FORAMINIFERA IN FIVE SEDIMENT CORES IN A PROFILE ACROSS THE NORWEGIAN CHANNEL SOUTH OF MANDAL

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The results presented are only part of a more comprehensive investigation which is still in progress.
Forty-six core samples were investigated micropaleontologically and sedimentologically. There occurred 115 species of foraminifera belonging to 50 genera and 18 families. For the purpose of this paper, the distribution of only the most common species of benthonic foraminifera and 4 species of planctonic foraminifera are mentioned. The bathymetric distribution of the benthonic species is studied, and four patterns of distribution are demonstrated. The distribution of planctonic foraminifera shows good correlation with the salinity in the surface water. An attempt has been made at using the total population of the benthonic foraminifera per unit volume of sediment as an index to the relative rate of deposition of sediment. This method indicates that the highest rate of sedimentation is nearest to the Norwegian and Danish coasts. The results of the sedimentological investigation show the increasing particle size in the sediment from north to south in the profile.

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Introduction

The present paper is based upon a quantitative and statistical study of recent and subrecent benthonic and planctonic foraminifera found in sediment cores situated in a NNW-SSE profile between Mandal and Hanstholm across the Norwegian Channel.

The material was collected during the summer of 1965 from the research vessel 'H. U. Sverdrup'.

The complete material consists of 50 sediment cores (sediment length: 1.0–2.5 m) and 18 dredge samples from different localities in the Skagerrak and Kattegat. The present study includes the examination of 5 cores which Professor H. Holtedahl has placed at my disposal, and consequently this work must only be considered as a basis for working out a scheme for further investigation of the complete material from the Skagerrak and Kattegat.

Methods

On the whole the same methods with regard to disintegration, washing, separation and examination are used by the present writer as those described and applied by Feyling-Hanssen (1958a, 1964). Nevertheless, the following differences must be mentioned:

In this paper the quantitative and statistical studies of the foraminifera are based on samples from equal volume (32 cm^3), and not from samples of equal dry weight. Phleger (1965) writes: 'There appear to be two schools of thought concerning the problem of equal samples, one favoring population counts from equal dry weight and the other from equal volume samples.'

Phleger mentions further an example which illustrates that the reference of benthonic foraminiferal populations to constant dry-weight samples may be misleading.

In the material examined the pyrite-filled foraminifera showed increasing frequency with increasing sediment depth. For this reason concentration of the foraminifera tests by means of heavy liquid could not be used. During the gravity separation the pyrite-filled foraminifera would have collected among the mineral grains instead of among the fossils. This would have distorted the statistical results.

Samples were taken at 10 cm intervals through the cores for the micropaleontological and sedimentological investigations.

The sedimentological investigation has been done with Andreasen's cylinder.

Distribution of the planctonic foraminifera

Planctonic foraminifera were not frequent in the present material, however, the four species of the genus *Globigerina* which were the most common ones among the planctonic forms were: *G. bulloides, G. pachyderma, G. dutertrei* and *G. eggeri.*

G. pachyderma and *G. dutertrei* appeared with the highest relative frequency. These two species are characterized in the literature as typical cold water forms.

Phleger (1965) writes: 'Bradshaw (1959) studied the distribution of foraminifera in more than 700 plankton tows from the north and equatorial Pacific. Four distinct planctonic faunas can be distinguished which have discrete distributions, a subarctic fauna, a transition fauna, a central fauna, and an equatorial west central fauna. These faunas appear to be characteristic of surface water masses which also can be distinguished by temperature and salinity characteristics.'

The most frequent planctonic species within Bradshaw's subarctic fauna are: *Globigerina eggeri, G. bulloides, G. quinqueloba* and *G. pachyderma.* This is a faunal composition similar to that in the examined material from the Skagerrak.

The relative and absolute frequency of the planctonic foraminifera from the northern to the southern station in the profile is as follows:

Station:	Sk. 47	Sk. 46	Sk. 45	Sk. 43	Sk. 42
	0–2.8%	0.2–4.6%	0.7–8.4%	3.9–23.2%	3.3–13.9%
	(0–11)	(1–18)	(3–33)	(23–161)	(4–34)

(Sk. = Skagerrak. Sk. 44 was a dredge sample and was not examined).

From the numbers listed above two facts are obvious (the position of the stations is given in Fig. 1):

1. The sediment nearest the Norwegian coast has the lowest content of planctonic foraminifera.
2. In the three sediment cores situated in the northern part of the profile, the planctonic foraminifera never constitute over 8.4% of the total fauna (benthonic plus planctonic foraminifera), whereas they reach a relative frequency of 23.2% in the southern part of the profile.

An increase both in absolute and relative frequency from north to south in the profile is thus indicated.

The occurrence of the planctonic foraminifera at different sediment levels within each core is very stable.

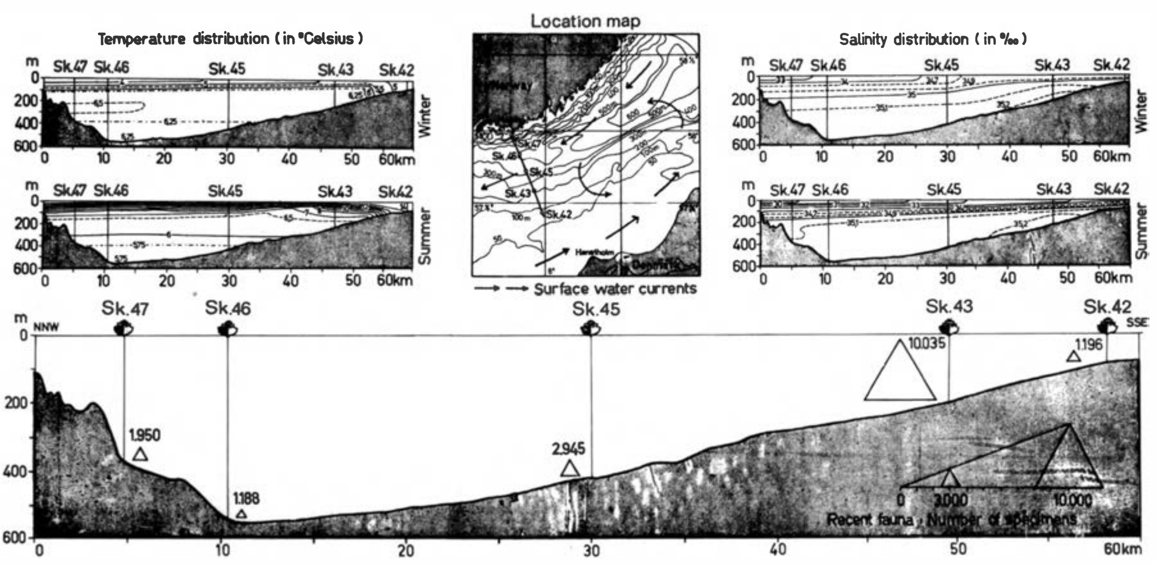

Fig. 1. Temperature and salinity distribution along the NNW-SSE profile Mandal-Hanstholm. Surface water currents in the area. (Echo sounding taken with Hughes sounder from research vessel 'G. M. Dannevig', 1954).

