

# Major features of the distribution of Antarctic foraminifera

Valeria I. Mikhalevich

*Zoological Institute of the Russian Academy of Sciences, 1, Universitetskaya Emb., 199034 St. Petersburg, Russia*  
e-mail: Mikha@JS1238.spb.edu

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**ABSTRACT:** Benthic foraminifers collected in different regions of the high Antarctic (Weddell Sea, Mawson Sea, Davis Sea and some other locations in East Antarctic) on the shelf and upper part of the bathyal zone (2-2315m) were analyzed to determine regularities in their distribution. Most samples contained living organisms. The composition of the foraminiferal assemblages is influenced by many factors of water characteristics such as temperature, salinity, nutrient composition, availability of carbonate and variations in CCD, presence of near-bottom flows. The changes of water masses at different depths or mixing of the different water masses are clearly seen in the changes of the foraminiferal species composition. In some cases the local variations of water characteristics, seasonality and ice melting are also responsible for the foraminiferal distribution. Two faunas were identified: those of the shelf associated with the cold-water masses ( $-1^{\circ}$  to  $1.9^{\circ}$ ) and the upper slope with warmer water ( $-0.5^{\circ}$ ), the majority of the characteristic forms being circumantarctic. Species abundance displays two maximums at depths of 180-300m and 1500-2300m. At depths to 500, and even to 700m, both arenaceous and calcareous forms, especially miliolids, are abundant. Below this boundary some living calcareous forms were also found, though arenaceous ones were dominant. The presence of calcareous foraminifers at the majority of the stations in our material may be explained by the higher resistance of living calcareous forms to carbonate dissolution comparing the empty tests, dissolving more rapidly. The overall pattern of these our data and of data from previous studies allows to draw some general conclusions with regard to the Antarctic foraminiferal fauna: a high degree of endemism which, for the shelf depths of 2-50m, sometimes reaches 80%; the gigantism of many species; a wide range of vertical distribution of many species; introduction of deep water species of other oceans onto the shelf and the upper part of the bathyal zone; often high species diversity and high quantity abundance of many species in the community; abundance of circumantarctic species, often with a great number of species belonging to a single genus; the abundance (often predominance) of agglutinated forms compared to calcareous ones. Some taxonomic notes and morphological observations are given, as well as comparisons of some closely related Arctic and Antarctic forms.

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## INTRODUCTION

The Foraminiferal faunas of the Antarctic area are still not well known despite a great number of published works beginning in the XIXth century (d'Orbigny 1839; Brady 1884), the first half of the XXth century (Heron-Allen and Earland 1922, 1932; Earland 1933, 1934, 1936; Wiesner 1931; Parr 1950; and others), and relatively recent ones (Uchio 1960; McKnight 1962; Pflum 1966; Kennett 1967, 1968; Echols and Kennett 1973; Fillon 1974, Lipps et al. 1972, Anderson 1975a, b, Saidova 1975, 1998; Osterman and Kellog 1979; Setty et al. 1980; Finger and Lipps 1981; Milam and Anderson 1981; Tai 1984; Bernhard 1987; Ward et al. 1987; Mead and Kennett 1987; Quilty 1985, 1988; Mackensen and Douglas 1989; Mackensen et al. 1990; Violanti 1996; Gazdzicki and Majewski 2003; and others), among which only studies in the high Antarctic dealing with modern sediments are included. Although the Southern Ocean is covered by a net of stations, they are scattered unevenly and it is difficult to obtain a generalized picture of foraminiferal distribution. In addition data collected by studies up to the first half of the last century are difficult to use for comparison. Furthermore, correct identification to the species level, described in these works is often tentative, and many species need to be revised. In many cases the understanding of the species concept was too broad and the majority of the species were assigned to previously described ones from the North Atlantic and from other ocean regions. Conclusions based on such taxonomic approach differ from those based on recent taxonomic ideas.

## MATERIAL

For this study, bottom samples from 170 stations were available. Among these were: 1) probes from 132 stations of the Soviet Antarctic Expedition (SAE) gathered mostly by the "Ob" in 1956-1972, and also by the "Akademik Fedorov" in 1990 in the Indian, Pacific and Atlantic sectors of the Antarctic (only stations of the shelf up to the upper part of the bathyal zone are included here); 2) diver's collections made from depths of 2 – 50m by the Russian zoologists E. Gruzov and A. Pushkin in 1965/66 on the shelf of the Davis Sea near the Station Mirnyj, and of A. Pushkin, 1989, in the Mawson Sea (Fish Tail Bay, Banger Oasis -  $66^{\circ}15'S$ ,  $100^{\circ}48'E$ , 20-50m); 3) and material from 29 stations of the German icebreaker "Polarstern" collected in the 1996 in the Weddell Sea near Cap Norvegia ( $71^{\circ}02'S$  to  $73^{\circ}25'S$ ,  $8^{\circ}15'E$  to  $22^{\circ}35'E$ , depth 118-2315m). Data on the stations from these areas were published earlier (on the SAE and Gruzov and Pushkin material – by Stschedrina (1979), on the Pushkin material in the Mawson Sea – by Mikhalevich (1991), on the Weddell Sea material collected by the "Polarstern" – by Mikhalevich (in Gutt et al. 2000) as well as brief information on their foraminiferal fauna (in 1961-1981, the author was employed as an assistant to Dr. Z. Stschedrina working on the Antarctic material). The area investigated includes only stations from high Antarctic waters within the line of the Antarctic convergence from 0–2315m (fig. 1, 2). All the specimens from the Mawson, Davis and Weddell Seas were gathered alive and were filled with cytoplasm often extruding from the aperture. In all, 112 agglutinated and calcareous

foraminiferal species were recovered from the shelf and the upper part of the bathyal zone.

## DISCUSSION

### Previous investigations

The materials studied here, together with previously published data on faunas from the different regions of the Southern Ocean permit some new observations on the foraminiferal distribution around the Antarctic.

We do not describe here the hydrologic conditions of the various areas, the nature of the water masses and position of the dissolution boundaries, as all these parameters were shown in detail in previous works (Kennett 1968, Anderson 1975a, Osterman and Kellog 1979, Milam and Anderson 1981, Mackenzen et al. 1990). In spite of local variations of these features in the different regions, there are some common circum-polar regularities of the distribution of the shelf and slope water masses, and in the temperatures and nature of the currents. Although the position of the dissolution boundary is highest in the Ross Sea (300–400m according to Fillon (1974) and even 243m near Adelie on the George V shelf not far from the Ross Sea according to Milam and Anderson (1981), its position is often displaced even in this region [(to 550m according to Kennett (1968)], and up to 587m according to Milam and Anderson (1981). The most variable temperature/salinity parameters are noted on the near shore continental shelf due to seasonal periods and ice melting. The light ice cover permits a higher rate of photosynthesis, which leads to a lower concentration of CO<sub>2</sub> and consequently the greater depth of the CCD (Osterman and Kellog 1979). Nevertheless, in spite of the instability of calcium carbonate at shallow depths all round the Antarctic, the first level of the CCD is situated rather high, at an average depth 500 – 550m, sometimes reaches to 700m (in the Weddell Sea, and even in the Ross Sea the seasonal depression of CCD was noted as deep as 755m (Osterman and Kellog 1979) (a second CCD level is at the greater depth of 3500–4000m). Bernhard (1987) has shown the dependence of agglutinated and calcareous foraminiferal assemblages on the nature of the sediment composition. Osterman and Kellog (1979), and Milam and Anderson (1981) also noted some cases of sediment influence and that the influence of calcium carbonate concentrations limits the calcareous fauna to the western part of the Ross Sea shelf. The same nature of the control of the glacial regime resulting in CO<sub>2</sub> concentrations and the CCD level were studied earlier in the Weddell Sea, where the calcareous shelf fauna is distributed in its eastern part (Anderson 1975a). Pflum (1966) and McNight (1962) also gave their explanation of this phenomenon. Nevertheless, Kennett (1968), Osterman and Kellog (1979) and Milam and Anderson (1981) noted that the foraminiferal distribution is not clearly related to any single environmental parameter and that it is difficult to establish the main predominant factor. Different predominantly agglutinated and predominantly calcareous assemblages in the eastern and western Ross Sea shelf, respectively, live under the same water mass conditions (Milam and Anderson 1981). From previous investigations and from our own data, the main factor influencing foraminiferal distribution appears to be the changes of the character of the water masses at the different depths.

