappan, p. 114, pl. 21, figs. 4, 5.

Greatest diameter of hypotype of figure 9, 0.24 mm, height of spire 0.08 mm.

Occurrence. – Single specimens of this species occurred in a few core samples from the Late Quaternary of the Oslofjord area, viz., in the Late Pleistocene subzone A_m and the Holocene zones E and F. One specimen occurred in zone G of boring no. 5 at Majorstuen, Oslo.

Remarks. – The present writer (1954 a) recorded *Patellina corrugata* in a sample with *Mytilus edulis* from Lund near Halden. Hessland (1943) found it in two Late Pleistocene samples from North Bohuslän in Sweden, and Madsen (1895 a) recorded it from the Danish Pleistocene. Its Recent distribution seems to be cosmopolitan (Nørvang, 1945).

Superfamily ROTALIOIDEA Ehrenberg, 1839
Family **DISCORBIDAE** Cushman, 1927
Subfamily **Discorbinae** Cushman, 1927
Genus Rosalina d'Orbigny, 1826
Rosalina globularis d'Orbigny

1826. *Rosalina globularis* d'Orbigny, p. 271, pl. 13, figs. 1, 2. Modèles No. 69.
1884. *Discorbina globularis* (d'Orbigny) – Brady, p. 643, pl. 86, fig. 13.
1931. *Discorbis globularis* (d'Orbigny) – Cushman, Bull. 104, pt. 8, p. 22, pl. 4, fig. 9 (with extensive synonymy).
1950b. *Discorbis globularis* (d'Orbigny) – van Voorthuysen, p. 64, pl. 3, fig. 8.

Greatest diameter of an unfigured specimen from subzone B_u, the deepest part of boring F 1 (O 700) of Storøymyr, Fornebo, 0.38 mm, thickness 0.16 mm. Greatest diameter of a specimen from subzone F_m of boring no. 5 (O 358) in Sandefjord, 0.31 mm, thickness 0.13 mm.

Occurrence. – A few specimens of this species occurred in some samples with zone F – associations in the northern part of the Oslofjord area as well as in the southern. One specimen was found in the deepest part of boring F 1 at Storøymyr, Fornebo, classified as latest part of subzone B_u. It was not observed in Pleistocene deposits of the area.

Remarks. – This species is common in Recent faunas about the British Isles and western Europe (Cushman, l.c.), but there are records even from Greenland (Cp. Nørvang, 1945, p. 78). Buch (1955, p. 617) recorded it from Riss and Mindel/Riss Interglacial of a boring at Inder Bjergum in Jutland. Van Voorthuysen (l.c.) found a few specimens in the Dutch Pliocene.

Rosalina vilardeboana d'Orbigny

Plate 18, figures 10, 11

1839b. *Rosalina vilardeboana* d'Orbigny, p. 44, pl. 6, figs. 13–15.
1884. *Discorbina vilardeboana* (d'Orbigny) – Brady, p. 645, pl. 86, fig. 9.
1937. *Discorbina vilardeboana* (d'Orbigny) – Föyn, p. 1–16, pl. 2, fig. 11.
1960. *Rosalina vilardeboana* d'Orbigny – Barker, p. 178, pl. 86, fig. 9.

Greatest diameter of hypotype of figures 10 and 11, 0.51 mm, least diameter 0.40 mm, thickness 0.19 mm. In subzone A_m of boring no. 27 (O 287) at Valle a specimen of this species had largest diameter 0.70 mm, least diameter 0.54 mm. A specimen from zone E of boring no. 1 (O 358), Sandefjord, had a greatest diameter of 0.36 mm, least diameter 0.30 mm.

Occurrence. – Some specimens of this species occurred both in Pleistocene and Holocene deposits of the Oslofjord area, viz., in subzone A_m of the Pleistocene, and the zones D, E, and F of the Holocene.

Genus Neoconorbina Hofker, 1951

Neoconorbina williamsoni (Chapman and Parr)

1858. *Rotalina nitida* Williamson (not *Rotalina nitida* Reuss, 1844), p. 54, pl. 4, figs. 106–108.
1932. *Discorbis williamsoni* Chapman and Parr – Parr, p. 226, pl. 21, fig. 25.
1949. *Discorbis nitida* (Williamson) – Cushman, p. 41, pl. 8, fig. 1.
1957. *Rosalina williamsoni* (Chapman and Parr) – van Voorthuysen, p. 34, pl. 24, fig. 19.
1958. *Neoconorbina williamsoni* (Parr) – F. L. Parker, p. 267, pl. 3, figs. 28, 29.
1960. *Rosalina williamsoni* (Chapman and Parr) – van Voorthuysen, p. 252, pl. 11, fig. 19.

A specimen from boring no. 1, Sandefjord, measured: greatest diameter 0.31 mm, thickness 0.10 mm.

Occurrence. – A few specimens occurred in the Holocene subzones F_m of Sandefjord and F_u of Fredrikstad. The species was rare.

Genus Valvulineria Cushman, 1926
Valvulineria minuta F. L. Parker
Plate 18, figures 12–14

1954. *Valvulineria minuta* F. L. Parker, p. 527, pl. 9, figs. 4–6.

The figured specimen had a greatest diameter of 0.27 mm, least diameter 0.22 mm, thickness 0.15 mm.

Occurrence. – A few specimens of this species occurred in the Post Glacial subzone F_u in Fredrikstad and Oslo.

Genus Buccella Andersen, 1952
Buccella frigida (Cushman)
Plate 18, figures 15–18

1922a. *Pulvinulina frigida* Cushman, p. 12.
1949a. *Eponides frigidus* (Cushman) – van Voorthuysen, p. 66, pl. 1, fig. 3.
1952. *Buccella frigida* (Cushman) – Andersen, p. 144, fig. 4–6.
1953. *Buccella frigida* (Cushman) – Loeblich and Tappan, p. 115, pl. 22, figs. 2, 3.
1954a. *Buccella frigida* (Cushman) – Feyling-Hanssen, p. 136.
1957. *Buccella frigida* (Cushman) – van Voorthuysen, p. 33, pl. 24, fig. 15.
1959. *Buccella frigida* (Cushman) – Boltovskoy, p. 92, pl. 13, fig. 5.

Greatest diameter of hypotype of figures 15 and 16, 0.28 mm, thickness 0.15 mm. Greatest diameter of hypotype of figures 17 and 18, 0.34 mm, thickness 0.16 mm.

Occurrence. – This species was rare in the Late Quaternary of the Oslofjord area. It occurred in zone C of boring no. F 1 (O 700) at Storøymyr, Fornebo, in zone D of boring no. 5 (O 283) at Majorstuen, Oslo, in subzone F_u of boring no. 2, profile C, Fredrikstad, and in subzone F_m of boring no. 1, Sandefjord. 8 specimens occurred in a sample of Mytilus clay at Strømmen northeast of Oslo. The figured specimens are from a Late Pleistocene sample from a terrace close to Tingsager Church, Lillesand, southwest of the Oslofjord area.

Remarks. – The present writer (1954 a) found this species in clay with *Mytilus edulis* at Lund in Idd, near Halden. Brotzen (1951) recorded it from a boring at Surte in Southwest Sweden, both from the Late Glacial and Post Glacial part of the boring. Van Voorthuysen (1949, 1957) found it in the Icenian, Early Pleistocene, and Eemian of the Netherlands.

Genus Epistominella Husezima and Maruhasi, 1944

Epistominella exigua (Brady)

Plate 18, figures 19, 20

1884. *Pulvinulina exigua* Brady, p. 696, pl. 103, figs. 13, 14.
1931. *Eponides exigua* (H. B. Brady) – Cushman, Bull. 104, pt. 8, p. 44, pl. 10, figs. 1, 2.
1954a. *Eponides exiguus* (H. B. Brady) – Feyling-Hanssen, p. 135, pl. 2, fig. 4.
1954. *Epistominella exigua* (H. B. Brady) – F. L. Parker, p. 533, pl. 10, figs. 22, 23.
1960. *Epistominella exigua* (Brady) – Barker, p. 212, pl. 103, figs. 13, 14.

The specimen of figure 19 had greatest diameter 0.17 mm, thickness 0.08 mm. The specimen of figure 20 had greatest diameter 0.16 mm, thickness 0.08 mm. Unfigured specimens from the present material had diameters ranging from 0.13 mm to 0.19 mm.

Occurrence. – This species was common in the Post Glacial zone F in the northern as well as in the southern part of the Oslofjord area. It occurred also in zone E, and single specimens were observed in subzone B_u. Some specimens occurred also in the Late Glacial deposits of boring no. 1 (O 953) at Sauøya, Halden.

Remarks. – The present specimens are small for the species. *E. exigua* was recorded by the present writer (1954a) as common in samples of Isocardia clay from the Oslofjord area.

Subfamily **Anomalininae** Cushman, 1927

Genus Cibicides Montfort, 1808

Cibicides bertheloti (d'Orbigny)

Plate 18, figures 21–24

1839a. *Rosalina bertheloti* d'Orbigny, p. 135, pl. 1, figs. 28–30.
1931. *Discorbis bertheloti* (d'Orbigny) – Cushman, Bull. 104, pt. 8, p. 16, pl. 3, fig. 2 (with extensive synonymy).
1948. *Discorbis bertheloti* (d'Orbigny) – Cushman, p. 69, pl. 7, fig. 14.
1959. *Cibicides bertheloti* (d'Orbigny), forma *typica* Boltovskoy, p. 104, pl. 17, fig. 4.
1960. *Discopulvinulina bertheloti* (d'Orbigny) – Barker, p. 184, pl. 89, figs. 11, 12.

The specimen illustrated in figures 21 and 22 broke during handling for photographing. Its greatest diameter was 0.50 mm, its thickness 0.15 mm. Greatest diameter of the specimen of figures 23 and 24, 0.31 mm, thickness 0.10 mm.

Occurrence. – Very few specimens of this species were observed in the Holocene zones C and E in Oslo, and in zone C of boring no. F 1 (O 700), Fornebo.

Cibicides lobatulus (Walker and Jacob)

Plate 19, figures 1–3

1798. *Nautilus lobatulus* Walker and Jacob, p. 642, pl. 14, fig. 36.
1931. *Cibicides lobatulus* (Walker and Jacob) – Cushman, Bull. 104, pt. 8, p. 118, pl. 21, fig. 3.
1954a. *Cibicides lobatulus* (Walker and Jacob) – Feyling-Hanssen, p. 136, pl. 2, fig. 5.
1958. *Cibicides lobatulus* (Walker and Jacob) – Batjes, p. 153, pl. 9, figs. 7, 8.
1961. *Cibicides lobatulus* (Walker and Jacob) – Nyholm, p. 157–196, pl. 1–5, text figs. 1–21.

Greatest diameter of hypotype of figures 1–3, 0.96 mm, least diameter 0.78 mm, thickness 0.43 mm.

Occurrence. – This species was common in Late Quaternary deposits of the Oslofjord area. It occurred in Post Glacial as well as Late Glacial deposits, but was most common in the latter, especially in the Late Pleistocene subzone A_m. It was more often met with in subzone B_l than in subzone B_u, more often in zone C than in zone D. Within the Post Glacial part of the deposits it was more common in zone E than in zone F. It was rare in zone G. *Cibicides lobatulus* was frequent in shallow-water samples e.g., together with the pelecypode *Mytilus edulis*.

Remarks. – This species was recorded from Late Quaternary deposits in the Oslofjord area already by Sars (1865, as *Truncatulina lobatula*). There are old and recent records of its Pleistocene occurrence in Sweden, Denmark, northern Germany, the Netherlands, Great Britain, and other countries. Van Voorthuysen (1949) recorded *C. lobatulus* from Oligocene to Recent sediments in the Netherlands, especially frequent at the beginning of Pliocene time (Cp. Batjes, 1958). Its distribution along Recent oceans seems to be cosmopolitan, most common in cool waters of moderate depth.

Nyholm (1961) studied the life cycle of *Cibicides lobatulus* and found that three main types of test were formed: "a monothalamous test resembling *Crithionina* or *Webbina*; a chambered test resembling *Cibicides*, *Dyocibicides*, *Annulocibicides*, *Cyclocibicides*, *Stichocibicides* or *Rectocibicides* according to the conditions of growth; and a planorbulinoid test". (Nyholm, l.c., p. 157). *Planorbulina mediterranensis* d'Orbigny, of which two specimens were found in Isocardia clay of the Oslofjord area by the present writer (1954 a, p. 137), represents a resting schizont of *Cibicides lobatulus* (Cp. also Le Calvez, 1937).

Cibicides pseudoungerianus (Cushman)

Plate 19, figures 4–6

1922b. *Truncatulina pseudoungerianus* Cushman, p. 97, pl. 20, fig. 9.
1931. *Cibicides pseudoungerianus* (Cushman) – Cushman, Bull. 104, pt. 8, p. 123, pl. 22, figs. 3–7.
1954a. *Cibicides pseudoungerianus* (Cushman) – Boltovskoy, p. 214, pl. 15, fig. 7.
1954a. *Cibicides pseudoungerianus* (Cushman) – Feyling-Hanssen, p. 136.
1958. *Cibicides pseudoungeriana* (Cushman) – van Voorthuysen, p. 22, pl. 7, fig. 81.
1960. *Cibicides pseudoungerianus* (Cushman) – Barker, p. 194, pl. 94, fig. 9.

The figured hypotype had a greatest diameter of 0.73 mm, least diameter 0.59 mm, thickness 0.27 mm. The specimens from the Late Quaternary of the Oslofjord area are in good accordance with those figured by Cushman, but the sutures are in most cases depressed and only slightly, if at all, limbate.

Occurrence. – This species occurred only in Holocene deposits in the Oslofjord area. It was never frequent but quite common in the Post Glacial zones E and F. Some specimens were found in the Late Glacial zone C, and a single one occurred in subzone B_{II} of boring F 1, Storøymyr, Fornebo.

Remarks. – The present writer found *Cibicides pseudoungerianus* in two samples of Isocardia clay from the Oslofjord area (1954 a). Hessland (1943) found it in Post Glacial samples from North Bohuslän in Sweden, and van Voorthuysen (1950 a, 1958) recorded it in Plio-Pleistocene and in Eemian deposits in the Netherlands.

Genus Gypsina Carter, 1877

Gypsina vesicularis (Parker and Jones)

Plate 19, figure 7

1860. *Orbitolina vesicularis* Parker and Jones, p. 31, no. 5.
1884. *Gypsina vesicularis* (Parker and Jones) – Brady, p. 718, pl. 101, figs. 9–12.
1931. *Gypsina vesicularis* (Parker and Jones) – Cushman, Bull. 104, pt. 8, p. 135.
1954. *Gypsina vesicularis* (Parker and Jones) – F. L. Parker, p. 545, pl. 13, fig. 12.

The specimen of figure 7 had a greatest diameter of 1.35 mm. Other clods of the present material had diameters ranging from 0.54 mm to 1.67 mm.

Occurrence. – Some specimens of this "species" occurred in Münster's collection from a Lower Tapes bed (zone F) at Smedholmen by Brevik. It was, however, not recorded on his list of Foraminifera from this locality. It was not found in clay sediments.

Remarks. – Nyholm (1962) showed by the study of living specimens that *Gypsina* is a resting stage of *Cibicides lobatulus*. Reproduction was by schizogony which could continue generation after generation and, especially on a rough substratum, build up enormous dense and aggregated *Gypsina* – populations.

Gypsina is in the present study maintained merely as a form genus.

Family **CERATOBULIMINIDAE** Cushman, 1927
Genus Ceratobulimina Toula, 1915
Ceratobulimina arctica Green
Plate 19, figures 8–13

1960. *Ceratobulimina arctica* Green, p. 71, pl. 1, fig. 1.

Length of the hypotype of figures 8–10, 0.21 mm, greatest breadth 0.14 mm, thickness 0.09 mm. Length of hypotype of figures 11–13, 0.22 mm, greatest breadth 0.16 mm, thickness 0.11 mm. Unfigured specimens from the same sample had lengths ranging from 0.17 mm to 0.22 mm.

Occurrence. – This small but conspicuous species occurred in the Late Glacial, Holocene, zone C, of boring no. 1 (F 226) at Skøyen, Oslo, a few specimens only. A single specimen occurred in subzone B_u of boring no. F 1 at Storøymyr, Fornebo. Another specimen was found in the lower part of the Post Glacial zone F of boring no. 2 (O 700) at the same locality.