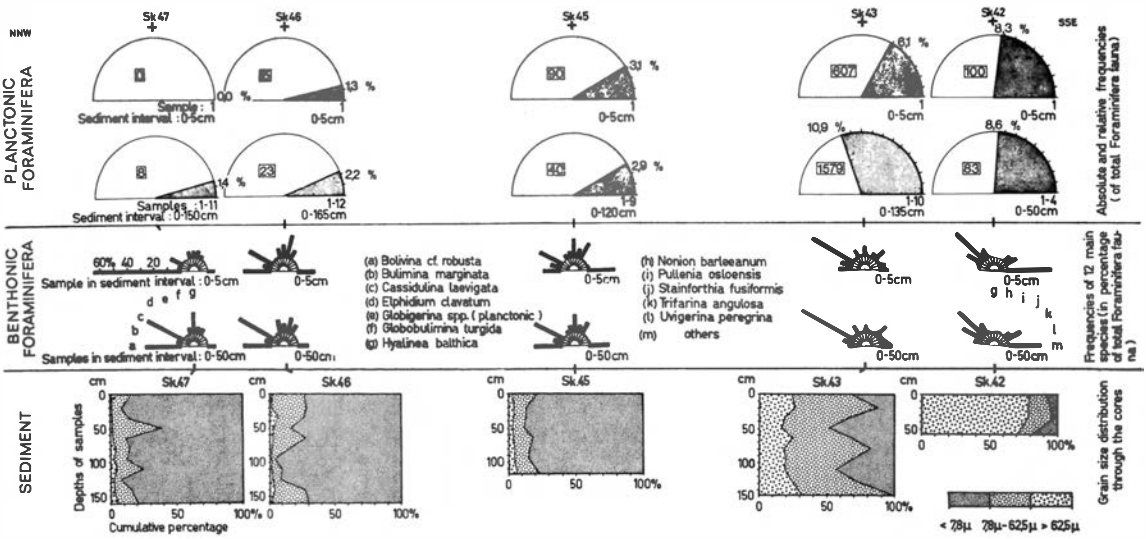

Fig. 2. Horizontal and vertical distribution of foraminifera and sediment at the core stations along the profile.

In Fig. 2 the occurrence of planctonic foraminifera is illustrated by circle diagrams. The five upper diagrams show how many specimens there are in the uppermost sample of each sediment core and how high a percentage of the total fauna these constitute. This sample corresponds with the sediment interval 0–5 cm, and is assumed to give an approximate picture of the recent (in the zoological meaning of the word) planctonic fauna in the surface water over the different localities.

The five lowest circle diagrams in Fig. 2 illustrate the average absolute and relative occurrence in all samples through each sediment core.

The two different types of circle diagram show a very good correlation.

From this observation it is now possible to conclude that the ecological conditions which influence the occurrence of the planctonic foraminifera have changed very little since the time when the sediment in these cores was deposited. It has been stated that the most important ecological factor governing the distribution of living planctonic foraminifera is the salinity of the water, and consequently this factor must have been very stable.

To the right of the 'location map' in Fig. 1 the vertical variation of the salinity in the water during winter and summer above the stations is indicated (after G. Kobe 1934). In both seasons the salinity in the surface water increases from north to south in the profiles. In the same direction the occurrence of the planctonic foraminifera shows increasing absolute and relative frequency.

Phleger (1965) writes: 'Planctonic foraminifera seems to be adjusted to the environments characteristic of offshore, oceanic water. They generally do not thrive in nearshore continental shelf waters of high-runoff areas. In such areas the water generally is characterized by variability of temperature, turbidity, and high organic production, the salinity may be lower than offshore values where there is land runoff.'

Specimens of planctonic foraminifera are most abundant in the upper 100 m of water depth, but living planctonic foraminifera have been obtained from all depths sampled in the Atlantic down to at least 2000 m (Schott 1935, Phleger 1945, 1951b, Bé 1959).

In the deeper part of the Skagerrak, oceanic water (over 35‰ salt) is situated below water of lower salinity. This fact may also have an influence on the distribution of planctonic foraminifera in the area.

As the sediment in core Sk. 47, which is located nearest to the Norwegian coast, has the lowest average content of specimens of planctonic foraminifera per sample, and as the recent material does not contain any, there is good reason to believe that the surface water above this station is influenced by the Baltic current. This current transports water of low salinity along the Norwegian coast.

It cannot be expected that specimens of living planctonic foraminifera will be found between the northern station in the profile and the Norwegian coast, as the salinity in the surface water in this area never exceeds 33‰ and has an annual variation of 10‰.

Calcareous, benthonic foraminifera

Fig. 2 (Benthonic foraminifera) shows the relative frequency of the eleven most common benthonic species in the material.

The reason why *Globigerina spp.* has a special place and a special letter (e) in this connection is to draw attention to the fact that the percentage of the benthonic foraminifera is calculated on the basis of the total number of foraminifera (benthonic plus planctonic).

The diagrams on the upper line in this part of Fig. 2 illustrate the relative frequency of the eleven benthonic species in the uppermost sample (sediment interval: 0–5 cm) of each sediment core. The five diagrams on the next line illustrate the average relative frequency per sample of the same species down to 50 cm sediment depth in each core. Frequencies below 1% have not been indicated.

The numbers referred to below show the occurrence of the eleven most frequent benthonic species in the uppermost sample as illustrated in Fig. 2:

Station	Sk. 42	Sk. 43	Sk. 47	Sk. 45	Sk. 46
Water depth	80 m	210 m	375 m	430 m	545 m
Species	%	%	%	%	%
Bolivina cf. robusta	0.3	10.3	11.7	66.0	20.3
Cassidulina laevigata	12.8	36.0	17.3	9.1	20.5
Nonion barleeanum	0.3	1.6	7.4	4.8	15.6
Hyalinea balthica	0.5	7.0	12.5	4.6	8.3
Globobulimina turgida	0.3	2.0	4.8	4.0	6.3
Pullenia osloensis	0.3	3.5	13.0	2.9	7.6
Bulimina marginata	2.4	9.0	6.6	1.6	6.3
Elphidium clavatum	29.1	1.0	0	0.3	0.2
Stainforthia fusiformis	5.3	9.0	0.5	0.3	0.2
Uvigerina peregrina	0	4.7	2.3	0.3	0.5
Trifarina angulosa	8.8	2.5	0.3	0	0.2

Four different patterns of distribution seem to be demonstrated here:

(I) Includes only *Bolivina cf. robusta*. This species increases both in absolute and relative frequency down to a water depth of 430 m, where it constitutes 66.0% of the total fauna in contrast to only 0.3% at the station at 80 m water depth.

The occurrence of *B. cf. robusta* at a water depth of 545 m is decreasing (20.3%). This fact indicates that the species has its maximum appearance at a water depth of about 400 m in the investigated area.

(II) Includes *Nonion barleeanum, Hyalinea balthica, Globobulimina turgida, Pullenia osloensis* and *Bulimina marginata*. These species show increasing frequencies down to a depth of 375 m, and then decrease down to 430 m.

At 545 m these five species again constitute higher percentages.

(III) Includes *Elphidium clavatum* and *Trifarina angulosa*. These two species show a distinct decreasing frequency with increasing water depth.

(IV) Includes *Stainforthia fusiformis* and *Uvigerina peregrina*, which increase in frequency down to 210 m depth and then decrease with increasing water depth.

Cassidulina laevigata does not seem to belong to any of these categories, and seems to be more eurybath in its bathymetrical distribution.

Recent fauna

The uppermost sample in every sediment core represents the upper 5 cm of the bottom sediment at the different stations, and is assumed to give an approximate picture of the recent fauna.

Over the bottom profile in Fig. 1 the total number of specimens in this sample is illustrated by means of triangles corresponding to 32 cm^3 of sediment.

There is a marked variation in the number of specimens at the different stations: The highest number (10035) is demonstrated at a water depth of 210 m (Sk. 43), and the lowest number (1188) is at the deepest station in the middle of the Norwegian Channel (Sk. 46, 545 m). The other numbers are given in the figure. The average numbers of specimens per sample down to a sediment depth of 50 cm from the northern to the southern station in the profile are as follows: 1225 (Sk. 47), 1290 (Sk. 46), 1523 (Sk. 45), 10453 (Sk. 43), 882 (Sk. 42).

Accordingly, the tendency mentioned before does not seem to be any coincidence, and this phenomenon therefore needs further explanation. There are many factors which can contribute to this, and I shall try here to discuss some of them. In this connection it is very important to be aware that it is usually a combination of many factors which has influence on the density of foraminifera per unit volume of sediment.

A low density of foraminifera per unit volume of sediment is interpreted by many authors by a fine-grained sediment and a high rate of deposition (Lankford 1959).

The results of the sedimentological investigation (samples taken at 10 cm intervals) are presented at the bottom of Fig. 2 under the respective stations.