## RESULTS

The results of this study reveal that the most evident factor controlling the distribution of the foraminiferal fauna in the Antarctic

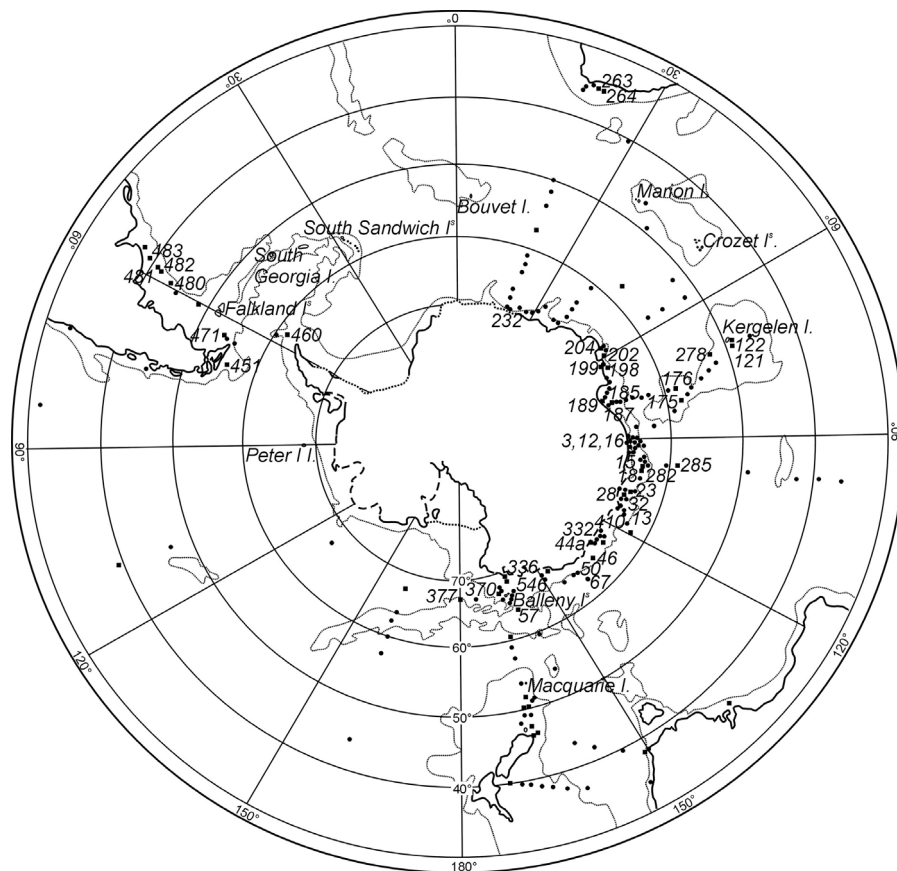
area studied is the character of the water masses, firstly their temperature/salinity parameters which changes with the depths.

The richest “alive” material available for this study was from the Weddell Sea, one of the most inaccessible areas of the World Ocean, which has now become one of the more fully investigated Antarctic regions. Our results are based on materials from this area.

The shelf boundary in the Antarctic is mostly at a depth of 500m (rarely 350m) and, in some cases, even at 700m, and is connected with a significant break in the Antarctic continental margin. Nevertheless, the maximum abundance, in both species and specimens number, was seen at depths of 180–300m both in the Western and Eastern parts of the Antarctic. Representative species include: *Saccammina basispiculata*, *Tholosina laevis*, *Psammophax consociata*, *Thurammina antarctica*, *T. protea*, *Pseudonodosinella margaritaria margaritaria*, *Pauciloculina* (*Labrospira*, *Cribrostomoides*) *antarctica*, *Cornuspira antarctica*, *Cornuspiroides lacunosus*, *Planispirinoides antarcticus*, *Pyrgo peruvianum*, *P. sarsii*, *P. latum*, *Pyrgoella sphaera*, *Cruciloculina subvalvularis*, *Lenticulina antarctica*, *Glandulina antarctica*, *Cibicides antarcticus*, *Ehrenbergina glabra*, *Anticleina* (*Globocassidulina*) *biora*, *Cassidulinoides parkerianus*, *Angulogerina* (*Trifarina*) *earlandi* and *Buccella antarctica*. These species characterize the shelf Antarctic foraminiferal fauna, the majority of them being circumantarctic. The predominance of coarsely fragmented sediment and the presence of strong near-bottom flows rich in detritus are favorable for the sessile forms (*Tholosina laevis*, *T. vesicularis*, *Dendrophrya erecta*, *Pseudoweberinella* sp.). In the shallowest parts of the upper shelf near the continent at depths up to 50m the fauna is significantly less rich and is usually represented by only 7–12 species. The most abundant species here are *Psammophax consociata*, *Pauciloculina antarctica*, *Planispirinoides antarcticus*, *Lenticulina antarctica*, *Glandulina antarctica*, *Cibicides antarcticus*, *Ehrenbergina glabra*, *Anticleina* (*Globocassidulina*) *biora*, *Cassidulinoides parkerianus*. These species occur in our materials in the Weddell, Davis, Mawson and Cosmonaut Seas and at many other locations in all three Antarctic sectors, and they are also recorded in nearly all published works on the continental Antarctic shelf. Their distribution appears to be circumantarctic due to the water temperature uniformity of this harsh area, with the lowest water temperatures (–1 to –1.9) in the circumantarctic current (Antarctic Coastal Current – ACC), and may also be due to the long period of isolation from the other shelf faunas. All of these species are Antarctic or Antarctic/subantarctic endemics.

Another characteristic feature of the Antarctic shelf foraminiferal fauna is introduction into shallow depths of a significant number of deep-water and cold water species (*Adercotryma glomerata*, *Quinqueloculina venusta*, *Pyrgoella sphaera*, *Spiroloculina pusilla*, and others) that are distributed in other World oceans only in the bathyal and abyssal zones and in regions of upwelling (see above). However, this fact is unsurprising as Antarctic shallow waters have the lowest temperature (–1° to –1.9°). The maximum number of species per station on the middle part of the shelf achieved in our materials is 60–70 species per sample. The high heterogeneity of the assemblages makes it difficult to separate the dominant forms.

The uppermost slope begins down off the shelf break at depths of 500–700m. Its fauna is represented by an assemblage transitional from the shelf to the slope fauna with an abundance of



TEXT-FIGURE 1

Sample locations of the Soviet Antarctic Expeditions (SAE) 1956-1990. Only those within the line of the Antarctic convergence are used in the present work. Dotted line marks shallow areas.

miliolids, *Angulogerina (Trifarina) angulosa*, and some agglutinated forms. The upper slope is influenced by the Circum Antarctic Current (CAC) and its fauna also has many common species in the three Antarctic sectors. Identical arenaceous species were recorded in the slope depressions of the Weddell and Ross Seas by Milam and Anderson (1981). The similarity of the Weddell Sea and Eastern Antarctic fauna was also noted for some invertebrate groups (Sirenko et al. 1999).