Remarks. – The present specimens seem to be slightly less compressed than the specimens described by Green. The proloculus of the present specimens seems to be somewhat smaller and the vestibule, formed by a dorsal extension of the chamber wall and opening into the ventral umbilicus, is slightly broader than shown in Green's figure. The specimens from the Late Quaternary of the Oslofjord area are five-chambered with glassy wall. Green described *Ceratobulimina arctica* from the shallowest stations of his survey, 433–510 m, west of Ellesmere Island, where it made up 7 % of the benthonic species.

Family **EPISTOMINIDAE** Wedekind, 1937
Genus Höglundina Brotzen, 1948
Höglundina elegans (d'Orbigny)
Plate 20, figures 1–6

1826. *Rotalia (Turbinulina) elegans* d'Orbigny, p. 276, No. 54.
1884. *Pulvinulina elegans* (d'Orbigny) – Brady, p. 699, pl. 105, figs. 3–6.
1931. *Epistomina elegans* (d'Orbigny) – Cushman, Bull. 104, pt. 8, p. 65, pl. 13, fig. 6.
1953. *Höglundina elegans* (d'Orbigny) – Phleger, Parker, and Peirson, p. 43, pl. 9, figs. 24, 25.
1954. *Höglundina elegans* (d'Orbigny) – F. L. Parker, p. 531, pl. 10, figs. 4, 8.
1961. *Höglundina elegans* (d'Orbigny) – Boltovskoy, p. 278, pl. 3, figs. 33, 34.

Greatest diameter of hypotype of figures 1–3, 0.61 mm, least diameter 0.54 mm, thickness 0.30 mm. Greatest diameter of hypotype of figures 4–6, 0.61 mm, least diameter 0.50 mm, thickness 0.27 mm. An unfigured specimen from subzone F_m of boring A, Onsøy, Østfold, had a greatest diameter of 0.78 mm.

Occurrence. – This species was found only in the Post Glacial zone F of the Holocene in the Oslofjord area. It was quite common in subzone F_m and the lowest part of subzone F_u in boring A, Onsøy in Østfold. It occurred in similar strata also in other localities, in the northern as well as in the southern part of the area, but was usually rare.

Remarks. – Crosskey and Robertson (1868) listed *Pulvinulina elegans* among the Foraminifera they collected from raised clay deposits in the Oslofjord area. Kiær (1900) recorded it from a collection of Quaternary Foraminifera made by M. Sars (Cp. p. 27 of the present paper).

Höglundina elegans is widely distributed in temperate waters of the Recent oceans.

Troelsen (1954) regards *Höglundina* as a junior synonym of *Epistomina*.

Family **ROBERTINIDAE** Reuss, 1850
Genus Robertinoides Höglund, 1947
Robertinoides normani (Goës)
Plate 19, figure 14

1894. *Bulimina normani* Goës, p. 47, pl. 9, figs. 437, 438.
1947. *Robertinoides normani* (Goës) – Höglund, p. 222, pl. 18, fig. 3; pl. 19, fig. 3; text fig. 199.

The hypotype of figure 14 had a length of 0.54 mm, breadth 0.39 mm. An unfigured hypotype from zone D of boring no. 15 (O 88) in Drammen, had a length of 0.65 mm, breadth 0.49 mm.

Occurrence. – Single specimens of this species occurred in the subzone B_u and the zones C, D, E, and F of the Holocene in the Oslofjord area.

Robertinoides pumilum Höglund
Plate 19, figure 15

1947. *Robertinoides pumilum* Höglund, p. 227, pl. 18, fig. 5.

Length of the figured hypotype, 0.31 mm, breadth 0.17 mm.

Occurrence. – Single specimens of this species occurred in subzone B_u and in the zones C, D, E, and F of the Holocene in the Oslofjord area.

Family **ORBULINIDAE** Schultze, 1854
Genus Globigerina d'Orbigny
Globigerina bulloides d'Orbigny

1826. *Globigerina bulloides* d'Orbigny, p. 277, No. 1, – Modèles, No. 17 and 76.
1839c. *Globigerina bulloides* d'Orbigny, p. 132, pl. 2, figs. 1–3, 28.
1884. *Globigerina bulloides* d'Orbigny – Brady, p. 593, pl. 79, figs. 3–7.

A single specimen was found in a sample from subzone A_m from the island of Hvaler. It was lost before it could be measured. An uncomplete specimen from a Late Pleistocene sample, subzone A_m, from the Ra ridge at Bøkeskogen, Larvik, had a greatest diameter of 0.22 mm. A worn specimen was recorded from a zone D sample from Borgen, Ullensaker, 30 km northeast of Oslo (Feyling-Hanssen, 1954 c).

Family **ELPHIDIIDAE** Galloway, 1933
Genus Elphidium Montfort, 1808
Elphidium bartletti Cushman
Plate 21, figures 1, 2

1933. *Elphidium bartletti* Cushman, p. 4, pl. 1, fig. 9.
1939. *Elphidium bartletti* Cushman, p. 64, pl. 18, fig. 10.
1953. *Elphidium bartletti* Cushman – Loeblich and Tappan, p. 96, pl. 18, figs. 10–14.

The figured specimen is a Recent one from Spitsbergen, greatest diameter 0.86 mm, thickness 0.40 mm.

Two specimens of this species occurred in the Pleistocene subzone A_m of boring no. 22 at Valle by Sarpsborg. One of them had a greatest diameter of 0.55 mm, thickness 0.27 mm. The other had a greatest diameter of 0.48, thickness 0.21 mm.

Elphidium excavatum (Terquem)
Plate 20, figures 7, 8

1879. *Polystomella excavata* Terquem, p. 25, pl. 2, fig. 2.
1938. *Elphidium excavatum* (Terquem) – Bartenstein, p. 389, 390, fig. 3.
1939. *Elphidium excavatum* (Terquem) – Cushman, p. 58, pl. 16, figs. 7–12.
1954a. *Elphidium excavatum* (Terquem) – Feyling-Hanssen, p. 142.

Greatest diameter of hypotype of figures 7 and 8, 0.48 mm, thickness 0.20 mm.

Occurrence. – The figured specimen is from a clay sample collected by B. G. Andersen in a terrace near Tingsager Church at Lillesand, southwest of the Oslofjord area. Molluscan shells from this sample were radiologically dated at 12 500 ± 200 years before present (submitted for dating by Andersen and dated by R. Nydal). According to this the sample is of Late Pleistocene age. In the Late Quaternary of the Oslofjord area *E. excavatum* was found mainly in Post Glacial deposits, i.e., in the foraminiferal zones E, F, and G. It occurred though in assumed Pleistocene deposits at Halden (p. 133). It was frequent only in sediments deposited in the shallowest water.

Remarks. – This species was recorded by the present writer from samples of Mytilus- and Cyprina clay and from Isocardia clay in the Oslofjord area (1954 a). Hessland (1943) and Brotzen (1951) recorded it from Late Quaternary deposits in southwestern Sweden. Its main Recent distribution is probably Boreal – Lusitanian.

Elphidium incertum incertum (Williamson)
Plate 19, figures 16, 17; plate 20, figures 9, 10

1858. *Polystomella umbilicatula*, var. *incerta* Williamson, p. 44, pl. 3, fig. 82a.
1884. *Polystomella striatopunctata* (Fichtel and Moll) – Brady, p. 733, pl. 109, fig. 23.
1932. *Elphidium incertum* (Williamson) – Macfadyen, p. 821, pl. 35, fig. 6.
1941. *Elphidium incertum incertum* (Williamson) – Brand, p. 58.
1944. *Elphidium incertum* (Williamson) – Cushman, p. 25, pl. 3, figs. 28–31.
1952b. *Elphidium incertum* (Williamson) – Phleger, p. 83, pl. 14, fig. 7.
1953. *Elphidium incertum* (Williamson) – Loeblich and Tappan, p. 100 (discussion).
1954a. *Elphidium incertum incertum* (Williamson) – Feyling-Hanssen, p. 141, pl. 2, fig. 10.

Greatest diameter of hypotype of figure 16 of plate 19, 0.38 mm, thickness 0.19 mm. Greatest diameter of hypotype of figure 17, 0.38 mm, thickness 0.18 mm. Greatest diameter of figures 10 and 11 of plate 20, 0.43 mm, thickness 0.22 mm. Other specimens of the present material had diameters ranging from 0.30 mm to 0.48 mm.

Occurrence. – *Elphidium i. incertum* was frequent in the Post Glacial zone E, frequent to common in the Post Glacial zone F. It was usually met with also in zone G of localities being situated higher than approximately 7–10 m above present-day sea level. In low-lying borings in which *Nonion labradoricum* occurred commonly in zone G and subzone F_u, *E. i. incertum* was absent or practically so, in the same units. A few specimens of *E. i. incertum* usually occurred in the Late Glacial zones B and C and in the Late Pleistocene subzone A_m. It occurred only casually in other Late Glacial units of the foraminiferal zonation in the Oslofjord area. By its frequency in Post Glacial Holocene deposits *E. i. incertum* was to some extent characteristic of such deposits.

Remarks. – The present writer found numerous specimens of this subspecies in Isocardia clay of the Oslofjord area and recorded it also from other Post Glacial samples there (1954 a, 1954 b). Hessland (1943) and Brotzen (1951) recorded *E. incertum* from Late Quaternary deposits in south-western Sweden, and Buch (1955) from Pleistocene deposits in Jutland. Its Recent distribution seems to be mainly Boreal (Nørvang, 1945).

Elphidium incertum clavatum Cushman
Plate 20, figures 11–15

1930. *Elphidium incertum* (Williamson), var. *clavatum* Cushman, Bull. 104, pt. 7, p. 20, pl. 7, fig. 10.
1939. *Elphidium incertum* (Williamson), var. *clavatum* Cushman, p. 57, pl. 16, fig. 1, 2.
1941. *Elphidium incertum clavatum* Cushman – Brand, p. 58.
1953. *Elphidium clavatum* Cushman – Loeblich and Tappan, p. 98, pl. 19, figs. 8–10.
1954a. *Elphidium incertum clavatum* Cushman – Feyling-Hanssen, p. 141, pl. 2, fig. 11.
1954b. *Elphidium incertum clavatum* Cushman – Boltovskoy, p. 275, pl. 24, fig. 7.
1961. *Elphidium selseyense* (Heron-Allen and Earland) – Richter (not *Polystomella striatopunctata*, var *selseyensis* Heron-Allen and Earland, 1915), fig. 1.

The dimensions of the specimen of figure 11 was not measured. The greatest diameter of hypotype of figure 12, 0.38 mm, thickness 0.15 mm. Greatest diameter of hypotype of figure 13, 0.41 mm, thickness 0.18 mm.

Greatest diameter of hypotype of figures 14 and 15, 0.36 mm, thickness 0.17 mm. Other specimens of the present material had diameters ranging from 0.19 mm to 0.48 mm. The size distribution of 200 specimens, 100 from zone A and 100 from zone D, was illustrated in figure 34.

Occurrence. – *Elphidium i. clavatum* predominated in the Late Glacial parts of the borings from the Oslofjord area, from the Late Pleistocene zone A through the Holocene zone D. It amounted to more than 90 % of the fauna in many samples from subzone A_I and A_{II} and from zone D. In the Post Glacial subzone E *Elphidium i. clavatum* and *Elphidium i. incertum* were almost equally frequent. In the other Post Glacial zones it was usually rare. *Elphidium i. clavatum*, thus, by its frequency is characteristic of Late Glacial deposits in the Oslofjord area whereas *Elphidium i. incertum* is characteristic of Post Glacial ones.

Remarks. – Cushman (1930) described this form as a variety of *Elphidium incertum*, Brand (1941) regarded it as a subspecies, and Loeblich and Tappan (1953) raised it to specific rank. As in the present material, especially in zone E, there occur transitional forms between typical *incertum* and typical *clavatum*, it seems to the present writer more reasonable to separate the two by an intraspecific category rather than by a specific one. Future cultivation experiments will probably provide an answer to the question about the real nature of the difference between *E. i. clavatum* and *E. i. incertum*. Wall structure investigations may also contribute to a solution of the problem. Priliminarily, as they appear to be of great stratigraphical significance in the present deposits, they are here regarded as subspecies, the writer being aware of the difficulties involved in this view (Cp. general discussion by Nørvang, 1957, p. 20–23). In some samples from subzone A_{II} there occurred specimens with rather wide umbilicus filled with clear shell material.

Elphidium i. clavatum was previously recorded from Late Glacial deposits in Sweden as well as in Norway (Sars, 1865; Munthe, 1896, 1901; Kiær, 1900, 1908; Hessland, 1943; Brotzen, 1951; Feyling-Hanssen, 1954 a, b, 1957, 1958 b; Risdal, 1962). In the Pleistocene of Denmark and Slesvick-Holstein it was found by Madsen (1895 a, b, 1900); Buch (1955) recorded it from the Esbjerg Yoldia clay (Mindel/Riss Interglacial). Brand (1941) found it in Post Glacial strata at the Jade Bay on the German North Sea coast, and van Voorthuysen (1949, 1950 a) found it in the Early Pleistocene of the Netherlands. Its main Recent distribution is Arctic-Boreal (Cp. i.a., Cushman, 1939; Ellinger, 1914).

Elphidium macellum (Fichtel and Moll)
Plate 20, figure 16

1798. *Nautilus macellus* Fichtel and Moll, p. 66, var. B, pl. 10, figs. h-k.
1932. *Elphidium macellum* (Fichtel and Moll) – Bogdanowicz and Fedorov, p. 8, text figs. 2–8, pl. 1, fig. 1.
1939. *Elphidium macellum* (Fichtel and Moll) – Cushman, p. 51, pl. 14, figs. 1–3; pl. 15, figs. 9, 10.
1943. *Elphidium macellum* (Fichtel and Moll) – Hessland, pl. 3, fig. 40.
1953b. *Elphidium macellum* (Fichtel and Moll) – Boltovskoy, p. 273, pl. 24, fig. 8.
1960. *Elphidium macellum* (Fichtel and Moll) – Barker, p. 226, pl. 110, figs. 8, 11.

Greatest diameter of hypotype of figure 16, 0.51 mm, thickness 0.21 mm. An unfigured specimen from the Post Glacial zone F of boring no. 1 in Sandefjord had a greatest diameter of 0.35 mm, thickness 0.15 mm. Another unfigured specimen from the latter sample measured, greatest diameter 0.43 mm, thickness 0.16 mm.

Occurrence. – *Elphidium macellum* occurred in the Post Glacial zone F of some borings. It was rare. A single specimen was observed in the deepest part of boring no. F 1 at Storøymyr, Fornebo, the part which was tentatively classified as B_u.

Remarks. – Hessland (1943) recorded this species from young Post Glacial deposits in southwestern Sweden. It was originally described from Recent Mediterranean faunas.

Elphidium subarcticum Cushman
Plate 20, figures 17–19

1944. *Elphidium subarcticum* Cushman, p. 27, pl. 3, figs. 34, 35.
1953. *Elphidium subarcticum* Cushman – Loeblich and Tappan, p. 105, pl. 19, figs. 5–7.
1954a. *Elphidium incertum selseyensis* (Heron-Allen and Earland) – Feyling-Hanssen (not *Polystomella striatopunctata*, var. *selseyensis* Heron-Allen and Earland, 1915), p. 142, pl. 2, fig. 12.
1954a. *Elphidium asterizans* (Fichtel and Moll) – Feyling-Hanssen (not *Nautilus asterizans* Fichtel and Moll, 1798), p. 140.

Greatest diameter of hypotype of figure 17, 0.27 mm, thickness 0.13 mm. Greatest diameter of hypotype of figure 18, 0.44 mm, thickness 0.19 mm. Greatest diameter of hypotype of figure 19, 0.32 mm, thickness 0.14 mm. Other specimens of the present material had diameters ranging from 0.26 mm to 0.86 mm.

Occurrence. – This species was found in most of the core samples from the Late Quaternary of the Oslofjord area, Holocene as well as Late Pleistocene, Post Glacial as well as Late Glacial. It usually made up less than 1 % of the faunas in which it occurred, but was more frequent in shallow-water deposits.