From station Sk. 43 (210 m depth) northward along the profile the particle size of the sediment becomes more and more fine-grained. In the same direction the density of the foraminifera per unit volume of sediment decreases, with the exception of station Sk. 47. Accordingly, in this part of the area there is a good correlation between the increasing number of specimens per unit volume of sediment and coarser sediment.

It becomes obvious that the size of the population depends not entirely on the sediment when considering this relation at station Sk. 42. In spite of very coarse sediment the number of specimens per unit volume of sediment is very low. This phenomenon can possibly be explained by studying the current conditions in this part of the investigation area. The bottom water at this station seems to be under the influence of the current outside West-Jutland, which apparently transports the foraminifera away and deposits them together with finer particles of sediment in calmer conditions. A high population of benthonic foraminifera per unit volume of sediment may indicate relatively slow deposition and a low population may indicate fast deposition.

With regard to the triangles and numbers over the bottom profile in Fig. 1, it should consequently be possible to get an impression of the relative rate of deposition at the different stations.

The number of specimens per unit volume of sediment at the two northern stations (Sk. 47, Sk. 46) in the profile indicates a relatively high rate of deposition, and decreasing rate of deposition at the next two stations (Sk. 45 and Sk. 43).

The low density of foraminifera at station Sk. 42 indicates a relatively high rate of sedimentation at this locality, probably in combination with current activity at this station.

This method indicates that the highest rate of sedimentation is nearest to the Norwegian and the Danish coasts.

Moore (1954) used the relative abundance of foraminifera as a measure of rate of sedimentation in a core collected from San Antonio Bay, Texas. The higher concentrations of foraminifera are interpreted by Moore as indicating slower rates of sedimentation. His work is based on the assumption that foraminifera were produced at a uniform rate at the location of his core; this assumption has not been proved, but may be a reasonable approximation. However, production rates of benthonic foraminifera vary in different areas and at different times in the same area, and there may be some loss of tests of foraminifera after deposition due to solution, abrasion, or reworking of the sediment. Furthermore, the strong current of heavy Atlantic water at the bottom of the Norwegian Channel might also contribute to an explanation of the extremely low number of specimens per unit volume sediment at stations Sk. 45, Sk. 46 and Sk. 47.

Parker (1948) concludes that bottom currents are of prime importance for the density of foraminifera in the sediment outside the banks of the northeastern coast of the USA.

Systematic part

In this section the benthonic foraminifera dealt with on the previous pages are treated systematically.

The systematic presentation of each species is followed by some dimensions of one or more specimens of the present material in the following way: For the planispiral and the trochospiral forms 'largest diameter' is the largest measure at right angles to the axis of coiling, and the largest measure parallel to this axis is named 'thickness'. For the other forms the measure from the aperture end of the test to the diametrically opposite end is named 'length' and the largest measure at right angles to this one is named 'breadth'.

The frequency of the species at different water depths in the recent sample and the intervals of frequencies of the same species throughout every sediment core are mentioned under 'occurrence'. Characters of systematic value are discussed in some cases under 'remarks'. The recent distribution is also given for these species.

Superfamily BULIMINOIDEA Jones, 1875.
Family BULIMINIDAE Jones, 1875.
Subfamily BULIMININAE Jones, 1875.

Genus *Bulimina* d'Orbigny, 1826.

Bulimina marginata d'Orbigny.

Pl. 1, Figs. 1–10.

1826 *Bulimina marginata* d'Orbigny, p. 269, Pl. 12, Figs. 10–12.
1947 *Bulimina marginata* d'Orbigny. – Høglund, p. 227. Pl. 20, Figs. 1–2, Pl. 22, Fig. 1, Text-figs. 205–218.
1956 *Bulimina marginata* d'Orbigny. – Lange, p. 77, Pl. 9, Fig. 5.
1967 *Bulimina marginata* d'Orbigny. – Michelsen, p. 225, Pl. 2, Figs. 7–8.

Size: Length: 0.23–0.44 m (144 specimens measured). Length of hypotype (Pl. 1, Fig. 2), 0.35 mm. Breadth about half the length in adults, comparatively greater in young specimens.

Occurrence: Bulimina marginata never constitute more than 12.6% of the total fauna.

In the recent sample it shows increasing frequencies down to a depth of 210 m, and then decreases down to 430 m. From this water depth and down to 545 m it again constitutes a higher percentage of the fauna.

The intervals of frequencies throughout each sediment core are as follows: Sk. 42: 1.2–8.3%. Sk. 43: 5.1–12.6%. Sk. 45: 2.5–10.6%. Sk. 46: 0.8–6.2%. Sk. 47: 1.6–6.3%.

Remarks: As shown in Pl. 1, Figs. 1–10, this is an especially variable species with regard to the spines on the lower margin of the chambers. The spines of the individual specimens vary considerably in number as well as in length and thickness. However, this variation actually appears more pronounced than it is in reality, as the spines are often broken or worn off.

Høglund (1947) made a similar observation in his material and after statistical investigation of this character compared with other systematical criteria (aperture and internal structures), he concluded that *B. marginata* is comprised of many forms previously listed as distinct species, e.g. Brady's *B. aculeata,* Williamson's *B. pupoides* var. *spinulosa* and Brady's *B. elegans.* A lot of other synonyms of *B. marginata* have been used in literature but it is not my intention here to give a complete list of references.

Phleger (1965) reports the recent distribution of *B. marginata* in the northwestern Gulf of Mexico within the depth range 0–350 m.

Genus *Globobulimina* Cushman, 1927.

Globobulimina turgida (Bailey).

Pl. 2, Figs. 1–2.

1851 *Bulimina turgida* Bailey, p. 12, Figs. 28–31.
1947 *Globobulimina turgida* (Bailey). – Høglund, p. 248, Pl. 20, Fig. 5, Pl. 21, Figs.

4,8, Pl. 22, Fig. 5, Text-figs. 247–257, 271.
1956 *Globobulimina turgida* (Bailey). – Lange, p. 77, Pl. 9, Fig. 8.
1964 *Globobulimina turgida* (Bailey). – Feyling-Hanssen, p. 306.

Size: Length: 0.40–0.66 mm (86 specimens measured). Length of hypotype of Pl. 2, Fig. 2, 0.53 mm. Breadth usually about 2/3 of length.

Occurrence: In the 45 core samples examined *Globobulimina turgida* never constituted over 18.0% of the fauna.

In the recent sample it shows increasing frequencies down to a depth of 375 m, and then decreases down to 430 m. At 545 m it again constitutes a higher percentage of the fauna. Thus, *G. turgida* reaches its highest absolute and relative frequency at the deepest station in the profile.

The intervals of frequencies throughout each sediment core are as follows: Sk. 42: 0–0.3%. Sk. 43: 1.1–5.2%. Sk. 45: 2.5–7.4%. Sk. 46: 2.7–18.0%. Sk. 47: 4.0–9.6%.

Remarks: This species occurred together with *Globobulimina auriculata,* but they are always distinguishable by the apical armature of *G. turgida*. '*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' (Feyling-Hanssen 1964, p. 306).

This species is not recorded from Recent Arctic faunas.

Genus *Stainforthia* Hofker, 1956.

Stainforthia fusiformis (Williamson).

Pl. 2, Fig. 3.

1858 *Bulimina pupoides* var. *fusiformis*. Williamson, p. 63, Pl. 5, Figs. 129, 130.
1947 '*Bulimina*' *fusiformis* Williamson. – Høglund, p. 232, Pl. 20, Fig. 3, Text-figs 219–233.
1963 *Virgulina fusiformis* (Williamson). – Lafranz, Pl. 1, Fig. 10.
1964 *Virgulina fusiformis* (Williamson). – Feyling-Hanssen, p. 307, Pl. 14, Figs. 15–18.
1967 *Stainforthia fusiformis* (Williamson). – Michelsen, p. 226, Pl. 2, Fig. 11.

Size: Length of hypotype of Fig. 3, 0.30 mm, breadth $\frac{1}{3}$ of length, thickness $^{2}/_{5}$ of length.