The next maximum of foraminiferal species was noted in our material at depths of 1500-2300m (upper part of the bathyal zone) where the number of species per station falls to 15-20 and less. The most characteristic species of this upper subzone of the bathyal zone are *Rhabdammina antarctica*, *Hyperammina elongata*, *Pilulina jeffreysii*, *Hormosina globulifera*, *H. normani*, *Nodosinum gaussicum*, *Pseudonodosinella antarctica*, *Ammodiscus antarcticus*, *Cribrostomoides antarcticus*, *Cyclammina orbicularis asellina*, *C. pusilla antarctica*, *Ammobaculites echinatus*, *Eggerella bradyi antarctica*, *Alabaminella widde- lensis profundus*, *Alabaminoides exiguus surtidus*, *Oridorsalis tenerus*, *Ioanella tumidula antarctica*, *Cibicides wueller- storfii antarcticus*, *Sphaeroidina bulloides quinqueloba*.

The antarctic endemic *Tritaxis earlandi* (see Mikhalevich, 1972) is also represented in significant number. Although the fauna of the Pacific sector is represented by the richest foraminiferal assemblages, most of these species noted are also

distributed around the Antarctic (see Kennett 1968; Fillon 1974; Osterman and Kellog 1979; Quilty 1988 in addition to our data). The temperature at this depth is higher ( $-0.5^{\circ}$ ) because of the mixing of cold polar waters with the more warm deep circum- polar waters (Antarctic Bottom Waters – ABW). When the cold waters running from the shelf predominate in this area of mixed water masses, the agglutinated species *Pseudonodosinella margaritaria elongata*, *Cyclammina orbicularis asellina*, *C. pusilla antarctica* dominate the samples. Some species occur in both levels investigated (shelf and upper bathyal zone): *Hormosinella distans*, *Pauciloculina antarctica*, *Nonionella antarctica*, *Pullenia antarcticaensis*, *Anticleina bora*. Many of the eurybathic species (*Pyrgo murrhinum*, *P. patagonicum*, *P. vespertilio*, *P. peruvianum*, *P. lateoralis*, *P. oblongus*, *Sigmoinea obesa*) were observed in the area studied at depths of not more than 621m. Only the eurybathic *Pyrgoella sphaera* is noted besides of the shelf at the depth of 1586m also. In contrast, *Planispirinoides antarcticus* was found at a depth of 2315m not characteristic for it.

In this study no evidence was seen of a strong correlation between sediment type and the composition of the benthic foraminiferal fauna. The overwhelming majority of assemblages investigated were of a mixed character containing both arenaceous and calcareous forms, though arenaceous ones were very abundant at the majority of the stations. Only in a few samples were the specimens fully arenaceous, for example at a sta-



tion collected by the “Akademik Fedorov”, 1990 (slightly to the East from the Glacier Lazarev at a depth of 380m) with *Psammospaera parva*, *Hormosinella* (*Reophax*) *distans antarctica*, *Conotrochammina antarctica* and some other species. In the trough of Alasheev Bay, only *Miliammina oblonga* occurs. However, it appears that the foraminiferal fauna here is monospecific due to dissolution. At one station in the Cosmonaut Sea only *Rhabdammina antarctica* was found at a depth 360m. Calcareous benthic foraminifera were absent also at two stations of the “Polarstern”, 1996: number 18 (between Vestkapp and Halley (21°29'E) (with *Rhabdammina antarctica*, *Saccammina basispiculata*, *Hormosina normani* and *Cyclammina orbicularis asellina*) at 1704m and number 25 (Kapp Norvegia, 14°18'E) at 622m. Moreover, calcareous forms were absent from three samples from the last station and only in one of them was an occasional *Rhabdammina* sp. found.

The presence of calcareous foraminifera at the majority of the stations in our material may be explained by the higher resistance of living calcareous forms to carbonate dissolution, whereas the empty tests dissolve more rapidly. This corroborates data of Mackensen et al. (1990) who noted a remarkable difference between the living and dead populations in the Weddell Sea. Among calcareous species, a high abundance of miliolid genera and species is noted in our material. It is possible that the high magnesium calcite in their tests is also less sensitive to the dissolution effect than the tests of other calcareous taxa such as nodosariids, spirillinids, and rotaliids.

## DISCUSSION

Living organisms reflect the sum of the environmental parameters in a complex manner. However, they may react differently to a change in any single parameter and the trophic conditions appear to be most important.

Some common peculiar features of the Antarctic foraminiferal fauna are:

1. The high degree of endemism. The endemic species comprise 35.7% of all species and is significant not only in shelf communities but even in the communities of the bathyal zone. For shelf depths of from 2-50m endemic forms sometimes reach 80%. Even in such a plastic group as the miliolids with a large number of eurybathyal species endemism can be as high as 24%. These data are based on a new taxonomic approach to the understanding of many Antarctic foraminiferal species following Crespin (1960), Kenneth (1967, 1970), Saidova (1975), Nomura (1984), and Mikhalevich et al. (2000).

2. The gigantism of many species. Though the average size of the foraminiferal test is 0.5 mm, forms of several millimeters up to 15mm (*Pseudonodosinella margaritaria margaritaria*) are seen. Examples of species in the 1-4mm size range are abundant (e.g., *Glandulina antarctica* – 1mm, many species of *Pyrgo* and *Cornuspiroides* – 3-4mm).

3. The wide ranges of bathymetric distribution of many species. Thus *Hormosinella distans antarctica*, *Pauciloculina antarctica*, *Conotrochammina antarctica*, *Nonionella antarctica*, *Pullenia antarcticaensis*, *Anticleina bora*, and many others normally found at the upper part of the shelf are found also on the deeper shelf parts and in the upper subzone of the bathyal zone. This may be due to the abruptness of the shelf and its significant extension, and also to the comparative uniformity of

environments with a small drop of temperatures and relative homogeneity of all other hydrologic parameters.

4. Distinct bathymetric boundaries of the shelf foraminiferal fauna, and that of the slope and the bathyal zone as well.

5. The abundance of circumantarctic species on the shelf and slope.

6. The increase of faunal differences from the shelf to the deeper depths. This phenomenon is unlike the usual occurrence when the shelf fauna is the most diverse and its variability falls with increasing depth. This feature of the Antarctic fauna may be explained by the long isolation of its shelf area and by the rather strong influence of the deep waters of the three oceans in the bathyal zone of the three Antarctic sectors.

7. The introduction of deep-water species from other oceans onto the shelf and the upper part of the bathyal zone.

8. Communities with not only high species diversity (polymixic), but also with the high quantity abundance of many species in the community that may be connected with the predominance of rough, unsorted sediments and the total lack of significant desalination (absence of river stock) in this region.

9. The high patchiness of the species distribution, especially in the shelf zone and its upper part, and at the same time the uniformity and repetitiveness of the bottom biotopes all around the Antarctic continent.