Genus Elphidiella Cushman, 1936
Elphidiella arctica (Parker and Jones)

1864. *Polystomella arctica* Parker and Jones, in Brady, 1864, p. 471, pl. 48, fig. 18.
1930. *Elphidium arcticum* (Parker and Jones) – Cushman, Bull. 104, pt. 7, p. 27, pl. 11, figs. 1–6.
1939. *Elphidiella arctica* (Parker and Jones) – Cushman, p. 65, pl. 18, figs. 11–14.
1941. *Elphidiella arctica* (Parker and Jones) – Ten Dam and Reinhold, p. 54, pl. 3, figs. 11, 12; pl. 6, fig. 3.
1943. *Elphidiella arctica* (Parker and Jones) – Hessland, pl. 4, figs. 44, 45.
1948. *Elphidium arcticum* (Parker and Jones) – Stschedrina, p. 19, pl. 4, fig. 7.
1949a. *Elphidiella arctica* (Parker and Jones) – van Voorthuysen, p. 64, pl. 1, fig. 1.
1953. *Elphidiella arctica* (Parker and Jones) – Loeblich and Tappan, p. 106, pl. 20, figs. 1–3.
1954a. *Elphidiella arctica* (Parker and Jones) – Feyling-Hanssen, p. 143, pl. 2, fig. 13.

Occurrence. – One specimen of this species occurred in the Late Glacial zone D of boring no. 18 at Bryn in Oslo. The present writer (1954 a) recorded it from two high-lying samples of Mytilus clay, one from Halden and one from Holmenkollen, Oslo.

Remarks. – Typically developed specimens of this species from Holocene deposits at the island of Barentsøya, Spitsbergen, were examined by the present author (1964, in press). They were large, and possessed shallow parallel grooves of different lenghts extending from the double row of sutural pores. Hessland (1943) recorded *E. arctica* in Late Glacial samples from northern Bohuslän in Sweden and Buch (1955) found it in Esbjerg Yoldia clay (Mindel/Riss Interglacial) at Inder Bjergum in Jutland. *E. arctica* is an index fossil of Early Pleistocene deposits in the Netherlands (Ten Dam and Reinhold, 1941; van Voorthuysen, 1949 a, b; 1950 a; 1953).

Genus Protelphidium Haynes, 1956

Protelphidium orbiculare (Brady)

Plate 21, figure 3

1881. *Nonionina orbicularis* Brady, p. 415, pl. 21, fig. 5.
1930. *Nonion orbiculare* (Brady) – Cushman, Bull. 104, pt. 7, p. 12, pl. 5, figs. 1–3.
1939. *Nonion orbiculare* (Brady) – Cushman, p. 23, pl. 6, figs. 17–19.
1940. *Nonion orbiculare* (Brady) – Macfadyen, p. 281, text fig. 2.
1943. *Elphidium orbiculare* (Brady) – Hessland, p. 262.
1948. *Nonion orbiculare* (Brady) – Cushman, p. 53, pl. 6, fig. 3.
1953. *Elphidium orbiculare* (Brady) – Loeblich and Tappan, p. 102, pl. 19, figs. 1–4.
1961. *Protelphidium orbiculare* (Brady) – Todd and Low, p. 20, pl. 2, fig. 11.

Greatest diameter of the figured specimen 0.81 mm, thickness 0.41 mm.

Occurrence. – A small specimen of this species occurred in the Late Pleistocene subzone A_{m} at Valle, and a few specimens were observed in a shallow-water layer of boring no. 3, 92.6 m above sea level at the crossing of Risløkkveien and Ulvenveien in Oslo. It was furthermore found in Mytilus clay at Strømmen, Skedsmo, radiologically dated at 9500 years before the present, and in Mytilus gravel at the marine limit in Skådalen, Oslo, 221.8 m above sea level. It was recorded from Mytilus clay at Vettakollen (Feyling-Hanssen, 1954 a).

Remarks. – The figured specimen is a Recent one from Spitsbergen, where the present writer collected it at 7, 8, 15, and 18 m depth. It is a common species of Arctic waters of to-day.

Family **ROTALIIDAE** Ehrenberg, 1839

Genus Ammonia Brünnich, 1772

Ammonia batavus (Hofker)

Plate 21, figures 4–13

1951. *Streblus batavus* Hofker, p. 492, 501, fig. 340.
1954a. *Streblus beccarii* (Linnaeus) – Feyling-Hanssen (not *Nautilus beccarii* Linné, 1767), p. 143, pl. 2, figs. 14, 15.
1957. *Streblus batavus* Hofker – van Voorthuysen, p. 28, text fig. 1 d.
1960. *Streblus batavus* Hofker ? – Barker, p. 220, pl. 107, fig. 5.

Greatest diameter of the specimen of figures 4 and 5, 0.75 mm, thickness 0.41 mm. Greatest diameter of specimen of figure 6, 0.78 mm, thickness 0.53 mm. Greatest diameter of specimen of figures 7 and 8, 0.81 mm, thickness 0.53 mm. Greatest diameter of figures 9 and 10, 0.86 mm, thickness 0.54 mm. Greatest diameter of specimen of figures

11–13, 0.40 mm, thickness 0.20 mm. 100 specimens from an Upper Tapes bed at Jettegryten by Brevik had greatest diameters ranging from 0.48 mm to 1.22 mm. Specimens from clay deposits did usually not exceed 0.50 mm in diameter.

Occurrence. – This species was frequent in the upper part of the Post Glacial zone F all over the Oslofjord area and common in the lower part of zone G. It occurred in the upper part of zone G as well, but was rare there. In the subzones F_m and F_l it was usually very rare and it occurred only occasionally in zone E. *A. batavus* did not occur in Late Glacial deposits in the Oslofjord area, except that two small specimens, probably of this species, occurred in the deepest sample of boring F 1 of Storøymyr, Fornebo. This deepest part was classified as subzone B_u. Two other small specimens, with hesitation referred to *A. batavus*, occurred in the deepest zone C sample of the same boring. Finally, a small specimen occurred in boring no. 1 at Sauøya, Halden, in a sample assumed to represent a temperate shallow-water deposit of Late Pleistocene age.

Remarks. – In accordance with Pokorný (1958, p. 361) and Cifelli (1962, p. 119) the genus *Streblus* Fisher, 1817, is regarded as a junior synonym of the genus *Ammonia* Brünnich, 1771.

Hofker (1951) separated *A. batavus* from *A. beccarii* i.a., as a smaller and less compressed form. Whereas the diameter of the tests of *A. beccarii* from the Adriatic ranged from 0.62 mm to 1.62 mm, with tops at 0.80 mm and 1.37 mm, the diameter of tests of *A. batavus* from the North Sea ranged from 0.30 mm to 0.80 mm. Differences in apertural and internal structures were discussed. Bermúdez (1952, p. 73) renamed the forms figured by Cushman (1928, pl. 15), and reproduced in plate 12 and 13 of Cushman's monography of the Foraminifera of the Atlantic Ocean (1931, pt. 8), by this referring fig. 2 of plate 13 to *Ammonia batavus*. Van Voorthuysen (1957) described *A. batavus* from Selsey Bill as a species with 8 to 10, usually 9, chambers in the last-formed whorl with an indistinct or divided umbilical plug. Its lobulate marginal outline is also quite characteristic.

The specimens collected by E. B. Münster from an Upper Tapes bed at Brevik, near Skien, are greater than most of the specimens from the clays of the core samples. The ventral plug is divided into a large number of bosses which are distributed also into the more or less excavated ventral sutures which are beaded and fluted. These specimens show some resemblance with *A. corallinorum* (d'Orbigny). Most of the specimens from the core samples of the borings were small and in many of them a ventral plug was hardly discernible (Cp. pl. 21, figs. 11–13). They display similarity with *A. beccarii*, var. *tepida* Cushman (= *A. catesbyanus*, var. *tepida* Cushman). In a sample collected by P. Sæbø from a terrace 40 m above sea level at Loe, Nesodden, near Oslo, large and small specimens intermingled. An umbilical plug appeared primarily in larger specimens, and the number of umbilical and sutural bosses increased with the size of the specimens. Similarly, the number of chambers in the last-formed whorl increased with the size of the specimen.

Hessland (1943, pl. 4, fig. 51) figured *Rotalia beccarii* from Altithermal deposits in northern Bohuslän, Sweden, and Brotzen (1951) referred this form to Cushman's var. *tepida*. According to Hessland's figure, it is very similar to the above-mentioned smaller specimens from the Post Glacial of the Oslofjord area. In addition to *Ammonia beccarii*, var. *tepida* Brotzen recorded typical *Ammonia beccarii*, which may probably correspond to the large forms of *A. batavus* of the Oslofjord area, from the uppermost part of the Surte boring. It would perhaps be practical also in the present area to regard the large form from Altithermal shell beds and the small form from clay sediments as two different varieties or forms.

Genus Hyalinea Hofker, 1951

Hyalinea balthica (Schroeter)

Plate 21, figures 14–16

1783. *Nautilus balthicus* Schroeter, p. 20, pl. 1, fig. 2.
1857. *Operculina complanata* Basterot – Parker and Jones, p. 285, pl. 11, figs. 3, 4.
1884. *Operculina ammonoides* (Gronovius) – Brady, p. 745, pl. 112, figs. 1, 2.
1931. *Anomalina balthica* (Schroeter) – Cushman, Bull. 104, pt. 8, p. 108, pl. 19, fig. 3 (with extensive synonymy).
1951. *Hyalinea balthica* (Schroeter) – Hofker, p. 508, figs. 345–348.
1952. *Hofkerinella balthica* (Schroeter) – Bermúdez, p. 74.
1960. *Hyalinea balthica* (Schroeter) – Barker, p. 230, pl. 112, figs. 1, 2.

Greatest diameter of hypotype of figure 14, 0.64 mm, thickness 0.13 mm. Greatest diameter of hypotype of figure 16, 0.57 mm, thickness 0.13 mm. The hypotype of figure 15 was lost before it was measured.

Occurrence. – This species was frequent in the Post Glacial subzone F_u in the southern as well as in the northern part of the Oslofjord area. Together with *Ammonia batavus* it characterized this subzone. It was rare in the other subzones of zone F and occurred only occasionally in zone E. It was not met with in Late Glacial deposits, except that three specimens occurred in the deepest part of boring F 1 of Storøymyr, Fornebo; that part was classified as subzone B_{II}.

Remarks. – As Hofker (1951) demonstrated the presence of a canal system in this species, he transferred it from *Anomalina* to his new genus *Hyalinea* which he placed in the family Rotaliidae. He was followed by Bermúdez (1952). In fact Hofker regarded *Hyalinea balthica* as a flattened *Streblus* (*Ammonia*) in which the so-called protoforamen is opening into the spiral suture rather than, as in *Ammonia*, into the radiating sutures.

Sars (1865) recorded this species (as *Operculina ammonoides*) as a fossil in Post Glacial shell beds at Ørlandet, near the Trondheimsfjord. It was found in Isocardia clay of the Oslofjord area (Feyling-Hanssen, 1954 a). Brotzen (1951) found it in the youngest Post Glacial zone of the Surte boring in southwestern Sweden. *H. balthica* appeared in the Mediterranean at the beginning of the Quaternary period and is, together with *Cassidulina laevigata carinata*, an index fossil in Quaternary deposits there. According to Nørvang (1945, p. 48) its main Recent distribution is in the Boreal and Lusitanian parts of the Atlantic and the Pacific, from 40 m down to 4500 m, but normally found in shallow water. It is common in the Recent Oslofjord (Kiær, 1900).

Sammendrag

Foraminiferer fra sen-kvartære avsetninger i Oslofjord-området

Bortimot 2 500 prøver fra 130 boringer i sen-kvartære (seneste Allerød til og med Sub-Atlantisk tid) leir-avsetninger i Oslofjord-området er blitt undersøkt mikropaleontologisk, dertil endel overflateprøver fra leirtak og utgravninger i forbindelse med byggearbeider.

Foraminiferene, som utgjorde hovedmassen av mikrofossiler i prøvene er emnet for nærværende utredning. 180 arter, underarter og former av foraminiferer, tilhørende 76 slekter og 23 familier av overfamiliene Astrorhizoidea, Lituoloidea, Milioloidea, Nodosarioidea, Buliminoidea, Spirillinoidea og Rotalioidea forekom. Bare én av artene vites å ha planktonisk levevis, de øvrige er benthoniske. To arter, *Dentalina drammenensis* og *Dentalina trondheimensis*, er beskrevet som nye. I tillegg til foraminiferene observerte s4 arter av thekamøber. De er i lister og diagrammer behandlet sammen med foraminiferene. Ut fra den marine grenses høyde i området, boringenes dybde og deres beliggenhet i forhold til nuværende havnivå, kan det sluttes at det maksimale dyp på hvilket de her beskrevne mikrofaunaer engang levet var ca. 250 m.

Statistisk analyse av foraminifer-innholdet i prøvene fra de forskjellige boringer viste at visse karakteristiske faunaer eller mikrofossil-selskaper opptrer med betydelig lateral persistens. Disse faunaer antas å reflektere forandringer i det marine miljø under avsetningen av de undersøkte sedimenter. En regional forbedring av forholdene, fra ekstremt arktiske til boreale eller endog boreo-lusitaniske, har foregått gjennom det tidsrom disse sedimenter representerer. Samtidig har en regional landhevning av isostatisk karakter, eller rettere en negativ forskyvning av strandlinjen i det undersøkte område, bevirket en oppgrunning av det tidligere fjorddyp i alle undersøkte lokaliteter. De aller fleste boringer ble foretatt på land, og alle disse lokaliteter har engang passert strandsonen under den negative strandlinjeforskyvnings gang.

Arter som dominerte faunaen under glaciale forhold, ble mindre hyppige, kan endog ha forsvunnet fra området, eftersom vanntemperaturen steg, for bare å nevne én faktor. Andre arter blomstret opp og kom til å prege faunaen under de endrede forhold. I almindelighet opptrer gruntvannsformer i prøvene fra de øvre deler av boringene og blir dominerende i topplagene.

Det ble foretatt en inndeling av sedimentene på grunnlag av sonasjonen i foraminifer-faunaen. For korthets skyld ble enhetene i denne, helt og holdent økologisk betingede, sonasjon kalt soner og angitt med bokstaver. 7 slike soner, fra A til G, og 10 undersoner, subsoner, ble utskilt. På grunnlag av sammenligninger av de fossile faunaer med recente fra miljøer som antas noenlunde å svare til dem de fossile faunaer engang levet under, er en interpretasjon av sonene forsøkt. Denne vurdering støtter seg også på radiocarbon-dateringer. Såvidt det har vært mulig er sonene korrellert med den tidligere etablerte mollusk-stratigrafi i området.

Subsone A_m (mellomste del av sone A), med dominans av *Elphidium incertum clavatum* og hyppig forekomst av *Nonion labradoricum*, ble funnet å være av Yngre Dryas alder, avsatt samtidig med dannelsen av Ra-ryggen, det Fennoscandiske substadium i isresessjonen i områdets sydlige del. Subsone B_l (lavere del av sone B), med rikelig forekomst av *E. i. clavatum* og *Cassidulina crassa* og hyppig opptreden av *Virgulina loeblichi* og *Nonion labradoricum*, antas å være av Pre-Boreal alder, avsatt samtidig med dannelsen av de glaciale Ås–Ski rygger. Sone C, av lignende sammensetning som ovennevnte subsone, men med hyppig forekomst av *Cassidulina laevigata carinata* istedenfor av *Nonion labradoricum*, ble også antatt å være av Pre-Boreal alder, muligens avsatt samtidig med dannelsen av Aker-substadiets morener. Sone D, med fattige faunaer dominert av *E. i. clavatum* og med *Cassidulina crassa* og *Quinqueloculina stalkeri* almindelig forekommende, omfatter sedimenter som antas å være avsatt under den endelige nedsmeltning av landisen og tilbakerykning av isfronten, da store mengder koldt, ferskt og rikt sedimentførende smeltevann flommet ut i den daværende Oslofjords grunne nordligste forgreninger. Sone E, med hyppig forekomst av *Elphidium incertum incertum* og *E. i. clavatum*, og særlig sone F, med dominans av *Bulimina marginata*, avspeiler postglaciale varmetidsforhold. Sone G, dominert av gruntvannsformer med agglutinerte sandskall, f. eks. *Eggerella scabra, Spiroplectammina biformis*, *Ammoscalaria runiana* og *Miliammina fusca*, representerer Holocene gruntvannsavsetninger, som regel samtidige med sone F-avsetninger, tildels også med sone E-avsetninger.