Occurrence: Most frequent at 210 m water depth where it can constitute 19.2% of the total fauna (station Sk. 43, sediment interval: 15–20 cm).

In the recent sample it increases in frequency down to 210 m water depth and then decreases with increasing water depth.

Remarks: Two forms of this species have been observed in the material (megalospheric and microspheric generation?). One having a terminal aperture and a terminal chamber of considerably smaller size and different shape from earlier chambers. The other form having a large and wide aperture (Cf. Høglund 1947, p. 233).

So radical a change in the shape of the chamber and the structure of the aperture in the ontogeny of this species, has been suggested earlier as representing two separate forms (Heron-Allen & Earland 1913, p. 61). Høglund (1947, p. 236) after comprehensive study of this problem concluded: 'Thus it appears to be beyond all doubt that the individuals with a terminal chamber represent the adult stage of the species, but furthermore, the addition of the terminal chamber seems to indicate that the individual process of growth is definitely completed, as not one of the many thousands of specimens which I have seen had more than one chamber of this kind.'

Subfamily UVIGERININAE Cushman, 1913.

Genus *Uvigerina* d'Orbigny, 1826.

Uvigerina peregrina Cushman.

Pl. 2, Figs. 4–8.
Pl. 3, Figs. 1–5.

1923 ***Uvigerina peregrina*** **Cushman, Bull. 104, pt. 4, p. 166, Pl. 42, Figs. 7–10.**
1947 ***Uvigerina peregrina*** **Cushman. – Høglund, p. 279, Pl. 23, Fig. 9, Text-figs. 291–304.**
1961 ***Uvigerina peregrina*** **Cushman. – Jarke, Pl. 2, Fig. 7a–b.**
1964 ***Uvigerina peregrina*** **Cushman. – Feyling-Hanssen, p. 316, Pl. 15, Figs. 27–29.**
1967 ***Uvigerina peregrina*** **Cushman. – Michelsen, p. 228, Pl. 2, Fig. 15.**

Size: Length of hypotype of Fig. 7, 0.6 mm (microspheric generation). Length of hypotype of Fig. 6, 0.5 mm (megalospheric generation).

Occurrence: U. peregrina increases in frequency down to 210 m depth and then decreases with increasing water depth.

The intervals of frequencies throughout every sediment core are as follows: Sk. 42: 0–2.7%. Sk. 43: 3.7–16.8%. Sk. 45: 0.4–6.7%. Sk. 46: 0.2–4.4%. Sk. 47: 0.2–1.9%.

Remarks: In my own material the specimens seem to agree very well with the description and figures given by Cushman, and for this reason the present writer prefers to follow Cushman.

This species shows a big variation within the sample itself: Spinocostate specimens are mixed together with purely costate forms, short, thick specimens together with long narrow ones. Variation in number of costae is observed too (cf. Figs. 4–8).

As the different variants merge into each other without sharp delimitation, I cannot see any reason to try separating them.

Nørvang (1945, p. 36) found the recent main distribution of *Uvigerina 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. Phleger (1960, p. 52) writes that *Uvigerina peregrina* Cushman seems to be characteristic of depths greater than approximately 100 m. Pokorný (1958, p. 131) includes *U. peregrina* in his third (lower) zone of the continental shelf (below 1600 m) where this species appears with maximum frequency, although it is already frequent at depths of 700 to 1600 m. This material is from Florida and West Indian region and was studied by Norton (1930).

Genus *Trifarina* Cushman, 1923.

Trifarina angulosa (Williamson).

Pl. 3, Figs. 6, 10, 11 (megalospheric generation).
Pl. 3, Figs. 7–9 (microspheric generation).

1858 *Uvigerina angulosa* Williamson, p. 67, Pl. 5, Fig. 140.
1923 *Uvigerina angulosa* Williamson. – Cushman, Bull, 104, pt. 4, p. 170, Pl. 41, Figs. 17–20 (with extensive synonymy).
1947 *Angulogerina angulosa* (Williamson). – Høglund, p. 283, Pl. 23, Fig. 8, Text figs. 305–308.
1956 *Angulogerina angulosa* (Williamson). – Lange, p. 78, Pl. 9, Fig. 10.
1964 *Angulogerina angulosa* (Williamson). – Feyling-Hanssen, p. 317, Pl. 16, Figs. 1–3.
1967 *Trifarina angulosa* (Williamson). – Michelsen, p. 227, Pl. 2, Fig. 13.

Size: Length of hypotype of Fig. 7, 0.40 mm, breadth 0.20 mm. Length of hypotype of Fig. 8, 0.30 mm, breadth 0.18 mm.

Occurrence: In the recent samples *T. angulosa* shows a distinct decreasing frequency with increasing water depth.

The intervals of frequencies throughout every sediment core are as follows: Sk. 42: 8.0–18.8%. Sk. 43: 2.0–4.2%. Sk. 45: 0.3–2.6%. Sk. 46: 0.2–0.4%. Sk. 47: 0.1–0.2%.

Remarks: Both microspheric and megalospheric specimens are observed in the material. As shown in Figs. 7–9, the microspheric generation is sharply pointed at the apical end, whereas the megalospheric generation (Figs. 6, 10, 11) is rounded in this part of the test and has a two to three times bigger proloculum than the microspheric generation as also recorded by Høglund (1947, p. 284).

According to Nørvang (1945, p. 37) in Recent time this species is mainly distributed in Lusitanian and Boreal parts of the Atlantic and the Pacific at depths of 0–3300 m. Its climatic requirements are in good agreement with its occurrence in the Holocene deposits of the Oslofjorden area (Feyling-Hanssen, 1964, p. 318).

Subfamily BOLIVININAE Glaessner, 1937.

Genus *Bolivina* d'Orbigny, 1839.

Bolivina cf. robusta Brady.

Pl. 4, Figs. 1–4 (microspheric generation).
Pl. 4, Figs. 5–7 (megalospheric generation).

1881 *Bolivina robusta* Brady, p. 421, Pl. 53, Figs. 7–9.
1931 *Bolivina robusta* Brady. – Cushman, p. 131, Pl. 117, Figs. 1–4.
1947 *Bolivina cf. robusta* Brady. – Høglund, p. 270, Pl. 24, Figs. 8–9, Pl. 16, Figs. 16–18, Text-fig. 287.
1956 *Bolivina cf. robusta* Brady. – Lange, p. 78, Pl. 10, Fig. 6.
1964 *Bolivina cf. robusta* Brady. – Feyling-Hanssen, p. 321, Pl. 16, Fig. 9.
1967 *Bolivina cf. robusta* Brady. – Michelsen, p. 223, Pl. 2, Fig. 4.

Size: Length: 0.27–0.44 mm (169 specimens measured). Breadth about $^3/_5$ of length, thickness about half the breadth. The microspheric specimens are usually smaller in size than the megalospheric specimens.

Occurrence: In the recent samples this species increases both in absolute and relative frequency down to a water depth of 430 m, where it constitutes 66.0% of the total fauna, in contrast to only 0.3% at the station at 80 m water depth. The intervals of frequencies throughout every sediment core are as follows: Sk. 42: 0–0.4%. Sk. 43: 0.1–10.3%. Sk. 45: 0–38.0%. Sk. 46: 0.7–53.0%. Sk. 47: 0.5–66.0%.

It shows a big fluctuation in its occurrence at different sediment levels.

Remarks: Both the microspheric and the megalospheric form are observed in this material. The microspheric form has a triangular outline, while the megalospheric form has a rounded apical part.

Like Høglund, Lange and Feyling-Hanssen I have not found a single specimen with even the rudiment of an apical spine. The basal margin of each chamber is furnished with only one identation in the vicinity of the median line (Brady and Cushman speak of a crenulation, due to the margins having a series of alternating lobes and re-entrants).

This is the reason why the present writer (as earlier ones) with some hesitation assigns this form to *Bolivina robusta* Brady.

Family CASSIDULINIDAE d'Orbigny, 1839.

Genus *Cassidulina* d'Orbigny, 1926.