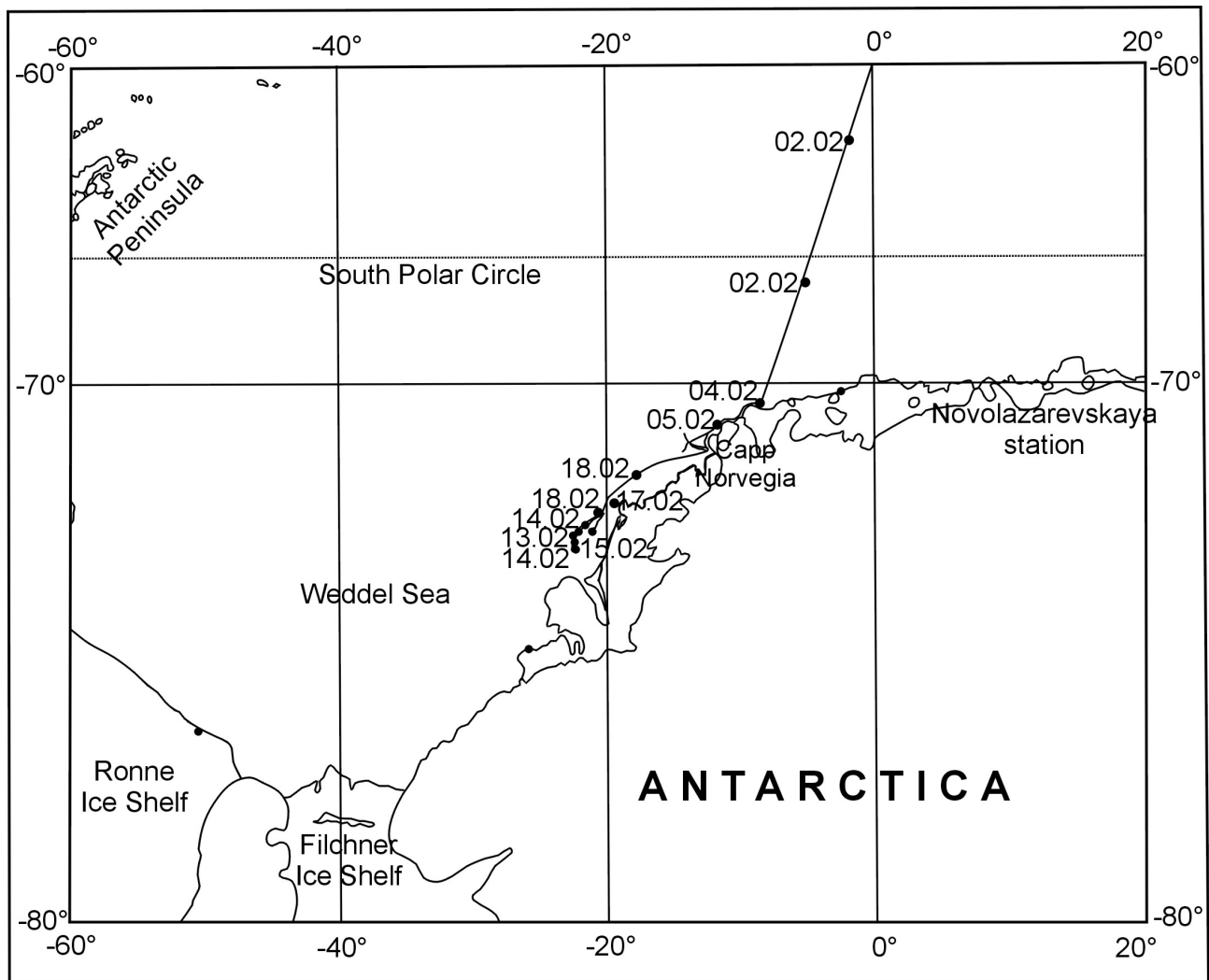
10. The high abundance of the number of species belonging to a single genus (e.g., *Rhabdammina*, *Tholosina*, *Thurammina*, *Textularia*, *Reophax*, *Pyrgo*, *Triloculina*). The example of the genus *Pseudonodosinella* is very characteristic. The subspecies of *Pseudonodosinella margaritaria* are differentiated not only from the Pacific deep-water form *P. nodulosa* (to which they were previously assigned), but also from the Antarctic deep-water species *P. antarctica*. Both Antarctic subspecies of *P. margaritaria* (*P. margaritaria margaritaria* and *P. margaritaria elongata*) are adapted to different depths (the first is a shallow water one, characteristic for the sublittoral, the second – a deep-water species, characteristic for bathyal zone).

11. The abundance (and often the predominance) of agglutinated forms compared to calcareous ones, which is obviously determined by low water temperatures and undersaturation of the water by CaCO<sub>3</sub>. It is interesting to note the abundance of miliolid tests among the calcareous forms, which suggests that the porcellaneous wall is less sensitive to the deficiency of CaCO<sub>3</sub>.

## TAXONOMIC NOTES

The complex and often confusing nomenclatural problems associated with many Antarctic species make it difficult to compare the data of different authors, especially those studied from the beginning of the 20<sup>th</sup> century and those not accompanied by morphological descriptions. Below we give the synonymy of some of more commonly encountered species whose understanding significantly varies in different works. Scanning Electron Micrographs (SEM) of the most abundant shelf and slope species are presented on Plates 1-5.

*Rhabdammina antarctica* Saidova  
Plate 5, figures 3, 4



TEXT-FIGURE 2

Sample locations of the icebreaker "Polarstern", 1996.

*Rhabdammina antarctica* SAIDOVA 1975, p. 16, pl. II, fig. 1, pl. XCIII, fig. 4.

*Rhabdammina abyssorum* M. Sars in Carpenter 1869. – STSCHEDRINA 1979, p. 148, pl. 1, fig. 14–16, (Antarctic form). – MILAM and ANDERSON 1981, p. 302, pl. 1, fig. 1 (non *Rhabdammina abyssorum* M. Sars, in Carpenter 1869).

*Saccammina basispiculata* Mikhalevich, Pronina et Nestell  
Plate 1, figures 10–12

*Saccammina basispiculata* MIKHALEVICH, PRONINA et NESTELL 2000, p. 187, pl. 1, fig. 1–8.

*Saccammina sphaerica* Brady 1871. – WIESNER 1931, p. 81, pl. V, fig. 48–52. – KENNETT 1968, table 4. – MILAM and ANDERSON 1981, p. 324. – FINGER and LIPPS 1981, p. 120, pl. 1, fig. 4. – MACKENSEN et al. 1990, p. 248. (non *Saccammina sphaerica* Brady 1871)

**Remarks:** Differs from *S. sphaerica* Brady in having an aperture without any neck, flush with the surface and the aboral end with an acute needle-like projection.

*Hormosinella distans antarctica* Saidova

*Hormosinella distans antarctica* SAIDOVA, 1975, p. 54, pl. X, fig. 5.  
*Reophax distans* Brady 1881. – WIESNER 1931, p. 90, pl. IX, fig. 104–105. – KENNETT 1968, p. 36, 38, table 4. – ANDERSON 1975, p. 74,

pl. 1, fig. 17. – OSTERMAN and KELLOG, 1979, p. 264, 268, pl. 3, fig. 4. – MACKENSEN et al. 1990, p. 248. (non *Reophax distans* Brady 1881).

*Ginesina guttifer* (Brady)

*Reophax guttifer* BRADY 1884, p. 295, pl. Xxi, figs. 10–15. – WIESNER 1931, p. 90, pl. IX, fig. 106. – ANDERSON 1975, p. 74, pl. 1, fig. 18.

*Pseudonodosinella margaritaria elongata* Saidova

Plate 2, figures 1–7

*Pseudonodosinella margaritaria elongata* SAIDOVA 1975, p. 65, pl. XIV, fig. 10.

*Reophax nodulosus* Brady 1879. – WIESNER 1931, p. 91, pl. IX, fig. 109. – STSCHEDRINA 1979, p. 150, pl. III, fig. 5, 6. – KENNETT 1968, p. 39, table 4. – ANDERSON 1975, p. 74, pl. 1, fig. 19. – FILLON 1974, p. 140. – OSTERMAN and KELLOG 1979, p. 264, 268, pl. 3, fig. 5, 6. – MILAM and ANDERSON 1981, p. 302, pl. 1, fig. 7. – FINGER and LIPPS 1981, p. 132, (non *Reophax nodulosus* Brady 1879).

*Pseudonodosinella margaritaria margaritaria* Saidova

Plate 2, figures 1–7

*Pseudonodosinella margaritaria margaritaria* SAIDOVA 1975, p. 65, pl. XIV, fig. 9.

*Reophax margaritarius* RHUMBLER 1931, p. 90, pl. IX, fig. 107. – STSCHEDRINA 1979, p. 153.

***Pauciloculina antarctica* (Saidova)**

Plate 2, figures 10-12

*Pauciloculina antarctica* (Saidova) 1975. – MIKHALEVICH 1991, p. 29, fig. 2.

*Labrospira canariensis antarctica* SAIDOVA 1975, p. 77, pl. XIX, fig. 10.

*Alveolophragmium jeffreysii* UCHIO 1960, p. 5, 6 10 13.