Резюме

Фораминиферы из поздне-четвертичных отложений в окрестностях Осло-фиорда

Около 2500 проб из 130 буровых скважин, произведенных в окрестностях Осло-фиорда в поздне-четвертичных глинах (начи ная с последней части Аллередского времени и до Суб-Атлантического), были микро-палеонтологически изучены. Кроме того было исследовано несколько проб из глиняных выработок, а также некоторые пробы, полученные при земляных работах в связи с постройками.

Фораминиферы, которые составляют главную массу микрофоссилей в этих пробах, являются темою настоящей работы.

Было найдено 180 видов, подвидов и форм фораминифер, принадлежащих к 76 родам и 23 фамилиям из надфамилий Astrorhizoidea, Lituoloidea, Milioloidea, Nodosarioidea, Buliminoidea, Spirillinoidea, Rotalioidea. Только один вид оказался планктонным, все остальные виды — бентонные. Два вида *Dentalina drammenensis* и *Dentalina trondheimensis*, описаны как новые виды.

Кроме фораминифер было найдено 4 вида Текоамеб. В таблицах и диаграммах они рассматриваются наряду с фораминиферами.

Исходя из высоты древних морских береговых линий в различных частях нашей области, а также из глубин буровых скважин и из их местонахождений по отношению к современному уровню моря, можно заключить, что наибольшая глубина, на которой в свое время жили описываемые микрофауны, равнялась приблизительно 250 метрам.

Статистический анализ фораминифер, найденных в пробах из различных буровых скважин, показал, что некоторые характерные фауны (или ассамблеи микрофоссилей) встречаются с большой постоянностью. Эти формы, по всей вероятности, отражают изменения в морской среде во время отложения изучаемых осадков. В течении периода времени, которое отвечает образованию данных осадков, произошло региональное улучшение условий существовния — от крайне арктических до бореальных или даже бореально-лузтианских. Одновременно с этим произошло обмеление фиордовых глубин во всех изучаемых местах, вызванное региональным поднятием суши изостатического характера — или вернее — негативное передвижение береговых линий. Большинство буровых скважин находится теперь на суше, но все эти места лежали когда-то в береговых зонах, во время негативного передвижения береговых линий.

Что-бы привести хотя-бы один пример, иллюстрирующий наше утверждение, заметим, что виды, преобладающие в фауне во время глациальных условий, делаются менее многочисленными и могут даже совершенно исчезнуть при постепенном под'еме температуры воды. Зато другие виды могут достигнуть быстрого развития и расцвета при благоприятно изменившихся условиях сделаться преобладающими в данной фауне. Мелководные формы появляются обычно в пробах из верхних частей буровых скважин, и делаются доминирующими в самых верхних слоях.

На основании зональности фауны фораминифер все отложения были разделены на отдельные части. Эти части, обусловленные исключительно экологической зональностью, были для краткости названы зонами и обозначены буквами. Вскго было выделено 7 таких зон — от A до G — и кроме того 10 подзон (суб-зон).

При помощи сравнения фоссильных фаун с современными, по всей вероятности живущими в тех-же условиях, в которых жиле когда-то фоссильные фауны, сделана попытка восстановить условия жизни в отдельных зонах. Эти исследования и попытки находят подтверждение и в радио-карбоновых определениях возраста осадков. Фораминиферовые зоны были, насколько это возможно, сопоставлены с ранее установленными стратиграфическими разделениями области на основании найденнвх моллюсков.

Подзона A_m (средняя часть зоны А), в которой преобладает ***Elphidium incertum clavatum*** и очень часто встречается ***Nonion labradoricum*** была определена как соответствующая верхне-дриасовому времени. Осадки отложены одновременно с образованием гряды Ра и с Фено-скандинавской подстадией отступления ледников в южной части области.

Подзона B_1, (Нижняя часть зоны В), с богатым нахождением ***E. i. clavatum*** и ***Cassidulina crassa*** и с частым присутствием ***Virgulina loeblichi*** и ***Nonion labradoricum***, относится по всей вероятности к до-бореальному периоду и была отолжена одновременно с образованием ледниковой грады Ос-Ши.

Зона С, приблизительно такого-же фаунистического типа как и вышеупомянупая подзона, но с преобладанием ***Cassidulina laevigata carinata*** вместо ***Nonion labradoricum*** должно-быть тоже относится к до-бореальному времени и, возможно, была отложена одновременно с образованием морен Акерской подстадии.

Зона D, бедная фауной с преобладанием ***E. i. clavatum*** и с обычно встречающимися ***Cassidulina crassa*** и ***Quinqueloculina stalkeri*** охватывает осадки, по всей вероятности отлеженные во время последней стадии таяния континентальных ледников и отступления ледникового фронта, когда большие массы холоднлй, пресной, богатой осадкоми воды, образовавшейся от таяния льдов, устремились в северные мелкие разветвления тогдашнего Осло-фиорда.

Зона Е с часто встречающимися ***Elphidium incertum incertum*** и ***E. i. clavatum*** и особенно *Зона F*, в которой преобладает ***Bulimina marginata***, отражают телпый после-ледниковый климат.

Зона G, в которой преобладают мелкдводные формы с агглютюнированными песчаными ракушками, как например ***Spiroplectammina biformis, Ammoscalaria runiana, Miliammina fusca*** представляет собою Голосенные пресноводные отложения. Они относятся, как правило, к тому-же времени, как и отложения зоны F и отчасти зоны Е.

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Chart of Foraminifera and Thecamoebina in the Late Quaternary of the Oslofjord area

Species, subspecies and forms	Page	Units of the zonation												
		A			B		C	D	E	F			G	
		l	m	u	l	u				l	m	u	l	u
Adercotryma glomeratum	226						•					•	•	
Alveolophragmium crassimargo	228						•	•	•	•	•	•	•	
Alveolophragmium nitidum	230											•		
Ammonia batavus	349					•			•	•	|	▌	|	ı
Ammoscalaria pseudospiralis	231												ı	•
Ammoscalaria runiana	232											•	ı	•
Amphicoryna cf. *perversa*	295											•		
Amphicoryna scalaris, f. *compacta*	296							•	•					
Angulogerina angulosa	317									•	ı	ı		
Angulogerina fluens	318		•	•										
Astrononion gallowayi	332	•	ı	ı	•	•	•	•	•	•	•			
Astrononion tumidum	333									•		•		
Biloculinella depressa	265									ı	•	•		
Biloculinella inflata	267					•	ı	•	•	•	•	•		
Bolivina albatrossi	318								•		•			
Bolivina pseudoplicata	319								•		•			
Bolivina pseudopunctata	319		•		•		•		•					
Bolivina pygmaea	320										•			
Bolivina cf. *robusta*	321					•					•			
Bolivina spathulata	321											•		
Buccella frigida	337						•	•		•	•	•		
Bulimina marginata	303		•		•	|	ı	•	▌	█	█	█	|	ı
Buliminella elegantissima	302										•	•	•	
Cassidulina crassa	322	▌	▌	▌	▌	|	▌	▌	|	ı	•	•		
Cassidulina laevigata laevigata	323				•	•	•		|	▌	ı	ı	•	
Cassidulina laevigata carinata	324		•	•	|	ı	▌	|	•	•	•	•		
Cassidulinoides bradyi	325											•		
Centropyxis arenatus	217												•	ı
Ceratobulimina arctica	341					•	ı			•				
Cibicides bertheloti	338						•	•	•					
Cibicides lobatulus	339	ı	|	ı	|	•	|	ı	ı	•	•	•	•	
Cibicides pseudoungerianus	340					•	•		|	|	ı	•		
Crithionina pisum	221												•	
Cyclogyra foliacea	245									•	•	•		
Cyclogyra involvens	246		•							•	•	•		
Dentalina advena	269				•				•	•	•	•		
Dentalina drammenensis	270				•		•	ı	•	•				
Dentalina filiformis	271												•	
Dentalina inornata bradyensis	272									•		•		
Dentalina ittai	273						•			•	•	•		
Dentalina trondheimensis	275								•	•	•	•		
Difflugia capreolata	217							•					•	•

Species, subspecies and forms	Page	Units of the zonation												
		A			B		C	D	E	F			G	
		l	m	u	l	u				l	m	u	l	u
Difflugia oblonga	217												•	•
Eggerella scabra	243								•	•	•	|	■	|
Elphidiella arctica	348							•						
Elphidium bartletti	343		•											
Elphidium excavatum	344								•	•	•	|	|	|
Elphidium incertum clavatum	345	■	■	■	▌	■	■	■	▌	|	|	|	•	
Elphidium incertum incertum	344	•	|	•	|	▌	|	•	▌	▌	▌	▌	|	•
Elphidium macellum	347					•				•	•	•		
Elphidium subarcticum	347	•	•	•	•	•	•	|	•	•	•	•	|	•
Epistominella exigua	338					•		•	|	|	|	|		
Esosyrinx curta	302								•				•	
Fissurina castanea	313								•			•		
Fissurina cf. *fasciata*	313						•					•		
Fissurina laevigata	314				•			•	•	•	•	•	•	
Fissurina lagenoides f. *tenuistriata*	314		•											
Fissurina lucida	315		•		•	•	|	|	|	•	•			
Fissurina marginata	315							•	•			•		
Globigerina bulloides	343		•					•						
Globobulimina auriculata arctica	305		•		•									
Globobulimina auriculata gullmarensis	305				•				•	•	•	•		
Globobulimina turgida	306					•			•	|	|	•		
Globulina inaequalis	298									•	|	•		
Globulina landesi	299											•		
Guttulina dawsoni	297		•	•				•						
Guttulina lactea	297			•					•	•	•	•	•	
Gypsina vesicularis	340										•			
Haplophragmoides bradyi	227											•		
Haplophragmoides pusillum	227												•	
Hauerinella inconstans	247							•	•	•	•	•		
Hyalinea balthica	351					•			•	•	|	▌		
Höglundina elegans	342									•	•	•		
Islandiella norcrossi	325		|								•			
Islandiella teretis	326		|	•										
Jadammina polystoma	241												•	|
Lagena apiopleura	284				•				•			•		
Lagena clavata	285					•			•		•	•	•	
Lagena curvilineata	285								•			•		
Lagena distoma	286				•	•	•	•	•	•	•	•		
Lagena elongata	287							•		•				
Lagena cf. *gracilis*	287								•	•	•	•		
Lagena gracillima	288						•	•	•	•	•	•	•	
Lagena hispidula	289								•	•				

Species, subspecies and forms	Page	Units of the zonation												
		A			B		C	D	E	F			G	
		l	m	u	l	u				l	m	u	l	u
Lagena laevis	289				•	•	•	•	•	•	•	•	•	
Lagena mollis	290	•	•	•	•	•	I	I	I	I	I	•	•	•
Lagena nebulosa	291								•	•	•	•		
Lagena semilineata	291		•											
Lagena semistriata	292					•								
Lagena setigera	292									•	•	•		
Lagena striata, f. *substriata*	294		•	•	•	•	•	•	•	•	•	I	•	
Lagena striata, f. *typica*	293				•		•		•	I	I	•		
Lagena sulcatu sulcata	294											•		
Lagena sulcata laevicostata	295									•		•	•	
Laryngosigma hyalascidia	302	•											•	
Lenticulina cf. *angulata*	277	•	•	•	•	•	I	I	•	•	•	•		
Lenticulina convergens	278								•					
Lenticulina cf. *gibba*	278							•	•	•				
Lenticulina limbosus chiriguanoi	279						•	•	•	•	•	•		
Lenticulina orbicularis	280								•					
Lenticulina rotulata, f. *cultrata*	280									•	•	•		
Lenticulina linearis	281										•			
Liebusella goesi	244								•	•				
Marginulina glabra	283									•	•			
Massilina secans	254											•		
Miliammina fusca	224									•	•	•	I	█
Miliolinella cf. *enoplostoma*	260									•				
Miliolinella cf. *subrotunda*	261	•	•	•	•	•	I	•	•	I	•	•		
Morulaeplecta bulbosa	234												•	
Neoconorbina williamsoni	336										•	•		
Nodosaria pyrula	268										•	•		
Nonion barleeanum	329					•			I	▎	▎	I		
Nonion depressulus asterotuberculatus	330		(•)						•	•	•	I	▎	▎
Nonion labradoricum	331	•	█	•	█	•	•	•	•	•	•	•	•	
Nonionella auricula	327		•									•		
Nonionella iridea	327					•				•		•	•	
Nonionella turgida	328		(•)			•			•	▎	▎	I		
Oolina borealis	310		•											
Oolina caudigera	310		•											
Oolina hexagona	311								•	•	•	•		
Oolina lineato-punctata	311						•	•	•					
Oolina melo	312		•						•	•	•	•		
Oolina squamoso-sulcata	312											•		
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Species, subspecies and forms	Page	A l	A m	A u	B l	B u	C	D	E	F l	F m	F u	G l	G u
Parafissurina lateralis, f. *carinata*	316					•	•		•	•	•	•		
Patellina corrugata	335		•						•	•	•		•	
Pateoris hauerinoides	256		•	•	•			•						
Pontigulasia compressa	217							•						
Protelphidium orbiculare	349		•				•		•					
Proteonina fusiformis	219									•		•	•	
Psammophaera fusca	218												•	
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Pseudopolymorphina suboblonga	300										•			
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Quinqueloculina arctica	248					•			•					
Quinqueloculina bicornis	249										|			
Quinqueloculina horrida	250					•								
Quinqueloculina lata	250											•	|	•
Quinqueloculina pulchella	250										•			
Quinqueloculina seminulum	251	•	•	•	•	•	|	•	|	|	•	•	•	
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Rosalina globularis	335					•					•	•		
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Units of the zonation: A (l, m, u), B (l, u), C, D, E, F (l, m, u), G (l, u).

Species, subspecies and forms	Page	Units of the zonation												
		A			B		C	D	E	F			G	
		l	m	u	l	u				l	m	u	l	u
Triloculina oblonga	257		•					•			•	•		
Triloculina tricarinata	258									•	•	•		
Triloculina trigonula	258									•		•		
Triloculina trihedra	259		•	•	•			•	•					
Trochammina adaperta	239												•	
Trochammina intermedia	239											•	•	•
Trochammina ochracea	240					•						•	•	
Uvigerina peregrina	316								•	ı	|	|	•	
Valvulina fusca	242												•	
Valvulineria minuta	337											•		
Verneuilina media	242								•	•	•	ı	less abundant	•
Virgulina concava	306								•			•		
Virgulina fusiformis	307		•		ı	|	ı	•	|	|	frequent	frequent	|	ı
Virgulina loeblichi	308	•	|	ı	frequent	|	frequent	ı	ı	•	•	•		
Virgulina schreibersiana	309	•	•	ı	•	•	•	ı	•	•				
Virgulina skagerakensis	310								(•)	•	•	ı	•	

Symbols indicate relative frequency:

Abundant	abundant
Less abundant	less abundant
Frequent	frequent
Common	|
Rare	ı
Very rare	•

Distribution in Sub-Atlantic (Recent) parts of subzone F_u and zone G is not considered in this chart.