Cassidulina laevigata d'Orbigny.

Pl. 4, Figs. 8–9.

1826 *Cassidulina laevigata* d'Orbigny, p. 282, Pl. 15, Figs. 4–5.
1958 *Cassidulina laevigata* d'Orbigny. – Nørvang, p. 38, Pl. 9, Figs. 27–31.
1961 *Cassidulina laevigata* d'Orbigny. – Jarke, Pl. 3, Fig. 5a–b.
1964 *Cassidulina laevigata* d'Orbigny. – Feyling-Hanssen, p. 323, Pl. 16, Figs. 14–16.
1967 *Cassidulina laevigata* d'Orbigny. – Michelsen, p. 246, Pl. 7, Fig. 4.

Size: Diameter: 0.23–0.34 mm (275 specimens measured).

Occurrence: Cassidulina laevigata seems to have a wide bathymetrical distribution after its appearance in the recent sample at the different stations.

The intervals of frequencies throughout each sediment core are as follows: Sk. 42: 12.8–18.7%. Sk. 43: 28.8–56.1%. Sk. 45: 17.3–36.8%. Sk. 46: 19.0–47.3%. Sk. 47: 9.1–41.5%. It is one of the most common species in the examined material.

Remarks: Feyling-Hanssen (1964) follows the division of *C. laevigata* d'Orbigny into two subspecies according to the shape of the margin – carinate or acute. As these characteristics are supposed to be within the normal variation (Nørvang, 1958), and as the present material does not allow a decision to be made to this question, all the specimens examined are classified as *C. laevigata* d'Orbigny.

Family NONIONIDAE Schultze, 1854.

Genus *Nonion* Montfort, 1808.

Nonion barleeanum (Williamson).

Pl. 4, Figs. 10–13.
Pl. 5. Figs. 1–3.

1858 *Nonionina barleeana* Williamson, p. 32, Pl. 3, Figs. 68–69.
1953 *Nonion zaandamae* (Van Vorthuysen). – Loeblich and Tappan, p. 87, Pl. 16, Figs. 11–12.
1960 *Gavelinonion barleeanum* (Williamson). – Barker, p. 224, Pl. 109, Figs. 8–9.
1961 *Nonion barleeanum* (Williamson). – Jarke, Pl. 1, Fig. 9.
1964 *Nonion barleeanum* (Williamson). – Feyling-Hanssen, p. 329, Pl. 17, Figs. 7–12.

Size: Diameter: 0.33–0.50 mm (213 specimens measured).

Occurrence: In the recent sample *N. barleeanum* increases both in absolute and relative frequency down to a depth of 375 m, and then decreases down to 430 m. At 545 m it again constitutes higher percentages of the total fauna.

The intervals of frequencies throughout every sediment core are as follows: Sk. 42: 0–4.8%. Sk. 43: 0.7–4.0%. Sk. 45: 2.6–16.5%. Sk. 46: 4.3–17.7%. Sk. 47: 3.4–10.0 %.

Remarks: The specimens examined are in good agreement with the figures of Feyling-Hanssen (1964). Concerning the different synonyms and the systematical position of this species, reference is made to the comprehensive discussions by Loeblich & Tappan (1953), Barker (1960), and Feyling-Hanssen. Nørvang (1945, p. 27) writes: 'Main distribution: Cosmopolitan. Vertical range: From the seashore down to 4100 m.'

Genus *Pullenia* Parker and Jones, 1862.

Pullenia osloensis Feyling-Hanssen.

Pl. 5, Figs. 4–5.

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.
1964 *Pullenia osloensis* Feyling-Hanssen. – Feyling-Hanssen, p. 334, Pl. 18, Figs. 5–6.

Detailed description of this species is given by Feyling-Hanssen, and the specimens examined are in good agreement with his description and figures.

Size: Greatest diameter of the figured specimen, 0.13 mm, least diameter, 0.12 mm, thickness 0.10 mm. The greatest diameter of 180 measured specimens was within the interval: 0.12–0.16 mm.

Occurrence: In the recent sample this species shows increasing frequencies down to a depth of 375 m, and then decreases down to 430 m. At 545 m it again constitutes higher percentages.

The intervals of frequencies throughout every sediment core are as follows: Sk. 42: 0–0.3%. Sk. 43: 0–5.1%. Sk. 45: 5.2–13.0%. Sk. 46: 5.1–18.6%. Sk. 47: 2.9–10.1%.

'This small, five-chambered, lobulate and translucent *Pullenia* was the only common representative of this genus in the Late Quarternary of the Oslofjord area' (Feyling-Hanssen 1964, p. 334).

Family ORBULINIDAE Schultze, 1854.

Genus *Globigerina* d'Orbigny.

Globigerina bulloides d'Orbigny.

1826 *Globigerina bulloides* d'Orbigny, p. 277.
1924 *Globigerina bulloides* d'Orbigny. – Cushman, p. 7, Pl. 2, Figs. 1–4.
1960 *Globigerina bulloides* d'Orbigny. – Barker, Pl. 79, Figs. 3–7.
1961 *Globigerina bulloides* d'Orbigny. – Jarke, Pl. 4, Fig. 7a–b.

Size: Three specimens were measured: 0.18 mm, 0.15 mm, 0.25 mm (diameter).

Occurrence: This species shows increasing frequencies from the northern to the southern station in the profile. Its occurrence is in good correlation with the salinity in the surface water.

Remarks: Nørvang (1945, p. 47): 'Distribution: The species is recorded from nearly every latitude in all oceans. Main distribution: Cosmopolitan.' Temperature distribution: *G. bulloides,* temperate (Phleger 1965, p. 221).

Globigerina dutertrei d'Orbigny.

1839 *Globigerina dutertrei* d'Orbigny, p. 95, Pl. 4, Figs. 19–21.
1921 *Globigerina dutertrei* d'Orbigny. – Cushman, p. 55, Pl. 12, Fig. 7.
1961 *Globigerina dutertrei* d'Orbigny. – Jarke, p. 30, Pl. 4, Fig. 4.

Size: Diameter: 0.45 mm.

Occurrence: Most frequent at the southern station (Sk. 42).

Remarks: Jarke (1961, p. 30): 'Vorherrschend in der Sedimenten der Nordsee sind in den meisten Gebieten *Globigerina pachyderma* und *G. dutertrei.*'

Temperature distribution: *Globigerina dutertrei,* Arctic and Antarctic (Phleger, 1965, p. 221).

Globigerina eggeri Rhumbler.

1901 *Globigerina eggeri* Rhumbler, p. 19, Text-fig. 20.
1960 *Globigerina eggeri* Rhumbler. – Barker, p. 164, Pl. 79, Fig. 17.
1961 *Globigerina eggeri* Rhumbler. – Jarke, p. 30, Pl. 4, Fig. 3.

Size: Diameter: 0.30 mm.

Occurrence: Very rare in the material examined.

Globigerina pachyderma (Ehrenberg).

1861 *Aristerospira pachyderma* Ehrenberg, p. 303.
1961 *Globigerina pachyderma* (Ehrenberg). – Jarke, p. 30, Pl. 4, Fig. 4.

Size: Diameter: 0.20 mm.

Occurrence: The most frequent planctonic species in the material examined.

Remarks: Nørvang (1945, p. 47): 'Main distribution: Bipolar with scattered outposts in temperate waters.'

Temperature distribution: *Globigerina pachyderma,* Arctic and Antarctic (Phleger, 1965, p. 221).

Superfamily ROTALIOIDEA Ehrenberg, 1839.
Family ELPHIDIIDAE Galloway, 1933.

Genus *Elphidium* Montfort, 1808.

Elphidium clavatum Cushman.

Pl. 5, Fig. 6.

1930 *Elphidium incertum* (Williamson), var. clavatum Cushman, Bull. 104, pt. 7, p. 20, Pl. 7, Fig. 10.
1961 *Elphidium clavatum* Cushman. – Jarke, Pl. 2, Fig. 1a–b.
1964 *Elphidium incertum clavatum* Cushman. – Feyling-Hanssen, p. 345, Pl. 20, Figs. 11–15.
1967 *Elphidium clavatum* Cushman. – Michelsen, p. 236, Pl. 4, Fig. 6.