*Cribrostomoides jeffreysii* KENNETT 1968, table 4. – ANDERSON 1975, p. 76, pl. 2, fig. 6. – MILAM and ANDERSON 1981, p. 304, pl. 2, fig. 8. – FINGER and LIPPS 1981, p. 120, pl. 1, fig. 15. – BERNHARD 1987, p. 290. – MACKENSEN et al. 1990, p. 249, 253, pl. IV, fig. 1. (non *Nonionina jeffreysii* Williamson 1858)

*Haplophragmoides canariensis* WIESNER 1931, p. 95, pl. 12, fig. 135, 136. – STSCHEDRINA 1979, p. 155. – ANDERSON 1975, p. 76, pl. 2, fig. 9. – OSTERMAN and KELLOG 1979, p. 255, 264. – MILAM and ANDERSON 1981, p. 304, pl. 2, fig. 7. – BERNHARD 1987, p. 290. – MACKENSEN et al. 1990, p. 252, 259, pl. VIII, fig. 3, 6. – ZAMPI et al. 1997, p. 367, fig 2A - F (non *Nonionina canariensis* d'Orbigny 1839)

**Remarks:** In his diagnosis of the genus *Haplophragmoides*, Cushman (1910) described its aperture as situated at the base of the septal face. However, the aperture has an areal position in *H. canariensis* d'Orbigny 1839, which he designated as the type species. This lack of correspondence gave rise to later taxonomic confusion. Subsequently, the genus *Labrospira* Hoeglund 1947, with the typical species *Haplophragmoides jeffreysii* Williamson 1858, was described as having an areal aperture. All species with a planospiral and involute test, simple wall and elevated aperture were later assigned to this genus. Alekseychik-Mickevich's (1973) investigations of *Haplophragmoides canariensis* tests from the British museum collections off Prince Edward Islands, as well as our own reviews of the species from the same British collections and from the tropical Atlantic in my own material (Mikhalevich 1983), as well as its comparison with *H. (Labrospira) jeffreysii* have revealed the presence of an areal aperture in all of them. Thus *H. jeffreysii*

becomes a synonym of *H. canariensis*, and *Labrospira* a synonym of *Haplophragmoides*. Similar species with an interiomarginal aperture at the base of the apertural face were assigned by Alekseychik-Mickevich (1973) to the new genus *Pauciloculina* with the type species *P. (Haplophragmoides) kirki* Wickenden 1932.

***Cribrostomoides antarcticus* Saidova**

Plate 5, figure 9

*Cribrostomoides antarcticus* SAIDOVA 1975, p. 78, pl. XX, fig. 5.

*C. subglobosus* G.O. Sars 1872. – FILLON 1974, p. 139. – ANDERSON 1975, p. 76, pl. 2, fig. 7. – STSCHEDRINA 1979, p. 153. – MILAM and ANDERSON 1981, p. 305, pl. 3, fig. 1. – MACKENSEN et al. 1990, p. 252, 253, pl. IV, fig. 7-9. (non *Lituola subglobosa* G.O. Sars 1872).

***Cyclammina orbicularis asellina* Rhumbler**

Plate 5, figures 10, 11

*Cyclammina orbicularis asellina* RHUMBLER 1931, p. 97, pl. XIII, fig. 150.

*Cyclammina orbicularis* Brady 1884. – UCHIO 1960, p. 6. – STSCHEDRINA 1979, p. 153. – KENNETT 1968, p. 39, table 4. – FILLON 1974, p. 139. – ANDERSON 1975, p. 76, pl. 2, fig. 13. – MACKENSEN et al. 1990, p. 248, 249. (non *C. orbicularis* Brady 1884).

***Cyclammina pusilla antarctica* Saidova 1975**

*C. pusilla antarctica* SAIDOVA 1975, p. 85, pl. XXIV, fig. 7.

*Cyclammina pusilla* Brady 1884. – WIESNER 1931, p. 97, pl. XIII, fig. 151. – KENNETT 1968, table 4. – FILLON 1974, p. 139. – STSCHEDRINA 1979, p. 153. – ANDERSON 1975, p. 76, pl. 2, fig. 14. – MACKENSEN et al. 1990, p. 248, 249, 259, pl. VIII, fig. 1, 2. (non *Cyclammina pusilla* Brady 1884).

***Conicotrochammina antarctica* Saidova**

*Conicotrochammina antarctica* SAIDOVA 1975, p. 105, pl. XCIX, fig. 6.

*Trochammina conica* EARLAND 1934, p. , pl. – FILLON 1974, p. 142. – ANDERSON 1975, p. 78, pl. 3, fig. 6. – MILAM and ANDERSON 1981, p. 305, pl. 3, fig. 5.

***Rotaliammina ochracea* (Williamson) 1858**

*Trochammina (Rotalia) ochracea* WILLIAMSON 1858, p. 191, text fig. 33 - 37. – WIESNER 1931, p. 112, pl. XVII, fig. 203. – FINGER and

**PLATE 1**

Species collected on the shelf. Scale bar = 100µm.

- 1-2 *Thurammina favosa* Flint *reticulata* Pearñey, 1, test view (×30); 2, part of the wall (×170), "Polarstern", 1996, Station 24.
- 3 *Thurammina protea* Earland (×30), "Polarstern", 1996, Station 24.
- 4 *Tholosina laevis* Rhumbler, "Polarstern", 1996, Station 26.
- 5-6 *Tholosina vesicularis* (Brady), 5, attached form (×20); 6, the lower detached part of another specimen (×60), "Polarstern", 1996, Station 24.

- 7-8 *Sorosphaera confusa* Brady, 7 (×30) "Polarstern", 1996, Station 2; 8, "Polarstern", 1996, Station 24.
- 9 *Psammophax consociata* Rhumbler (×10), "Polarstern", 1996, Station 2.
- 10-12 *Saccammina basispiculata* Mikhalevich, Pronina, and Nestell, 10, 11, test view (11 - shows the cyst around the aperture); 12, apertural view of another specimen, "Polarstern", 1996, Station 26.