PLATES 1–21

PLATE 1

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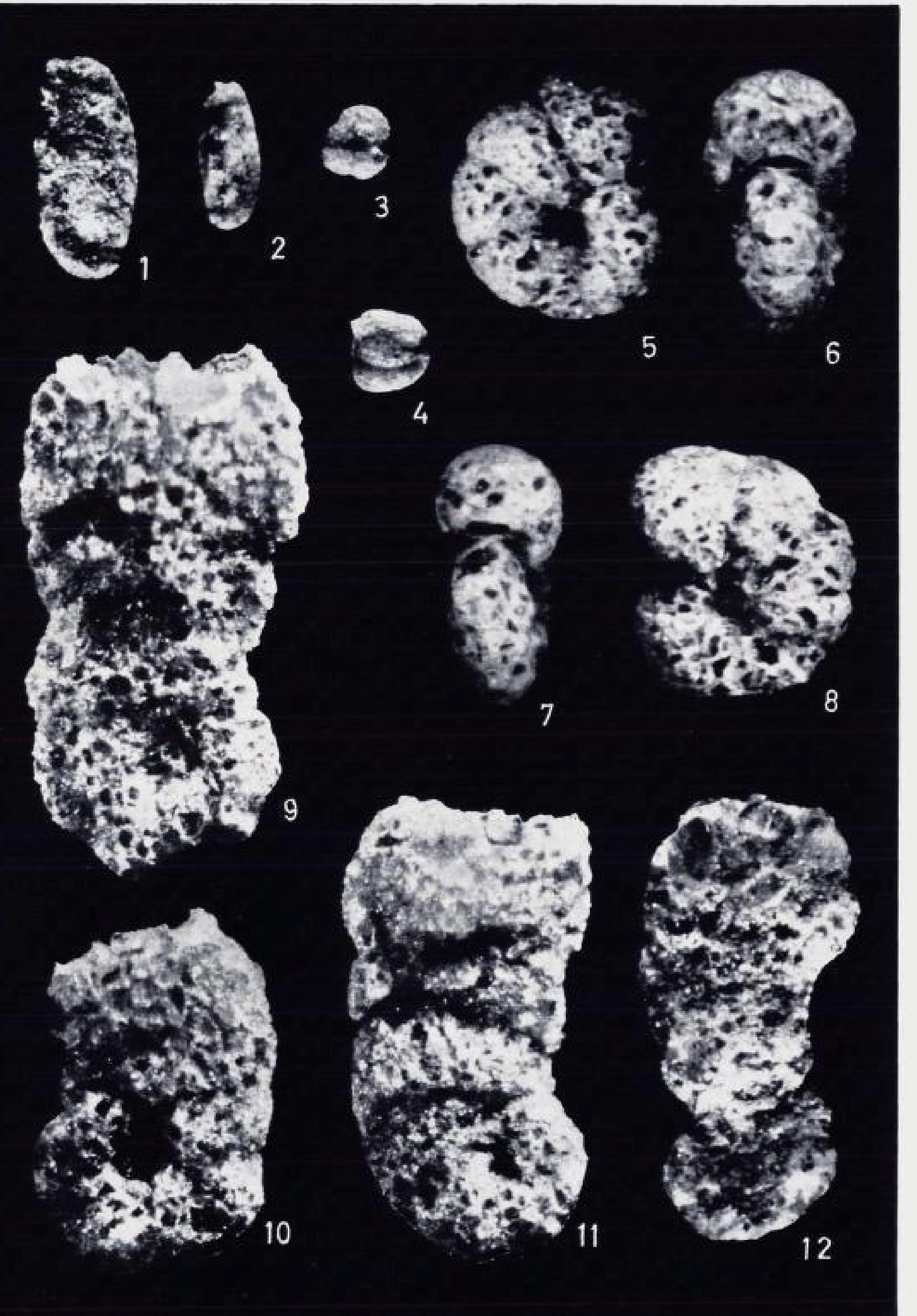
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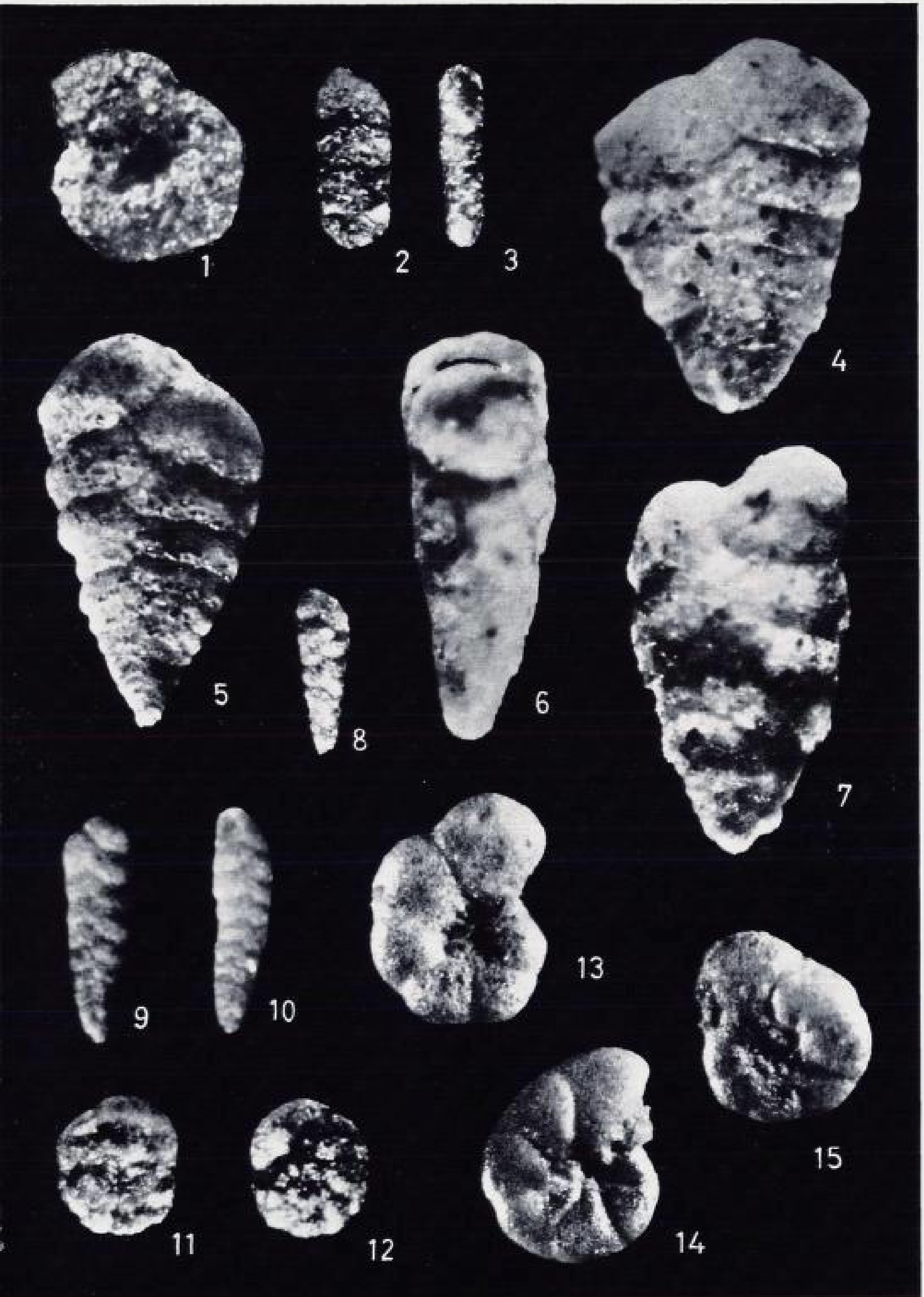
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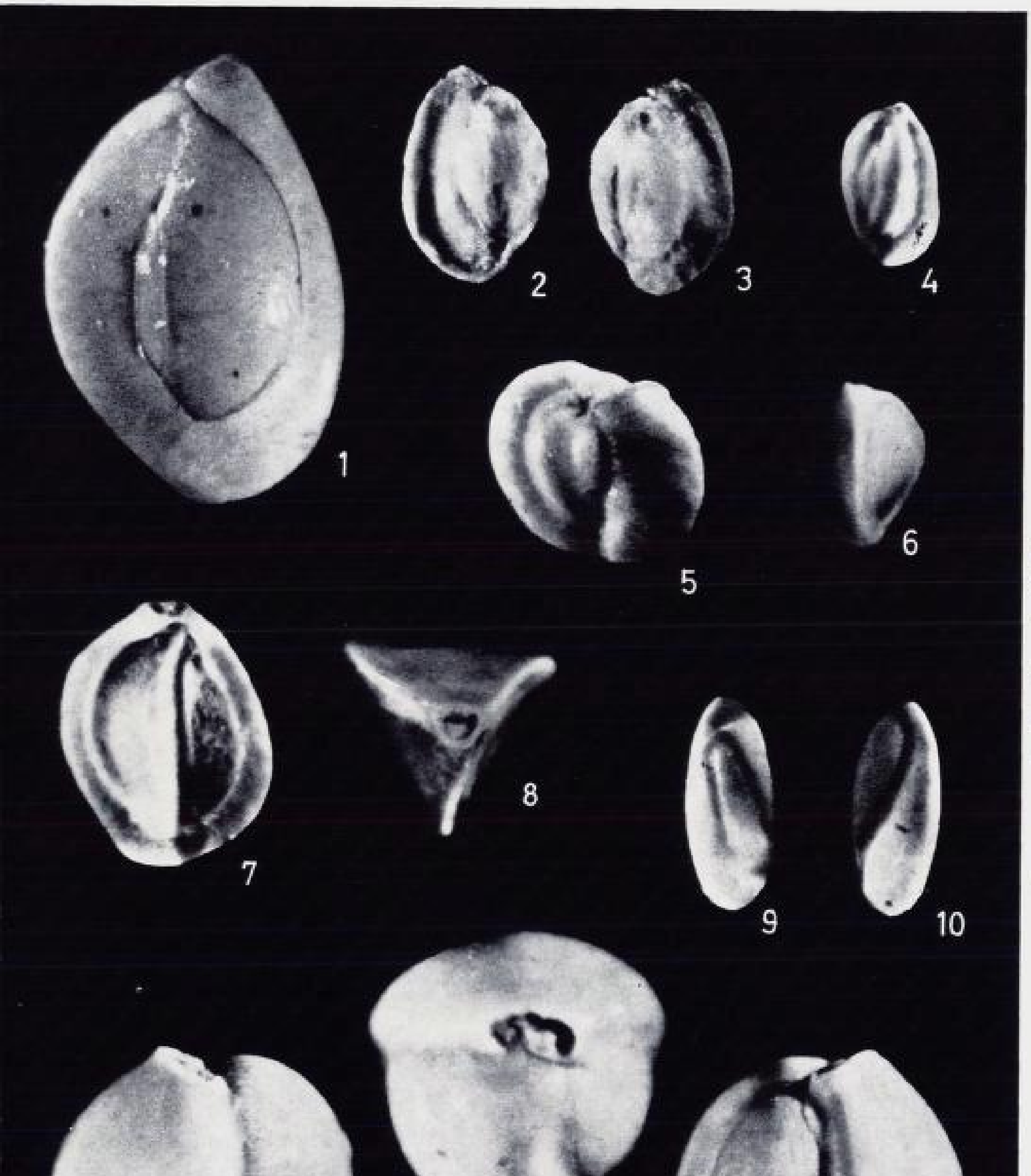
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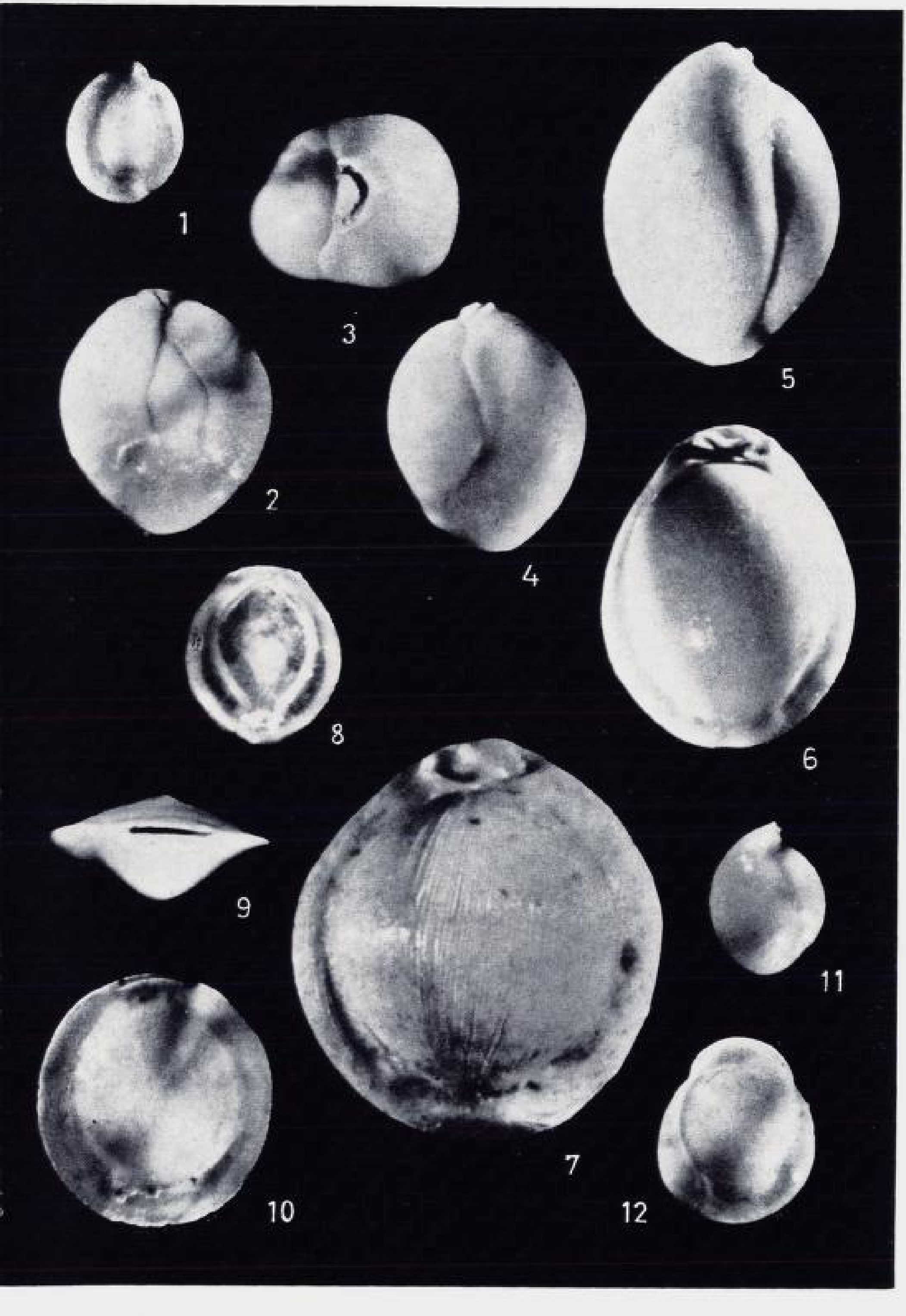
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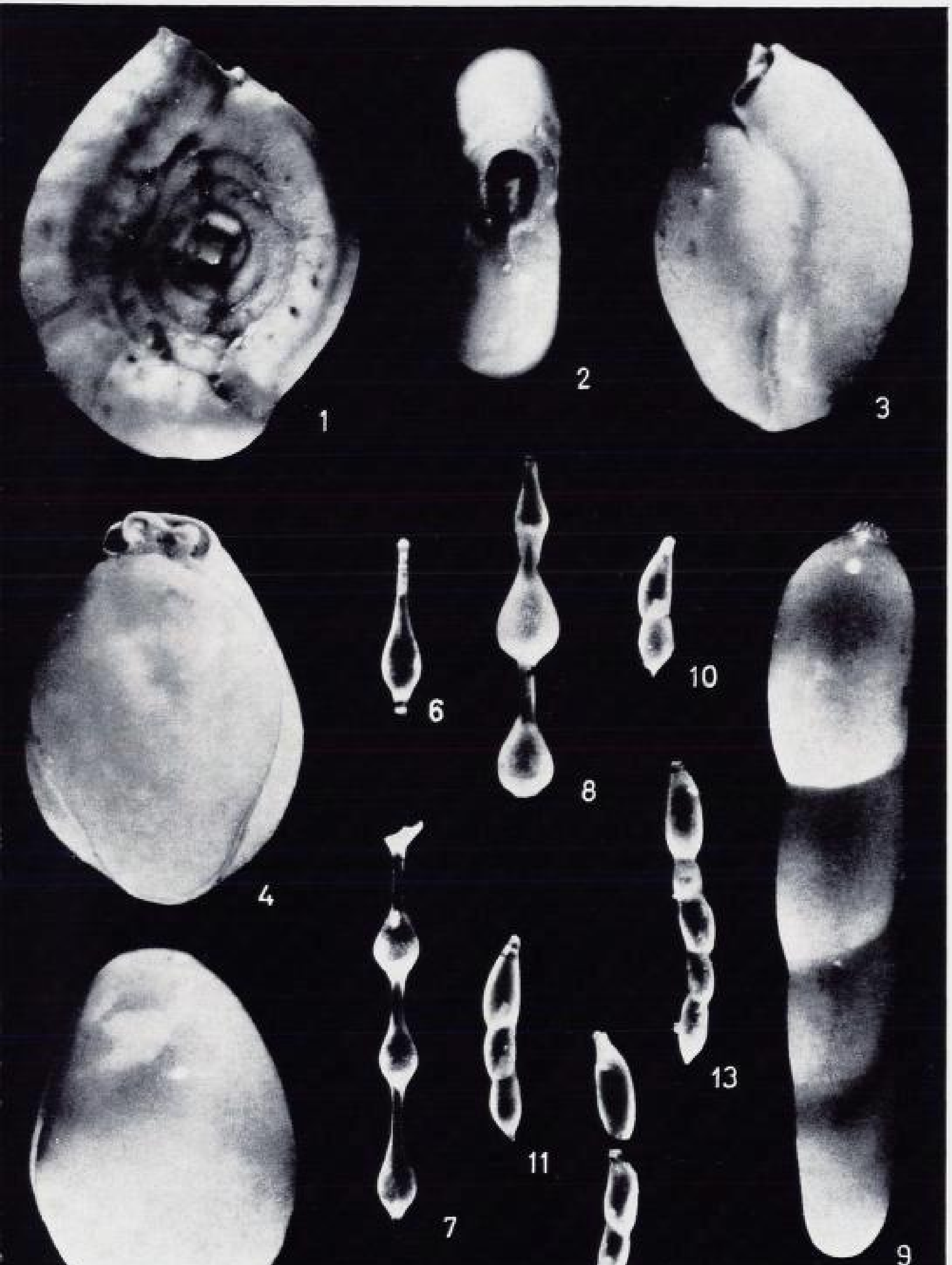
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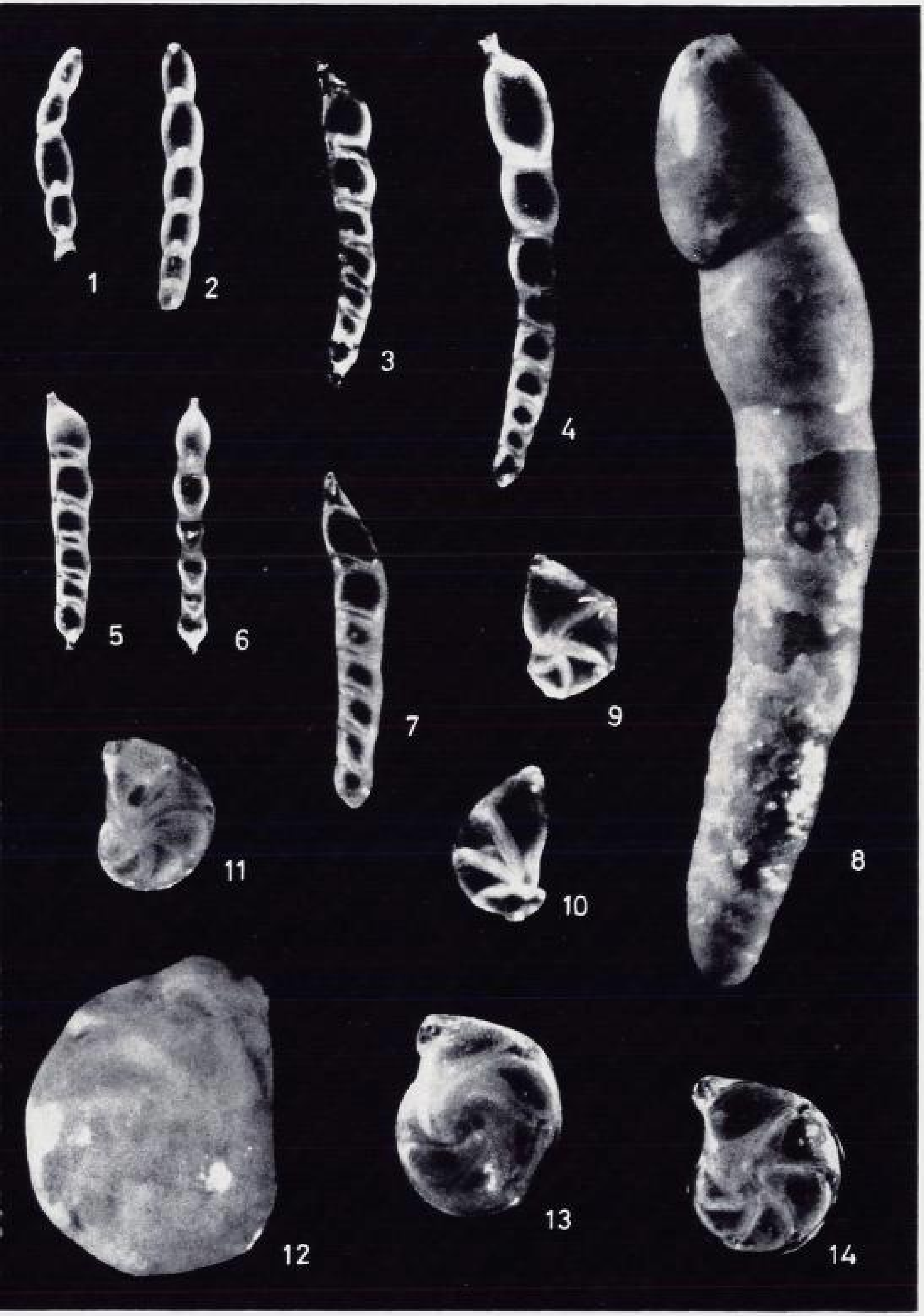
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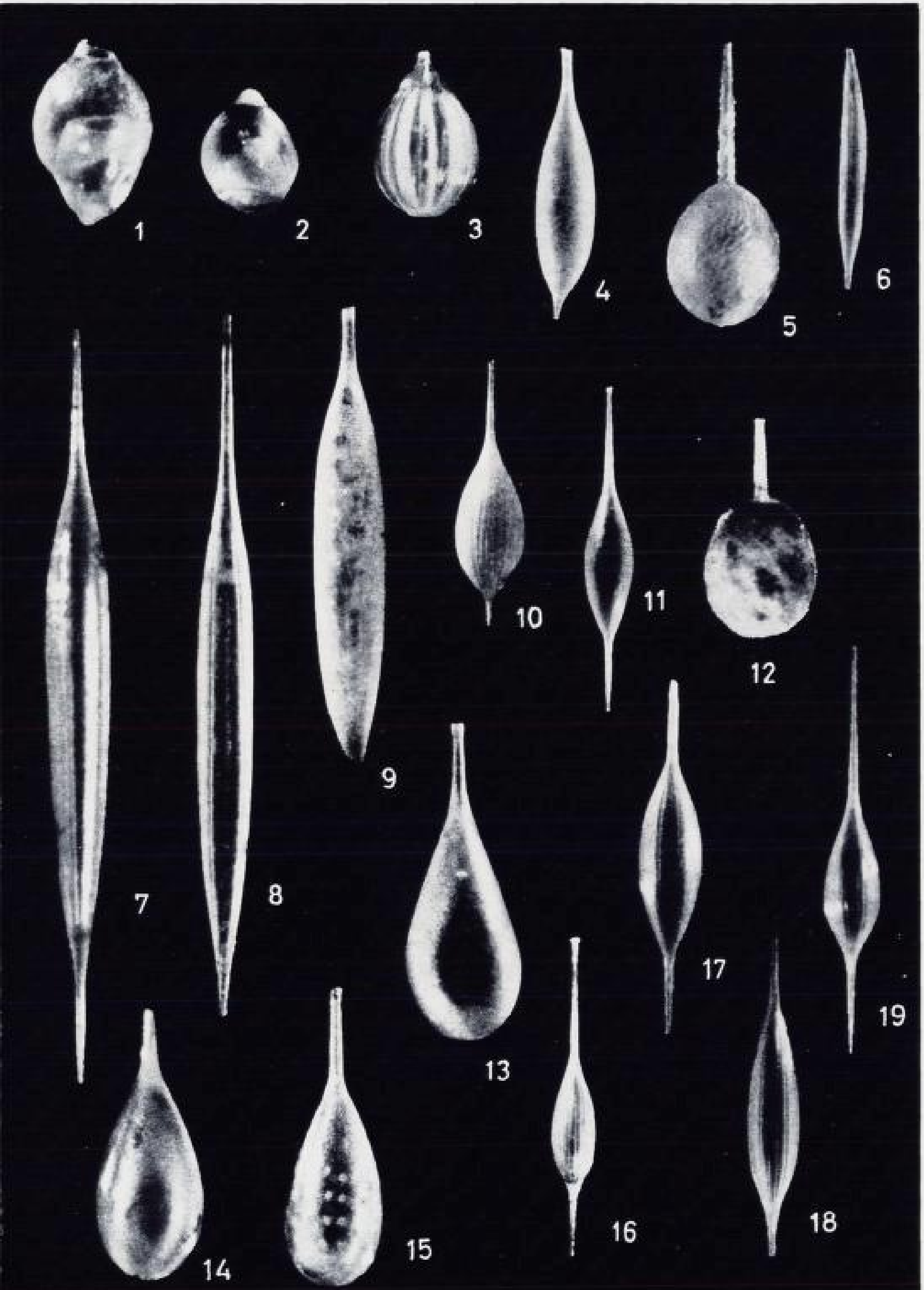
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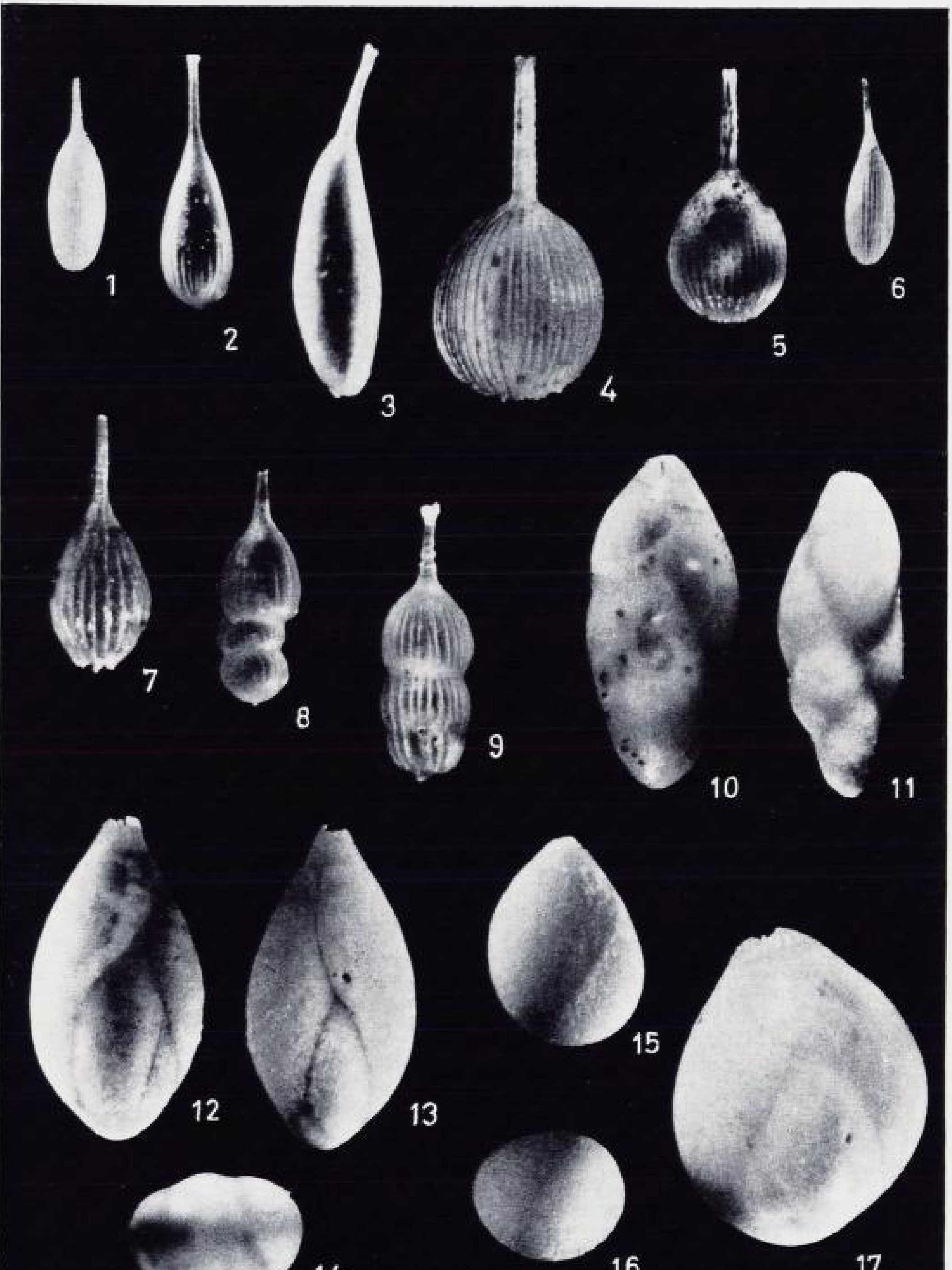
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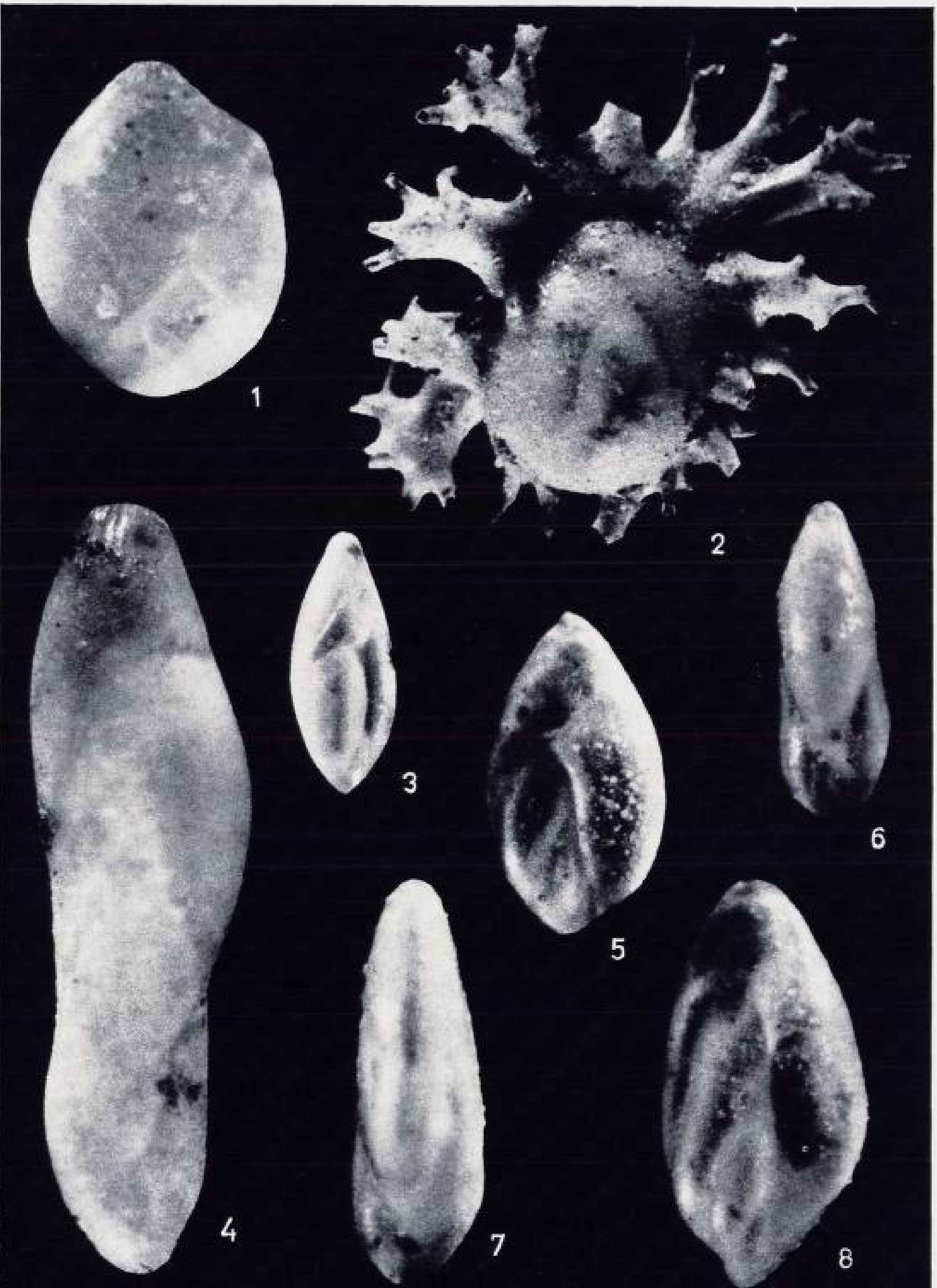
PLATE 13