The morphological variation discussed by Michelsen is also found in the material examined here.

Size: Largest diameter of the figured specimen, 0.30 mm, thickness 0.15 mm.

An examination of the size distribution of this species was presented by Feyling-Hanssen (1964, p. 187, Fig. 34).

Occurrence: E. clavatum appears very sporadically in the three northern sediment cores in the profile, and here constitutes seldom more than 1% of the total fauna. In the southern and most shallow situated sediment core (Sk. 42.80 m) it constitutes between 20.4% and 29.2% of the fauna.

Thus *E. clavatum* shows a distinct decreasing frequency with increasing water depth.

Remarks: In Feyling-Hanssen's (1964) zone E transitional forms between typical *E. incertum* and *E. clavatum* occurred, and he therefore regarded them as subspecies (cf. Brand 1941). *Elphidium incertum clavatum* predominated in the Late Glacial parts of the borings from the Oslofjorden area, from the Late Pleistocene zone A through the Holocene zone D. In the other Post Glacial zones it was usually rare. Its recent main distribution is boreal to Arctic.

Loeblich & Tappan (1964, pp. 632–633) writes about the genus *Elphidium:* 'Habitat shallow water or tide pools on sandy or shelly bottoms, with algae, radiating pseudopodia binding together a mass of sand to prevent dislodging during moderate turbulence.'

Family ROTALIIDAE Ehrenberg, 1839.

Genus *Hyalinea* Hofker, 1951.

Hyalinea balthica (Schroeter).

Pl. 5, Figs. 7–11.

1783 *Nautilus balthicus,* Schroeter, p. 20, Pl. 1, Fig. 2.
1931 *Anomalina balthica* (Schroeter). – Cushman, Bull. 104, pt. 8, p. 108, Pl. 19, Fig. 3.
1956 *Anomalina balthica* (Schroeter). – Lange, p. 80, Pl. 9, Fig. 4.
1961 *Anomalina balthica* (Schroeter). – Jarke, Pl. 3, Fig. 7.
1964 *Hyalinea balthica* (Schroeter). – Feyling-Hanssen, p. 351, Pl. 21, Figs. 14–16.

Size: Largest diameter of 196 measured specimens was within the size interval: 0.34–0.55 mm.

Occurrence: In the recent sample it shows increasing frequencies down to a depth of 375 m, and then decreases down to 430 m. At 545 m it again constitutes a higher percentage of the fauna.

The intervals of frequencies throughout every sediment core are as follows: Sk. 42: 0–0.5%. Sk. 43: 2.6–7.4%. Sk. 45: 4.6–21.9%. Sk. 46: 4.2–19.7%. Sk. 47: 4.6–23.6%.

In the material examined all transitions between a translucent and an opaque form were observed.

Hyalinea balthica appeared in the Mediterranean at the beginning of the Quarternary period and is, together with *Cassidulina laevigata carinata,* an index fossil in Quaternary deposits there (Feyling-Hanssen 1964, p. 352). Nørvang (1945, p. 48) writes: 'Its Recent distribution is boreal and lusitanian in the Atlantic and Pacific Oceans, where it may occur at depths of 40–4500 m but it is normally found in shallow water.'

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December 1970

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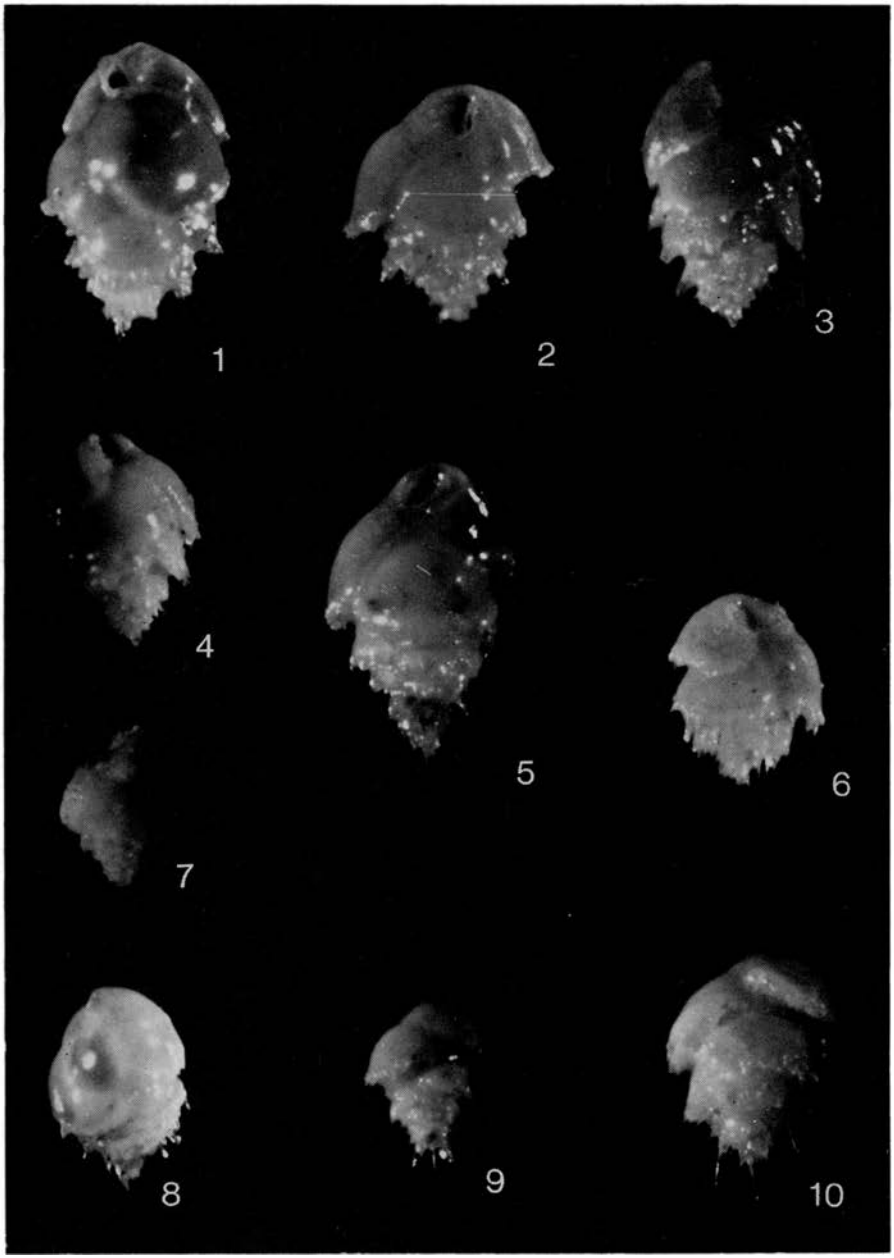

Plate 1.
Family BULIMINIDAE Jones, 1875.
Figs. 1–10. *Bulimina marginata* d'Orbigny .... page 269
Boring Sk. 45, samples 1–5. 75×.