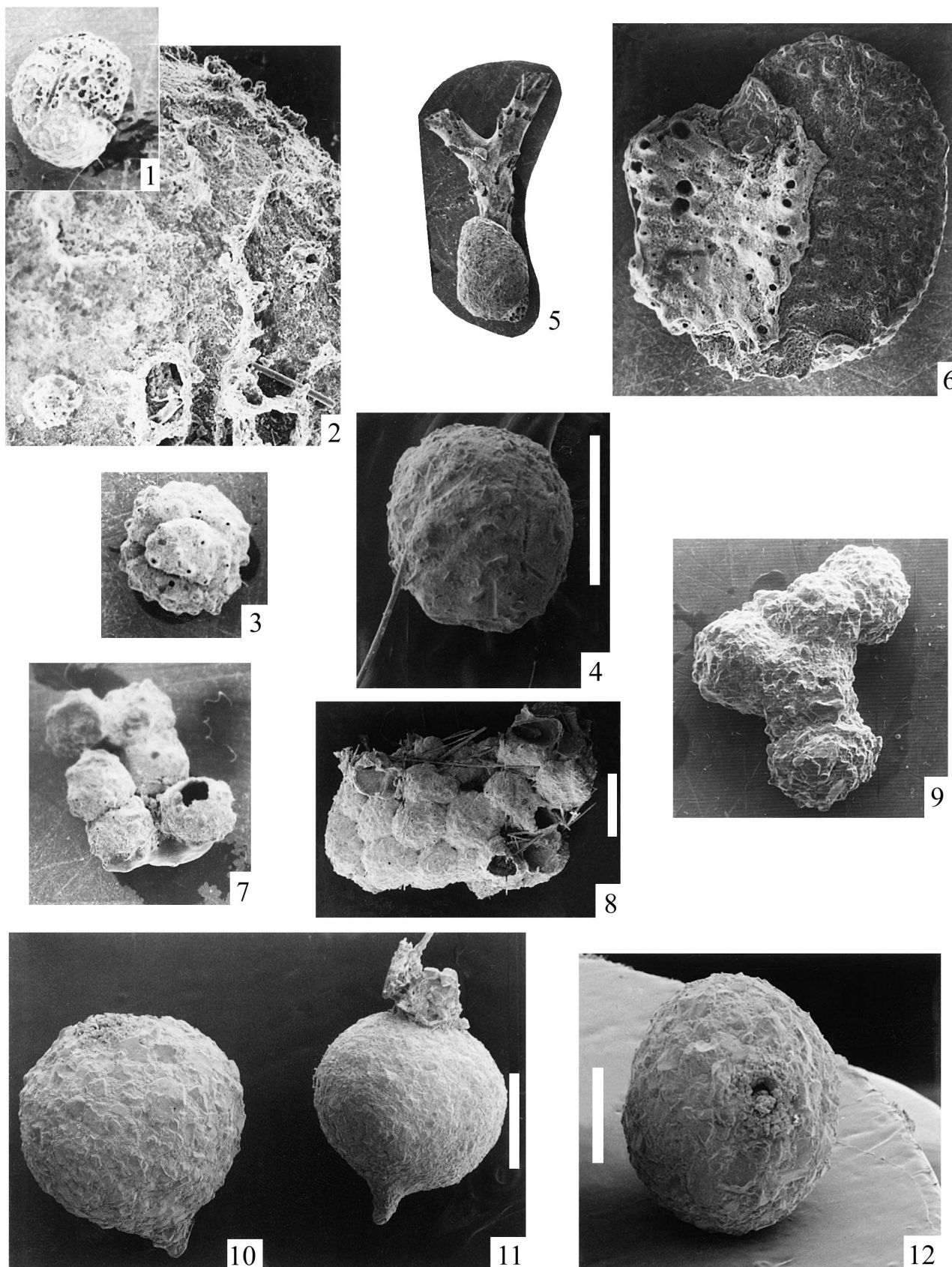


TABLE 1

Closely related species from Antarctic, North Atlantic, and other deep-water oceans.

<i>Rhabdammina antarctica</i>	<i>Rhabdammina abyssorum</i>
<i>Saccammina basispiculata</i>	<i>Saccammina sphaerica</i>
<i>Thurammina favosa reticulata</i>	<i>Thurammina favosa</i>
<i>Pseudonodosinella margaritaria margaritaria</i>	
<i>P. margaritaria elongata</i>	<i>Pseudonodosinella nodulosa</i>
<i>Reophax subfusiformis</i>	<i>Reophax fusiformis</i>
<i>Pauciloculina antarctica</i>	<i>Pauciloculina canariensis</i>
<i>Cribrostomoides antarcticus</i>	<i>Cribrostomoides subglobosum</i>
<i>Cyclammina orbicularis asellina</i>	<i>Cyclammina orbicularis</i>
<i>Cyclammina pusilla antarctica</i>	<i>Cyclammina pusilla</i>
<i>Vanhoeffenella foliacea</i>	<i>Vanhoeffenella cardioformis</i>
<i>Hormosinella distans antarctica</i>	<i>Hormosinella distans</i>
<i>Adercotryma glomerata antarctica</i>	<i>Adercotryma glomerata</i>
<i>Trochammina rossensis</i>	<i>Trochammina indica</i>
<i>T. Subglobigeriniformis</i>	<i>T. globigeriniformis</i>
<i>Trochammina wiesneri</i>	<i>Trochammina karica</i>

LIPPS 1981, p. 117, pl. 1, fig. 20. – BERNHARD 1987, p. 290. – MACKENSEN et al. 1990, p. 248.

***Planispirinoides antarcticus* Saidova**

*Planispirinoides antarcticus* SAIDOVA 1975, p. 157, pl. CII, fig. 3, 4.  
*Miliolina bucculenta* var. *placentiformis* BRADY 1884. – WIESNER 1931, p. 108, pl. XV, fig. 179, 180.

*Planispirinoides bucculentus* (Brady) 1884. – UCHIO 1960, p. 7. – FILLON 1974, p. 140, pl. 3, fig. 5, 6, 8. – MILAM and ANDERSON 1981, p. 323. (non *Planispirinoides* (*Miliolina*) *bucculentus* (Brady) 1884).

***Cibicides antarcticus* (Saidova)**

Plate 3, figure 10

*Lobatula antarctica* SAIDOVA 1975, p. 231, pl. CX, fig. 3.

*Cibicides antarcticus* (Saidova) 1975. – MIKHALEVICH 1991, p. 36, fig. 5.

*Cibicides lobatulus* UCHIO 1960, p. 9, 11, 13. – ANDERSON 1975, p. 92, pl. 10, fig. 4. – OSTERMAN and KELLOG 1979, p. 264, pl. 1, fig. 4, 5. – FINGER and LIPPS 1981, p. 120, pl. 3, fig. 2. – MACKENSEN et al. 1990, p. 248, 249.

*Cibicides* cf. *lobatulus* MILAM and ANDERSON 1981, p. 311, pl. 9, fig. 4. (non *Cibicides* (*Nautilus*) *lobatulus* (Walker and Jacob 1798).  
*Cibicides* sp. A FILLON 1974, p. 148, pl. 5, fig. 5 - 7.

***Anticleina biora* (Crespin)**

Plate 4, figures 5, 6

*Cassidulina biora* CRESPIN 1960, p. 28, 29, fig. 1-10, p. 30, pl. 3, fig. 11.

*Anticleina antarctica* SAIDOVA 1975, p. 331, pl. LXXXIX, fig. 14, pl. CXIV, fig. 5. – MIKHALEVICH 1991, p. 34, fig. 3.

*Cassidulina crassa* d'Orbigny 1839. – WIESNER 1931, p. 131, pl. XXI, fig. 259. – UCHIO 1960, p. 9 (non *Cassidulina crassa* d'Orbigny 1839).

*Globocassidulina crassa rossensis* KENNETT 1967, p. 134. – FILLON 1974, p. 140, pl. 1, fig. 1-7. – OSTERMAN and KELLOG 1979, p. 264, pl. 2, fig. 2. – MILAM and ANDERSON 1981, p. 312, pl. 10, fig. 1. – FINGER and LIPPS 1981, p. 136, pl. 4, fig. 5.

*Globocassidulina* sp. – FINGER and LIPPS 1981, p. 136, pl. 4, fig. 1-4.  
? *Globocassidulina. crassa* - MILAM and ANDERSON 1981, p. 323, 248. – MACKENSEN et al. 1990, p. 248.

*Globocassidulina biora* - KENNETT 1968, p. 42. – FILLON 1974, p. 139, 140, pl. 1, fig. 8-15. – OSTERMAN and KELLOG 1979, p. 264, pl. 2, fig. 1. – MACKENSEN et al. 1990, p. 249.

*Cassidulina subglobosa* - UCHIO, 1960, p. 9. – ANDERSON, 1975, p. 94, pl. 11, fig. 1 (non *Cassidulina subglobosa* Brady 1881).).

**Remarks:** As was shown by Nomura (1984), the age stages of *Anticleina* (*Globocassidulina*) *biora* were previously assigned to different species. The age stages of the formation of the aperture were also demonstrated by Finger and Lipps (1981), though assigned to different forms).

***Robertina chapmani* (Heron-Allen and Earland)**

Plate 4, figures 7, 8

*Bulimina chapmani* HERON -ALLEN and EARLAND 1922, p. 130, pl. IV, fig. 18 - 20. – UCHIO 1960, p. 9. – ANDERSON 1975, p. 86, pl. 7, fig. 22.

*Pseudobulimina chapmani* (Heron-Allen and Earland) 1922. – KENNETT 1968, table 4. – OSTERMAN and KELLOG 1979, p. 268.