Polymorphinidae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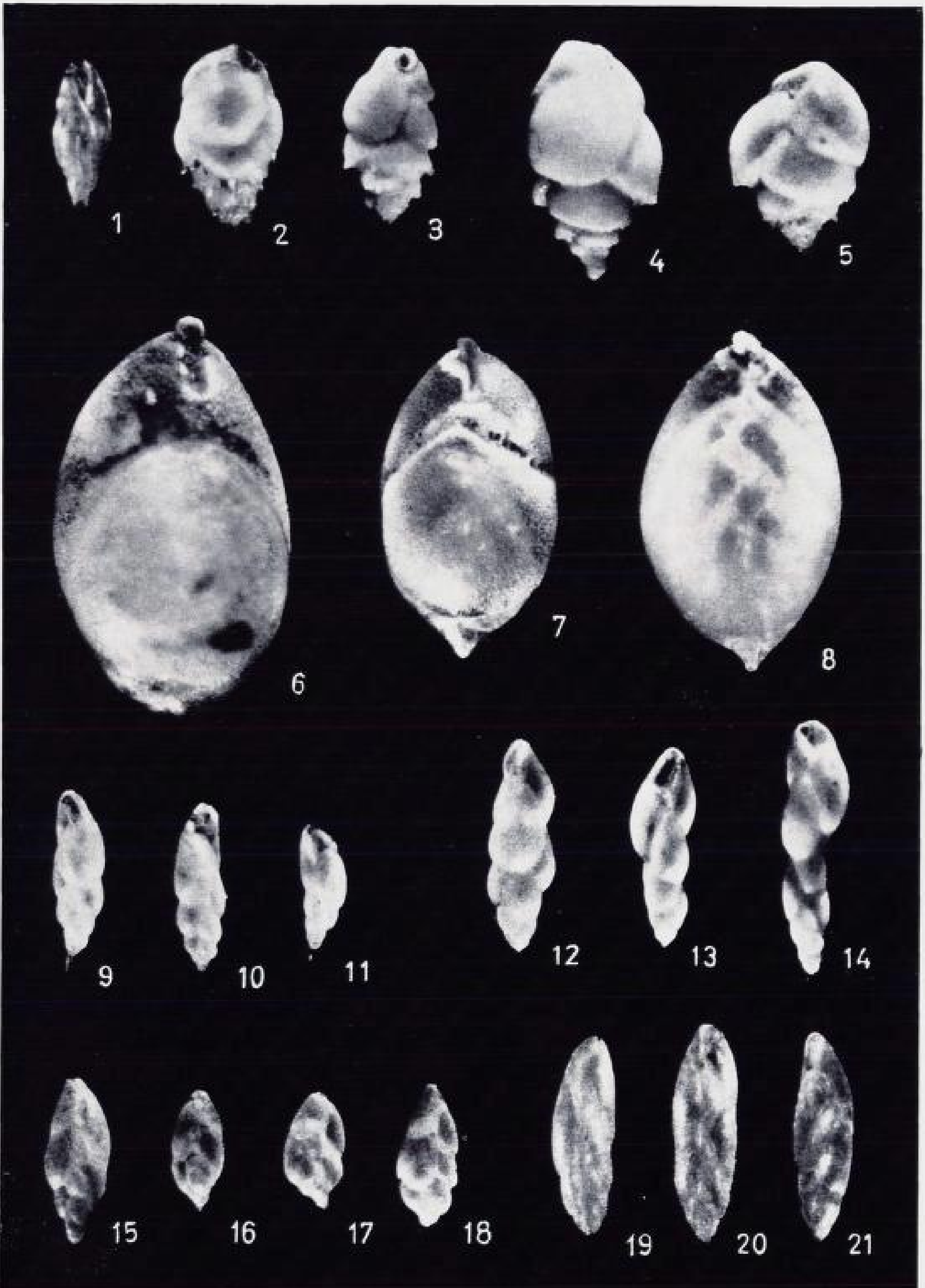
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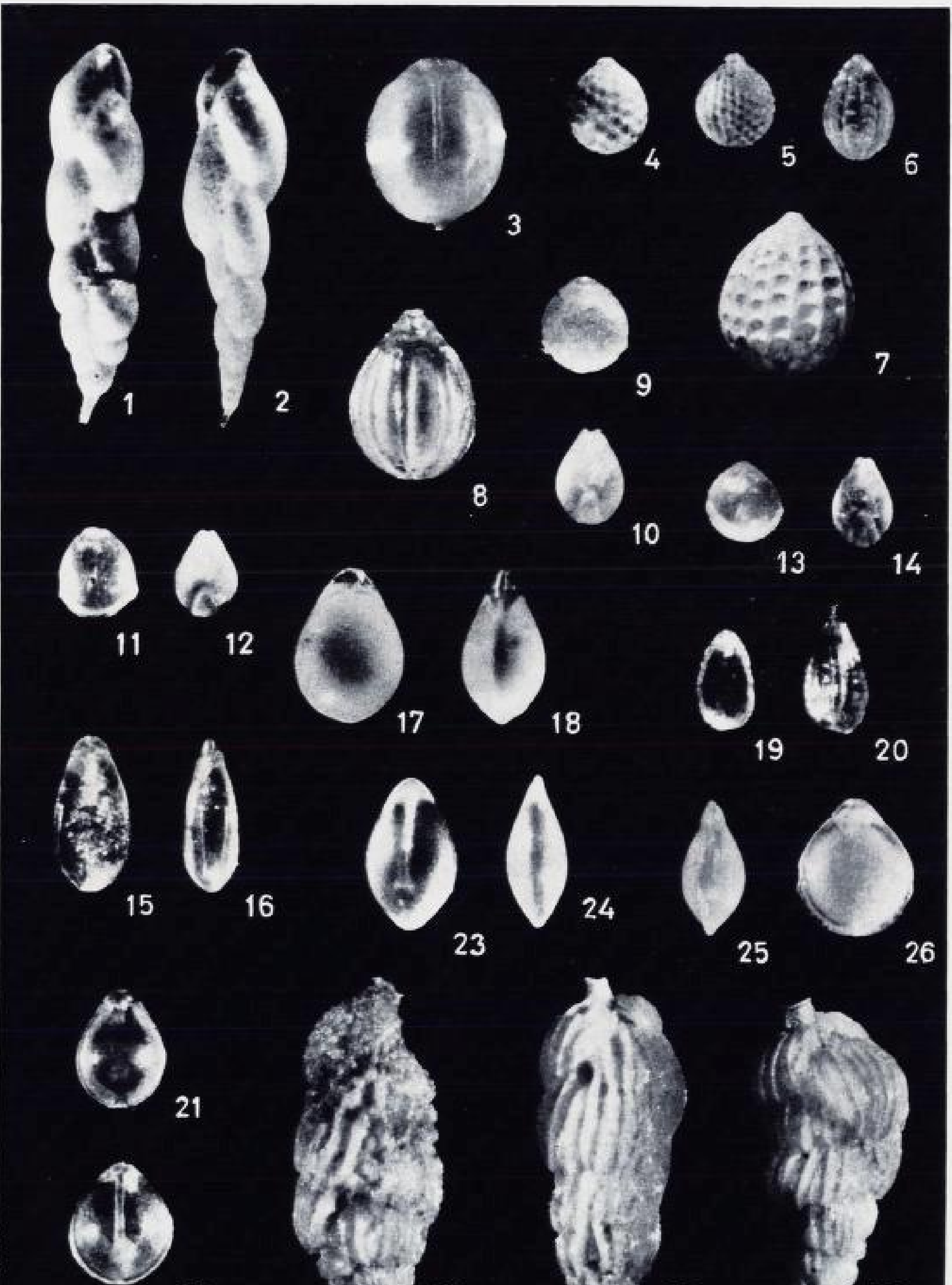
PLATE 15