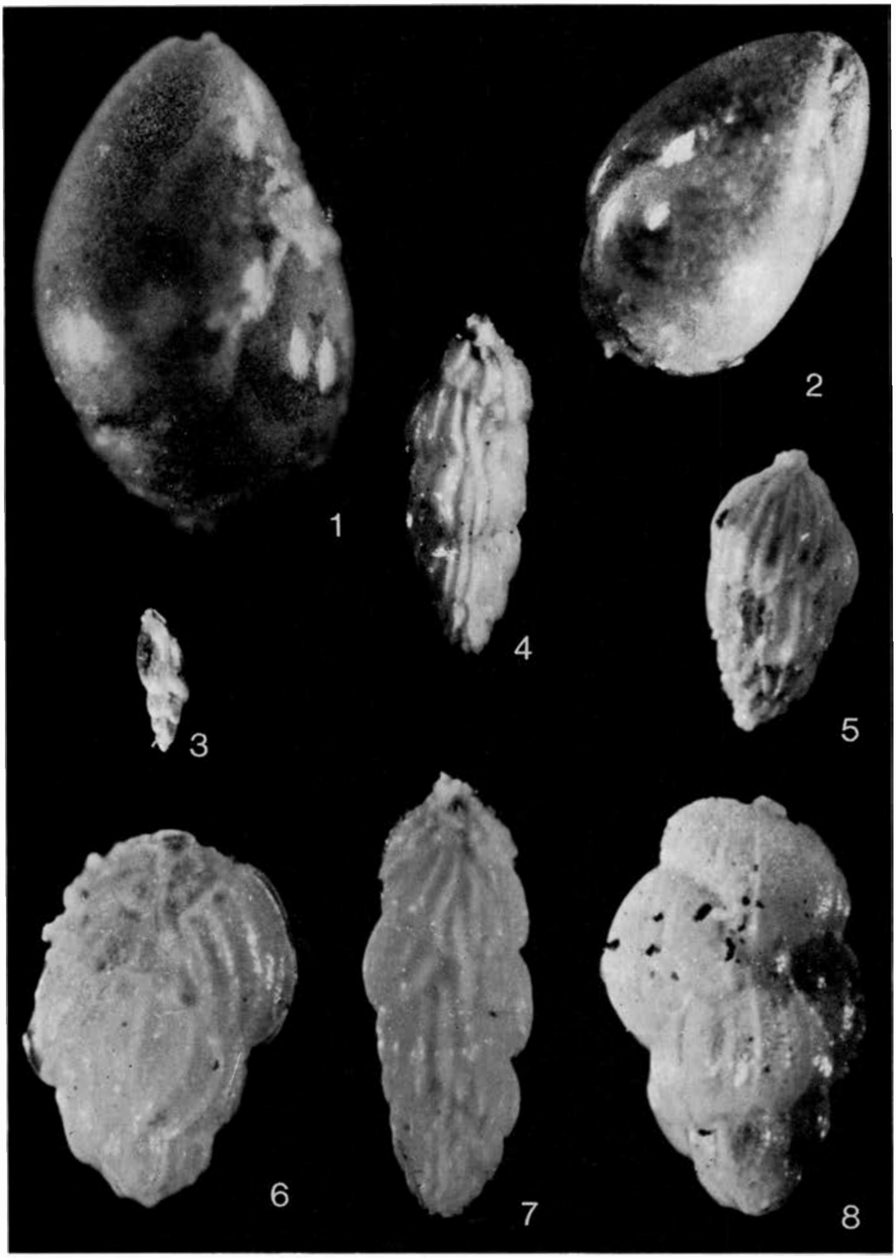

Plate 2.
Family BULIMINIDAE Jones, 1875.
Figs. 1–2. *Globobulimina turgida* (Bailey) .... page 269
Boring Sk. 45, sample 1. 75×.
Fig. 3. *Stainforthia fusiformis* (Williamson) .... page 270
Boring Sk. 43, sample 1. 75×.
Figs. 4–8. *Uvigerina peregrina* Cushman .... page 271
Boring Sk. 43, samples 1–7. 75×.
Figs. 4, 5, 7. Microspheric specimens.
Figs. 6, 8. Megalospheric specimens.

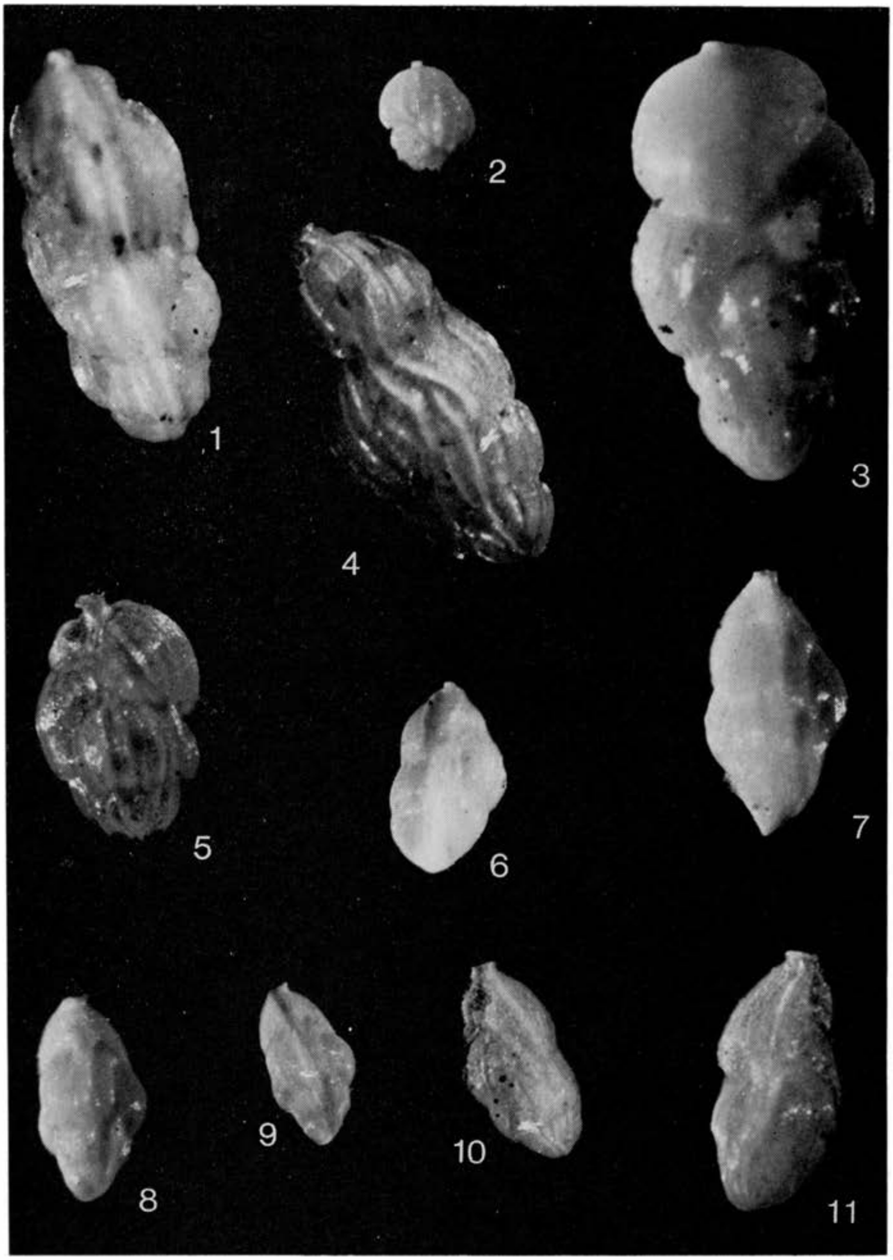

Plate 3.
Family BULIMINIDAE Jones, 1875.
Figs. 1–5. *Uvigerina peregrina* Cushman .... page 271
Boring Sk. 43, samples 1–7. 75×.
Figs. 1–4. Megalospheric specimens.
Fig. 5. Microspheric specimens.
Figs. 6–11. *Trifarina angulosa* (Williamson) .... page 272
Boring Sk. 42, samples 1–4. 75×.
Figs. 6, 10, 11. Megalospheric specimens.
Figs. 7, 8, 9. Microspheric specimens.