*Robertina chapmani* (HERON-ALLEN and EARLAND 1922). – WIESNER 1931, p. 124, pl. xx, fig. 239.

The species of the genus *Pelosina* Brady 1979 reported from the Antarctic as foraminifers do not belong to this group at all, but to the Xenophiophoria (Mikhalevich and Voronova 1999).

**PLATE 2**

Species collected on the shelf. Scale bar = 100µm.

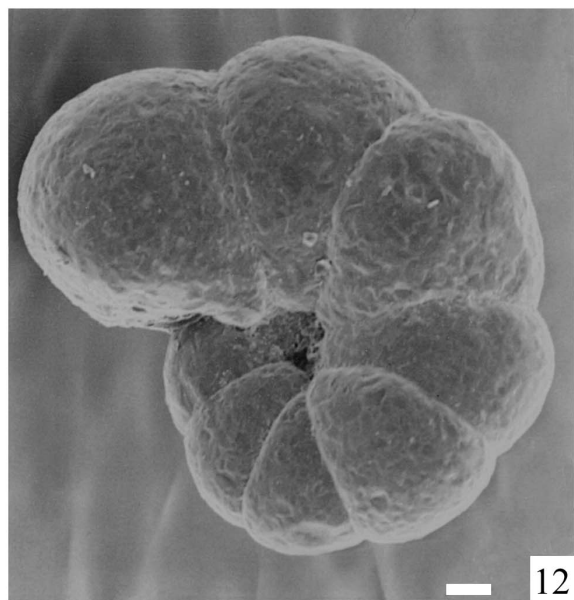
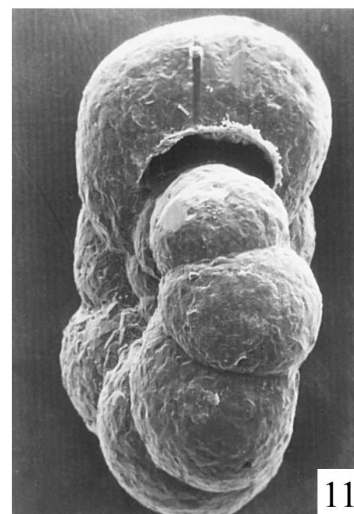
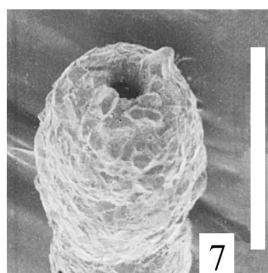
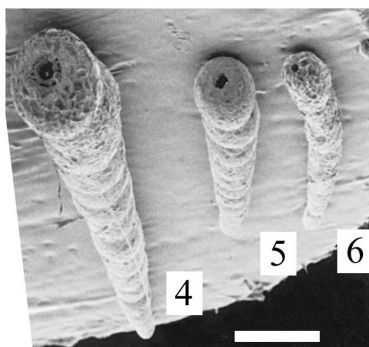
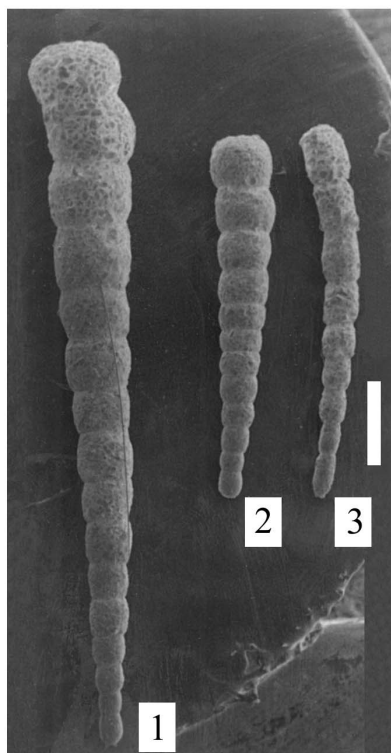
- 1-7 *Pseudonodosinella margaritaria* (Rhumbler) *margaritaria* Saidova, "Polarstern", 1996, Station 24; 1, 2, megalosphaeric; 3, microsphaeric specimens; 4, 5, 6, apertural view of the same specimens; 7, enlarged apertural view of the specimen 6.
- 8-9 *Reophax subfusiformis* Earland, 8, mi form; 9, ma form, "Polarstern", 1996, Station 24.
- 10-12 *Pauciloculina antarctica* (Saidova) (×150), 10, side view; 11, apertural view (×150), collected by diver A.

Pushkin, Mawson Sea, Fish Tail Bay, 12 – specimen from "Polarstern", 1996, Station 2.

- 13 *Cornuspira antarctica* Rhumbler, "Polarstern", 1996, Station 6.

- 14 *Cornuspiroides lacunosus* (Brady), "Polarstern", 1996, Station 14.





### Comparison with other regions

The separation of new Antarctic species and subspecies makes it possible to elucidate the high degree of endemism of the Antarctic foraminiferal fauna. With the separation of new Arctic specific and subspecific forms during the last decades, more and more species considered previously to be bipolar ones appear to be more restricted in their distribution. This observation is especially demonstrative in representatives with an arenaceous test wall. Nevertheless, some bipolar species still exist, although sometimes their North and South representatives differ in some morphological and textural features. The Antarctic forms often form pairs of closely related species with those from the North Atlantic or from deep water of the other oceans. Examples are given in Table 1.

In all of these cases we can surely speak of paired species. In some cases the comparison was based on literature descriptions because of insufficient Antarctic material at our disposal. However, for the pairs of species given in [Table 1, with the single exception of the possible pair *Adercotryma glomerata antarctica* — *A. glomerata*], a detailed investigation and comparison a detailed investigation and comparison of the Antarctic tests with the tests of closely related species of other oceans was made based on a study of our laboratory material.

*Sorosphaera confusa* occurs also in deep water of the North Atlantic (Kuhnt et al. 2000), but there it differs from the typical form (*S. cf. confusa*). The tubes of the Antarctic *Saccorhiza ramosa* are two times wider in diameter than in the typical form. *Psammophax consociata*, *Tholosina laevis*, *Nodosinum gaussicum* and *Haplophragmoides umbilicatum* are described from the Antarctic and could be considered as its typical representatives. Among 32 agglutinated species only for three of them, *Astrammmina rara*, *Hormosina globulifera* and *Psamosphaera parva* (the first two being deep-water species, the last one - eurybathyal), no differences were noticed between Antarctic forms and the forms recorded in different regions of the World Ocean. Nearly all agglutinated foraminiferal species living on the Antarctic shelf (excluding the eurybathyal ones) are

endemics (*Saccammina basispiculata*, *Psammophax consociata*, *Tholosina laevis*, *Thurammmina favosa reticulata*, *Pseudonodosinella margaritaria margaritaria*, *Pauciloculina antarctica* and others), and not only the shelf species but many of the deep-water species are also (*Rhabdammina antarctica*, *Nodosinum gaussicum*, *Pseudonodosinella margaritaria elongata*, *Cribrostomoides antarcticus*, *Cyclammmina orbicularis asellina*). The adaptation of species and subspecies of the genus *Pseudonodosinella* to the shelf and bathyal Antarctic zones was mentioned above.

### CONCLUSIONS

The composition of the foraminiferal assemblages is influenced by many factors of water characteristics such as temperature, salinity, nutrient composition, availability of carbonate and variations in CCD, presence of near-bottom flows. The changes of water masses at different depths or mixing of the different water masses are clearly seen in the changes of the foraminiferal species composition. In some cases the local variations of water characteristics, seasonality and ice melting are also responsible for the foraminiferal distribution. Species characteristic for the shelf and the upper slope were differentiated, the majority of them being circumantarctic. The abundance of species achieves two maximums at depths of 180-300m and 1500-2300m. At depths of 500 and even 700m, both arenaceous and calcareous forms, especially miliolids, are abundant. Some living calcareous forms were also encountered below this boundary, though arenaceous ones prevailed.