Buliminidae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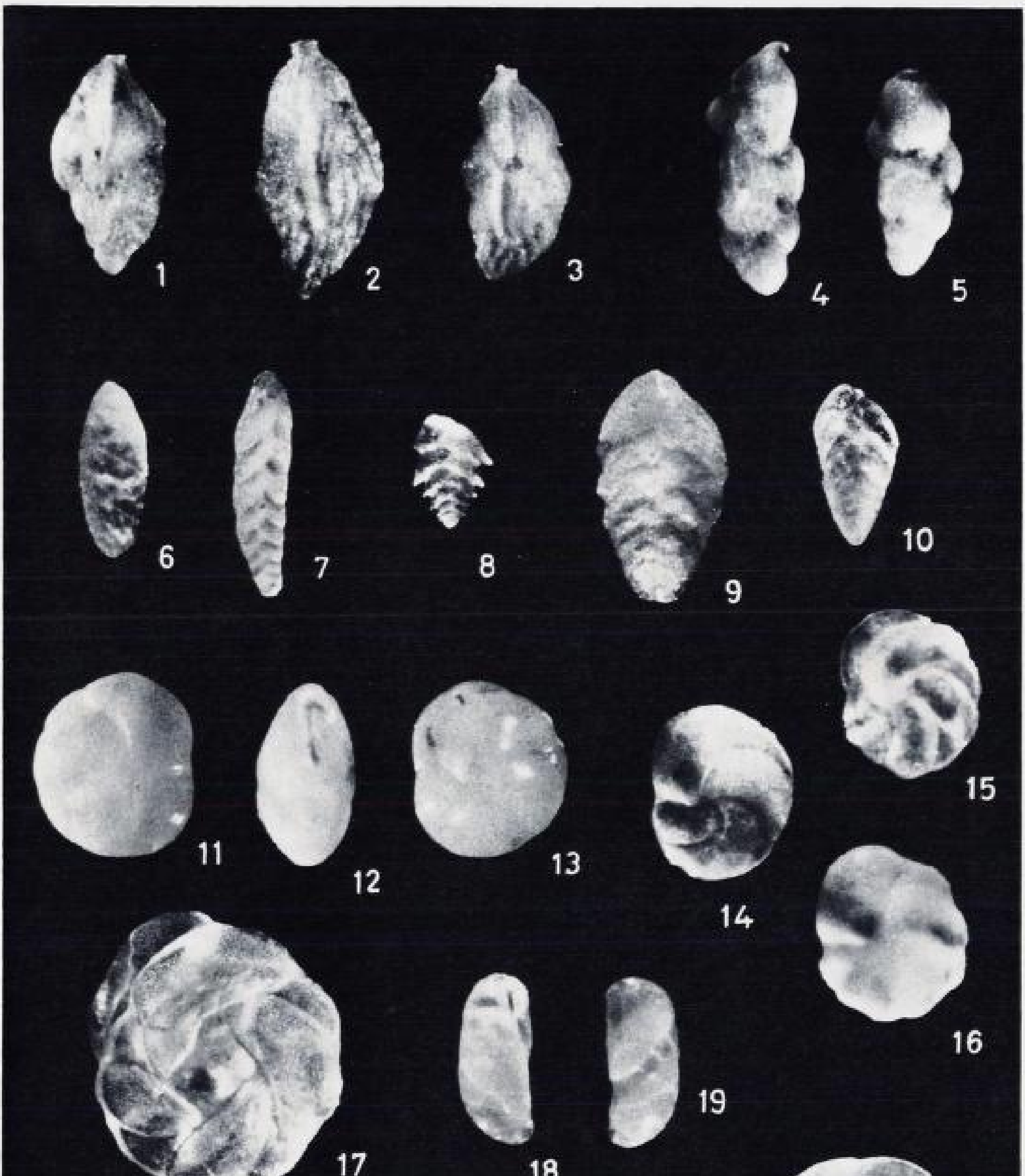
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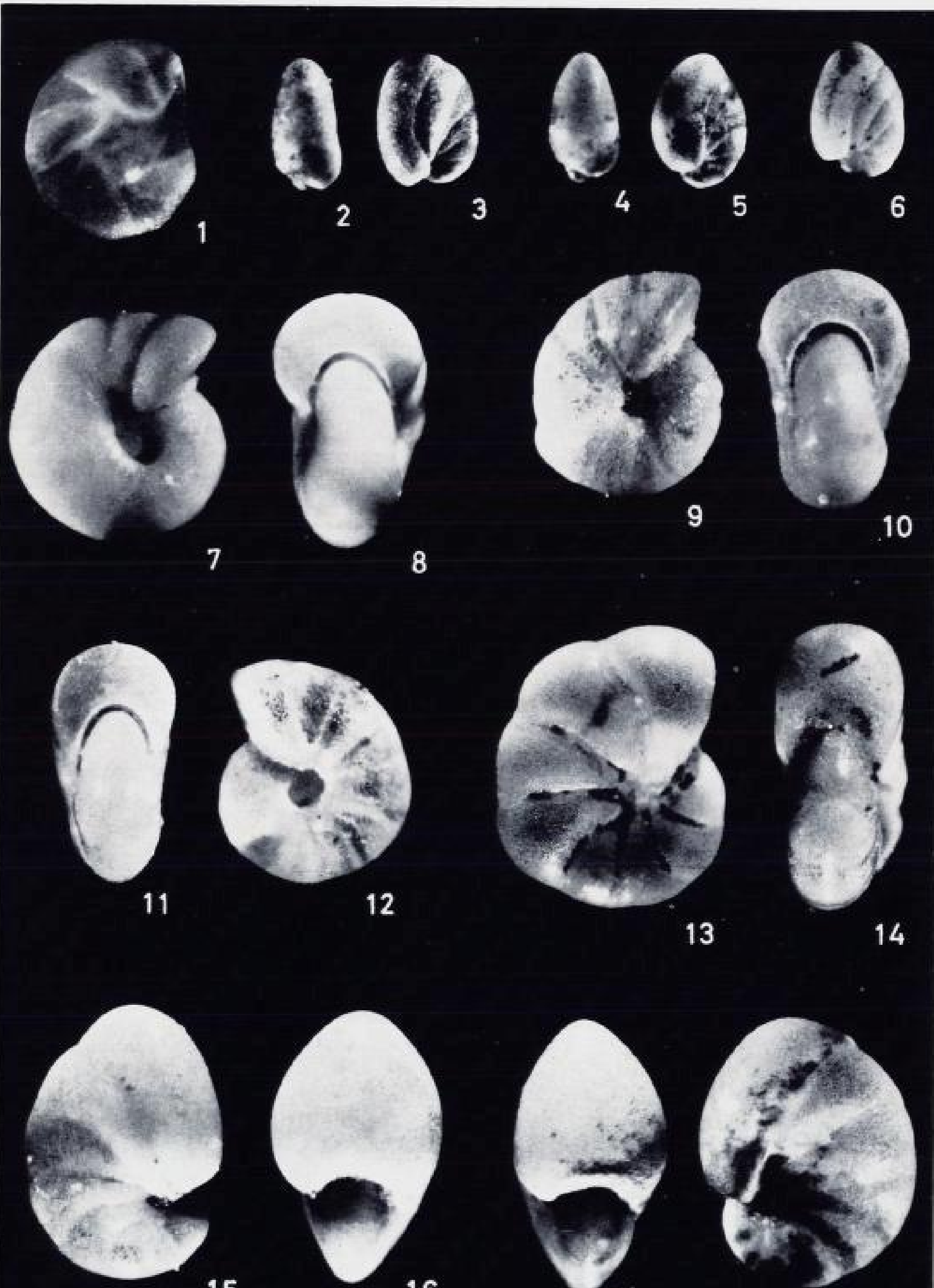