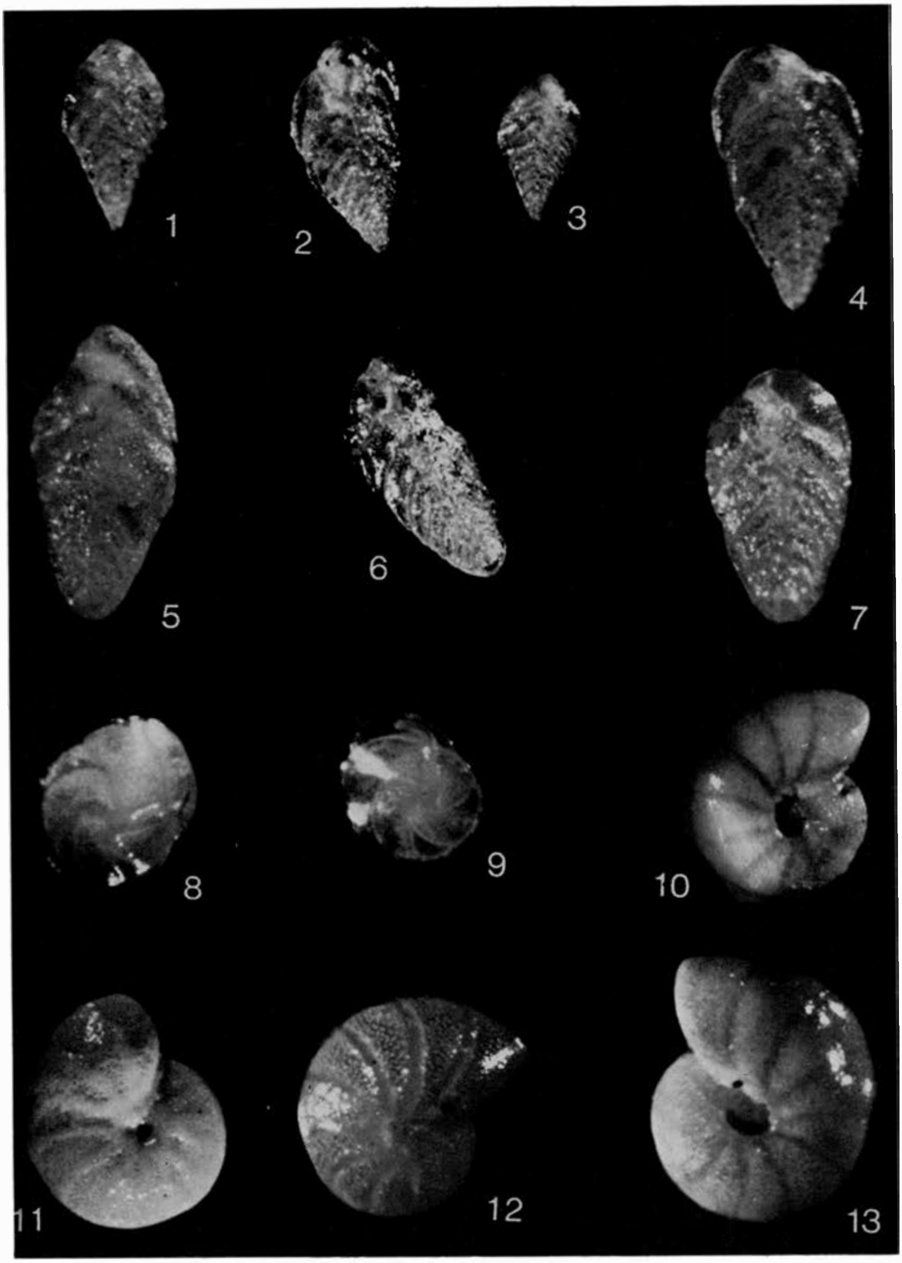

Plate 4.
Family BULIMINIDAE Jones, 1875.
CASSIDULINIDAE d'Orbigny, 1839,
NONIONIDAE Schultze, 1854.
Figs. 1–7. *Bolivina cf. robusta* Brady .... page 273
Boring Sk. 47, samples 1–2. 75×.
Figs. 1–4. Microspheric specimens.
Figs. 5–7. Megalospheric specimens.
Figs. 8–9. *Cassidulina laevigata* d'Orbigny .... page 274
Boring Sk. 45, sample 1. 75×.
Figs. 10–13. *Nonion barleeanum* (Williamson) .... page 274
Boring Sk. 45, samples 1–6. 75×.

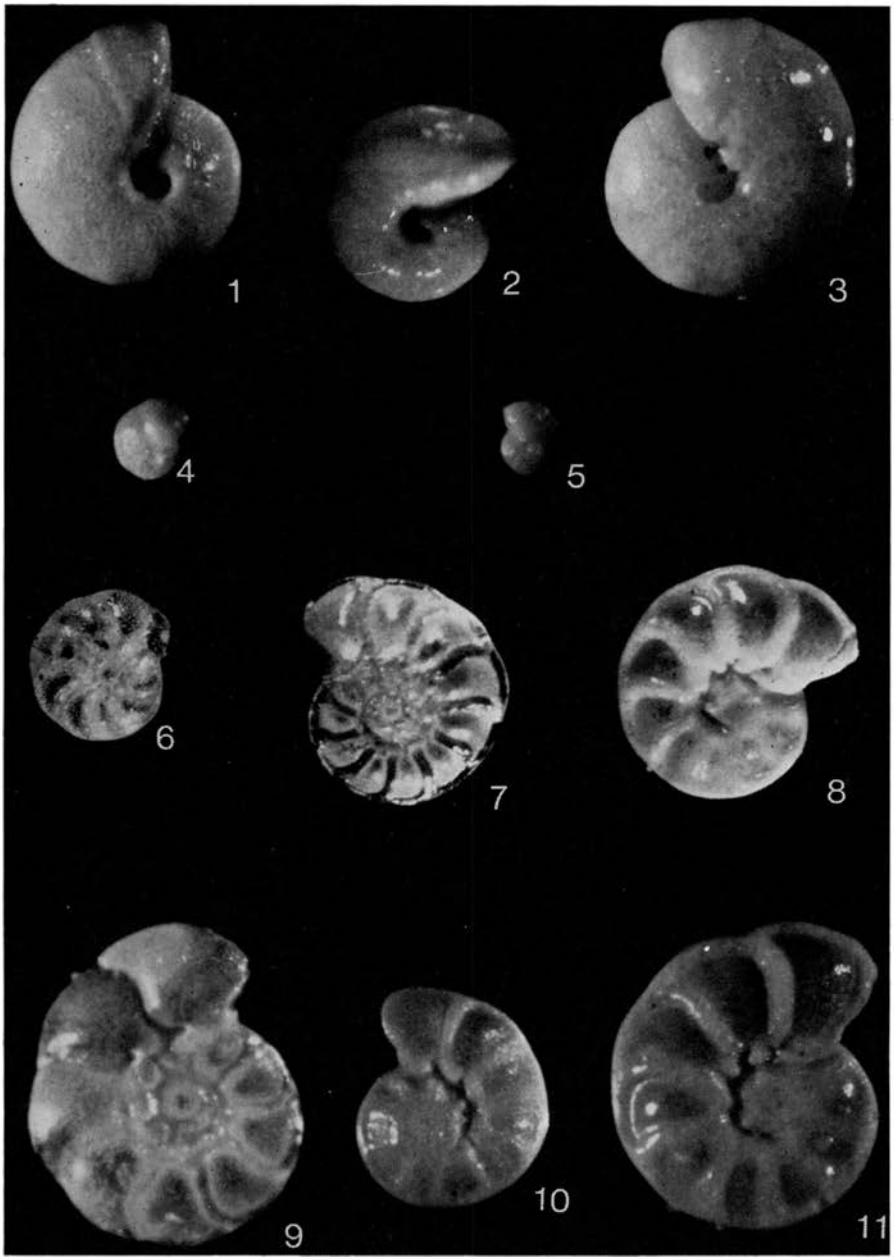

Plate 5.
Family NONIONIDAE Schultze, 1854,
ELPHIDIDAE Galloway 1933,
ROTALIIDAE Ehrenberg 1839.
Figs. 1–3. *Nonion barleeanum* (Williamson) .... page 274
Boring Sk. 45, samples 1–6. 75×.
Figs. 4–5. *Pullenia osloensis* Feyling-Hanssen .... page 275
Boring Sk. 45, sample 1. 75×.
Fig. 6. *Elphidium clavatum* Cushman .... page 277
Boring Sk. 42, sample 1. 75×.
Figs. 7–11. *Hyalinea balthica* (Schroeter) .... page 278
Boring Sk. 47, samples 1–4. 75×.