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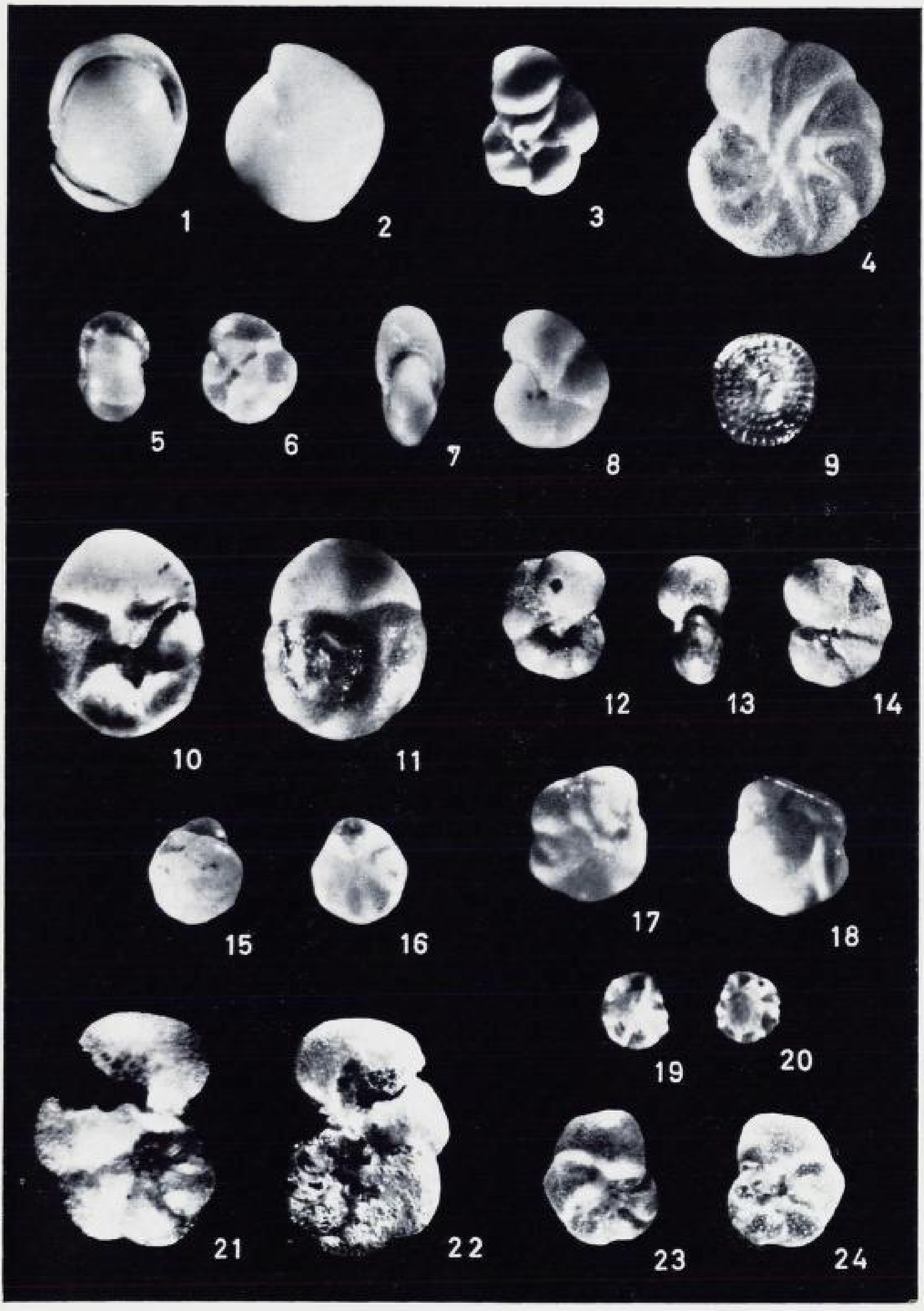
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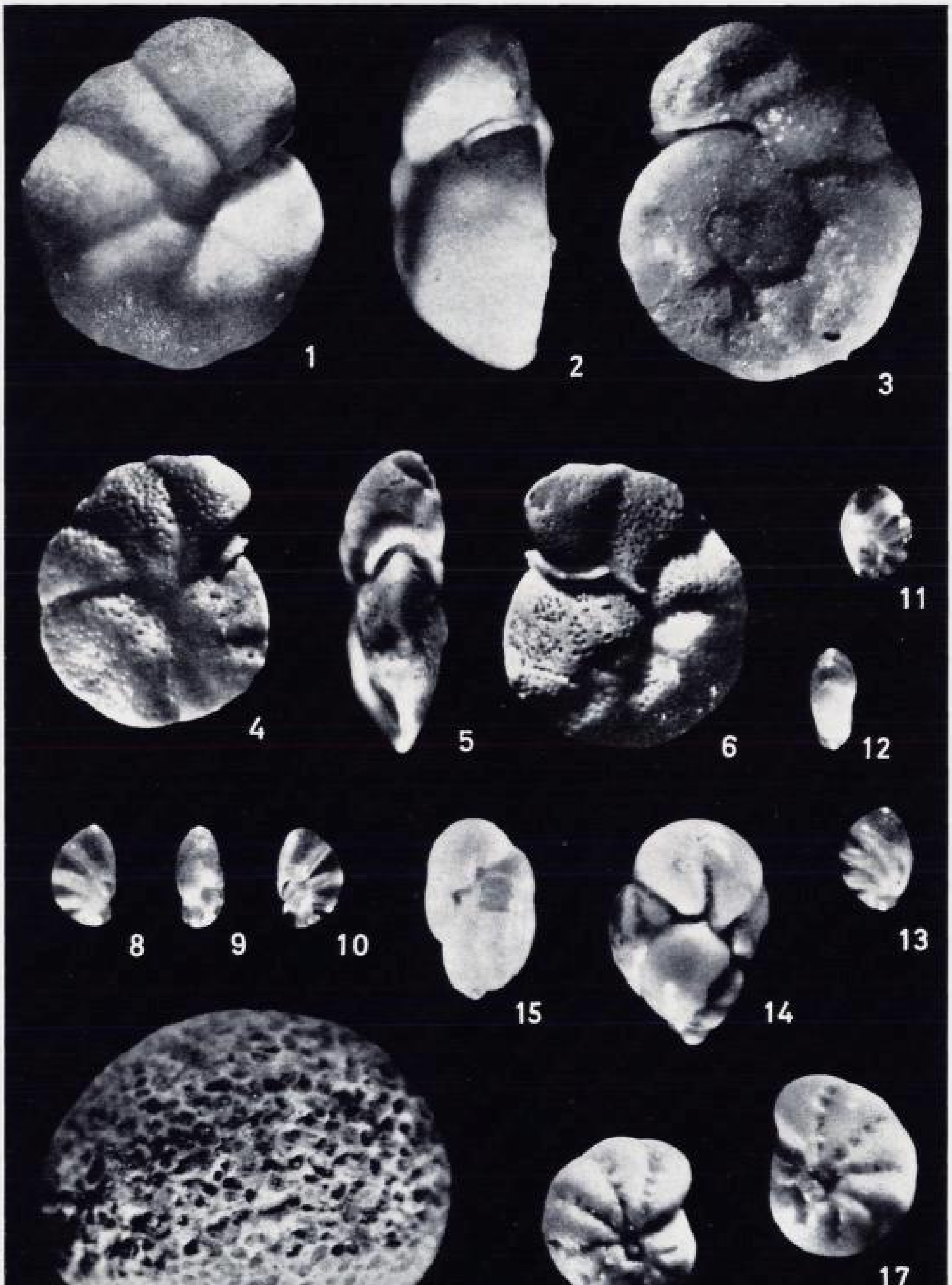

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9, Edge (slightly oblique) view of a specimen from the Post Glacial zone E of boring no. 22 at Valle, near Sarpsborg. 10, Side view. P.M.O. no. 73496. × 65.

Figs. 11–15. *Elphidium incertum clavatum* Cushman 345
11, Side view of a specimen from the Late Pleistocene subzone A_m of boring no. 1 in Sandefjord. P.M.O. no. 73497. 12 and 13, Side view of two specimens from subzone A_m of boring no. 3b in the Ra ridge at Borregaard, Sarpsborg. 12, P.M.O. no. 73498. 13, P.M.O. no. 73499. 14, Edge view of a specimen from the Post Glacial zone E of boring no. 22 at Valle. 15, Side view of the latter specimen. P.M.O. no. 73515. All × 65.

Fig. 16. *Elphidium macellum* (Fichtel and Moll) 347
Side view of a specimen from the Post Glacial zone F of boring no. 5 in Sandefjord. P.M.O. no. 73500. × 68.

Figs. 17–19. *Elphidium subarcticum* Cushman 347
Side view of three specimens from the Post Glacial zone F of boring no. 1 in Sandefjord. 17, P.M.O. no. 73501. 18, P.M.O. no. 73502, the youngest chamber of this specimen was broken off. 19, P.M.O. no. 73503. All × 63.

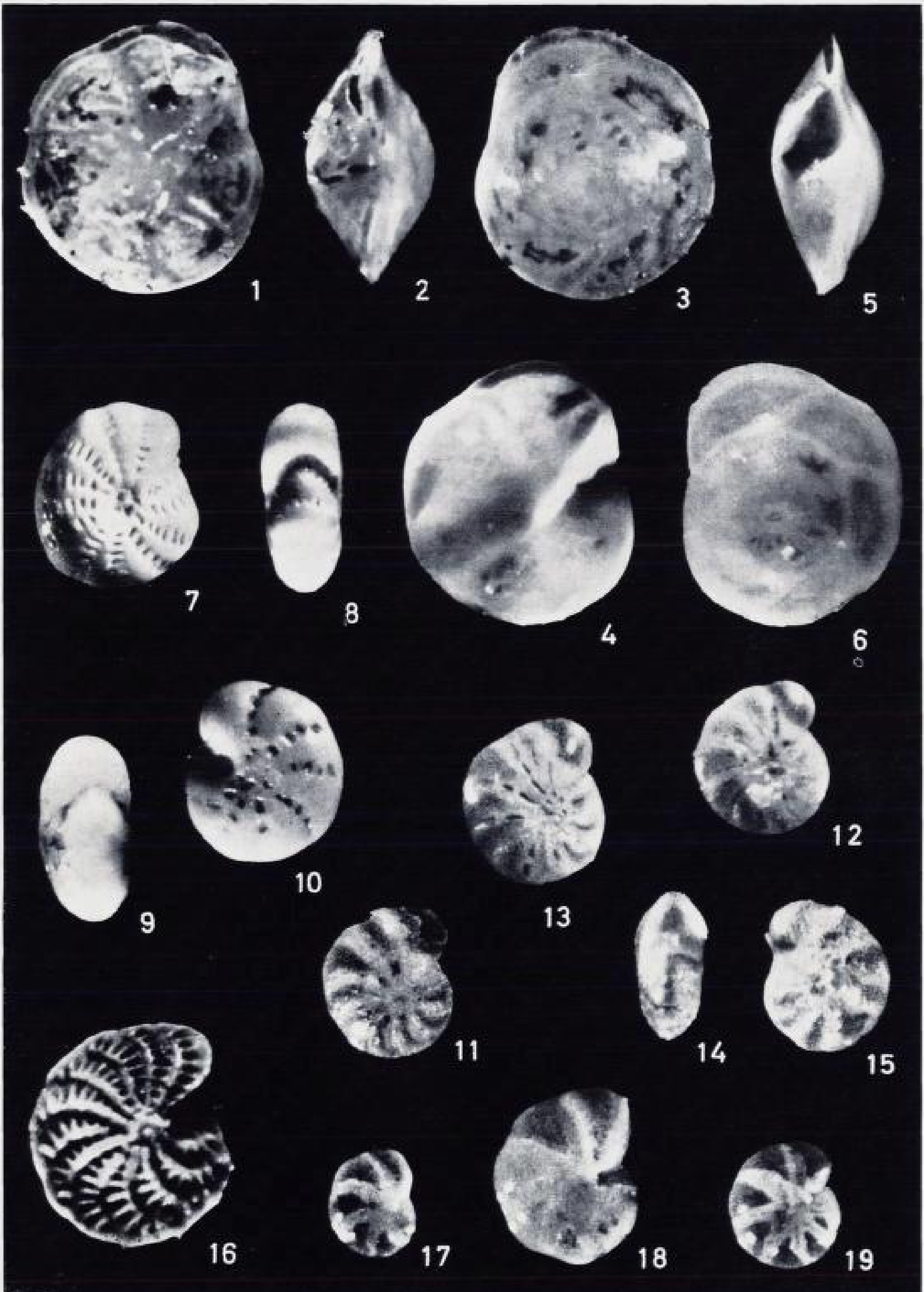
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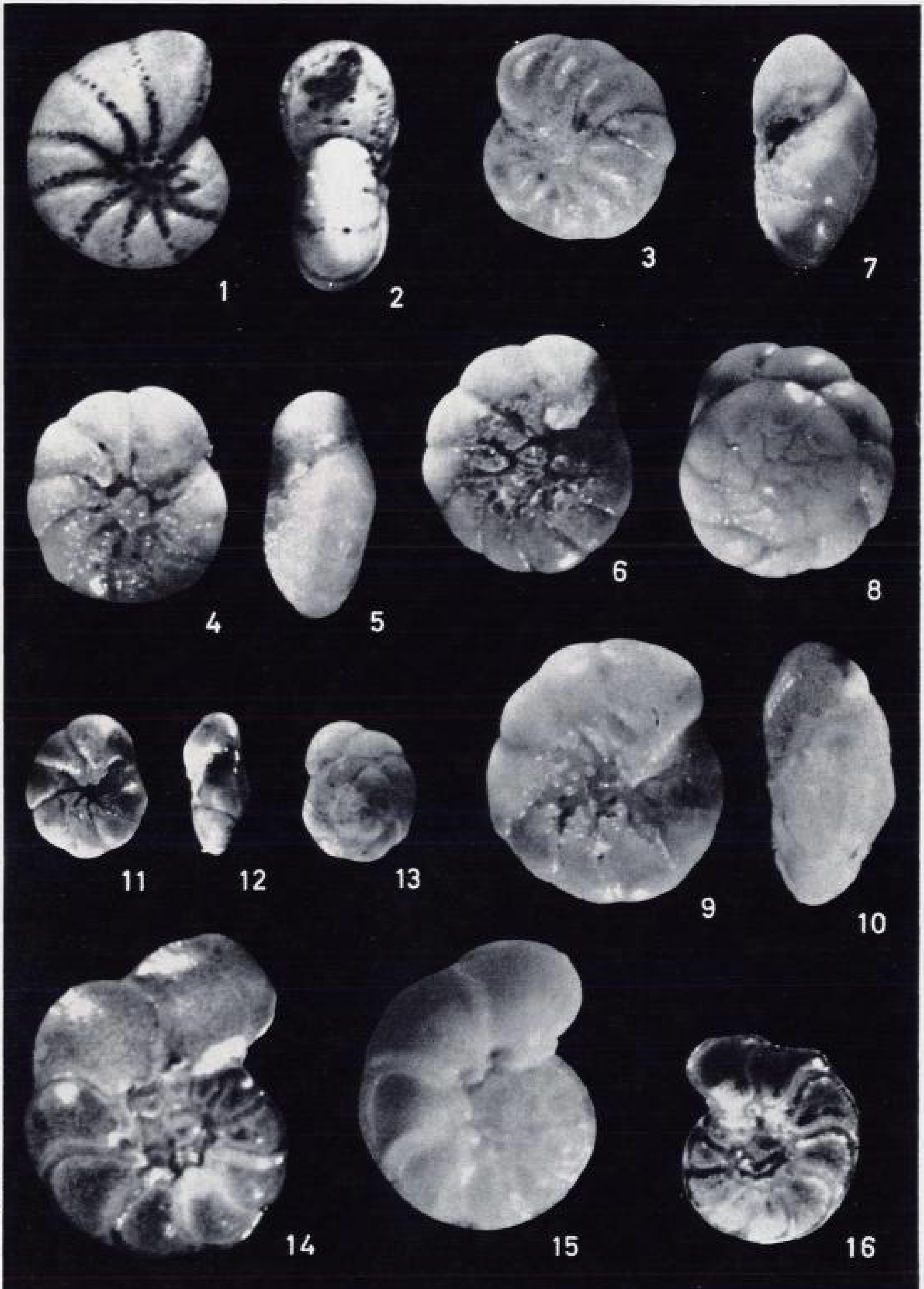
PLATE 21

Elphidiidae, Rotaliidae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