Some unique features of the bottom Antarctic foraminiferal fauna as a whole are:

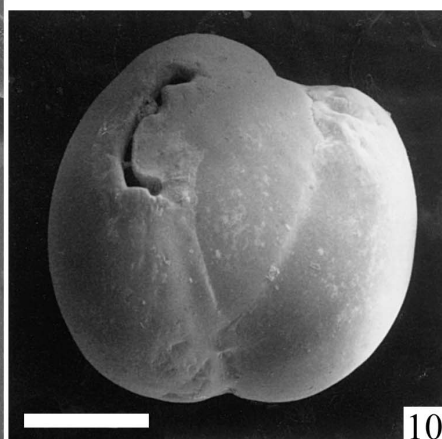
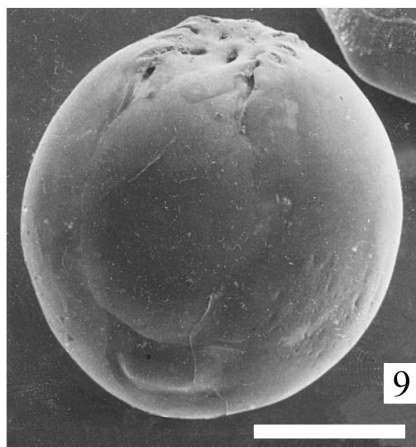
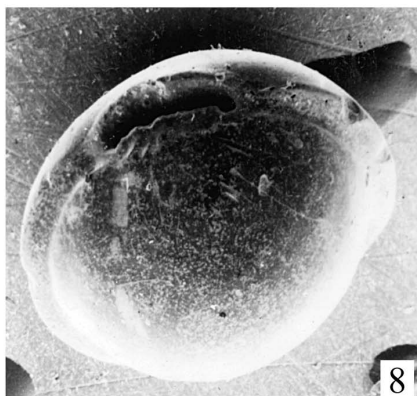
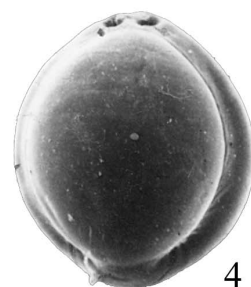
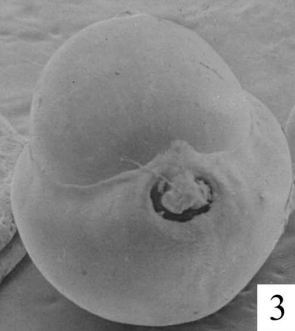
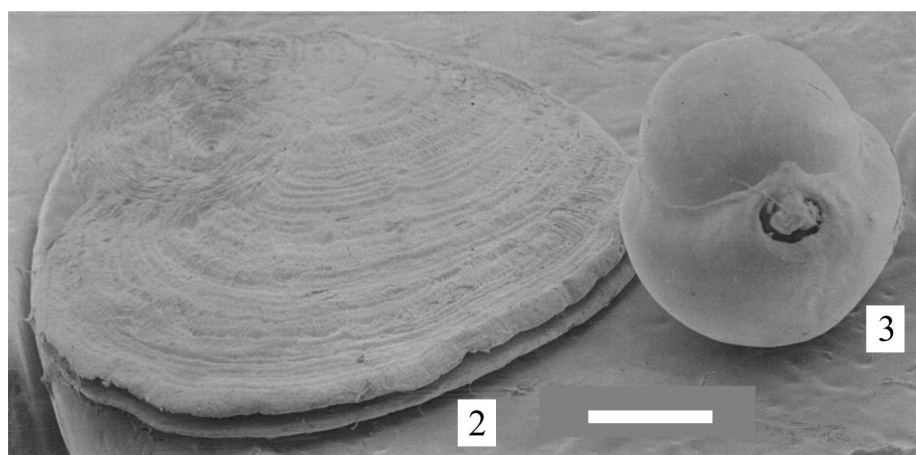
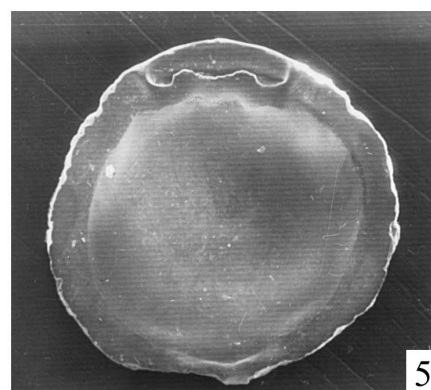
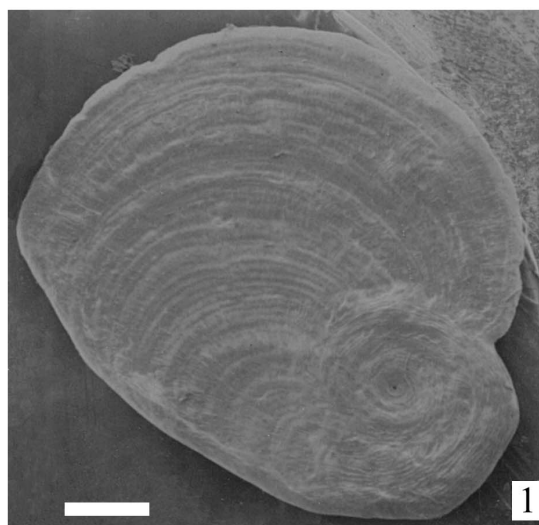
1. The high degree of endemism, which reaches 35.7% and is significant not only in the shelf communities, but even in communities of the bathyal zone. For the shelf depth of 2-50m endemism achieves sometimes as much as 80%. It can be 24% even in such a plastic group as the miliolids with a large number of eurybathyal species.
2. Gigantism of many species.
3. The wide bathymetric range of vertical distribution of many species.
4. Distinct bathymetric boundaries of the foraminiferal fauna of

### PLATE 3

Species collected on the shelf. Scale bar = 100µm.

- |   |   |
|---|---|
| 1 <i>Cornuspiroides expansus</i> Chapman, "Polarstern", 1996, Station 2.  | 6-7 <i>Pyrgo patagonicum</i> (d'Orbigny) (×15), "Polarstern", 1996, Station 24.   |
| 2 <i>Cornuspiroides expansus</i> Chapman (apertural view), "Polarstern", 1996, Station 2. 3. <i>Pyrgo peruvianum</i> (d'Orbigny) (apertural view), "Polarstern", 1996, Station 1. | 8 <i>Pyrgo sarsii</i> (Schlumberger) (×15), "Polarstern", 1996, Station 2.  |
| 4 <i>Pyrgo peruvianum</i> (d'Orbigny) (×20), "Polarstern", 1996, Station 9.   | 9 <i>Pyrgoella sphaera</i> (d'Orbigny) (×15), "Polarstern", 1996, Station 5 (eurybathyal, occurs also in the deep water). |
| 5 <i>Pyrgo depressus</i> (d'Orbigny) (×100), (eurybathyal), collected by diver A. Pushkin, Mawson Sea, Fish Tail Bay.   | 10 <i>Planispirinoides antarcticus</i> Saidova (×15), "Polarstern", 1996, Station 1.                                      |







the shelf, of the slope, and of the bathyal zone. 5. The abundance of circumantarctic species on the shelf and the slope. 6. The increase of faunal differences from the shelf to the deeper levels. 7. The introduction of deep-water species known from other oceans onto the shelf and the upper part of the bathyal zone. 8. The heterogeneity of the bottom communities. 9. The high patchiness of the species distribution, especially in the shelf zone and its upper part, and at the same time the uniformity and repetitiveness of the bottom biotopes all around the Antarctic continent. 10. The abundance of a number of species of one genus, (e.g., genus *Pseudonodosinella*). 11. The abundance (and often predominance) of agglutinated forms compared to calcareous ones, which is determined by the low water temperatures and low carbonate content under saturation of the water by  $\text{CaCO}_3$ .

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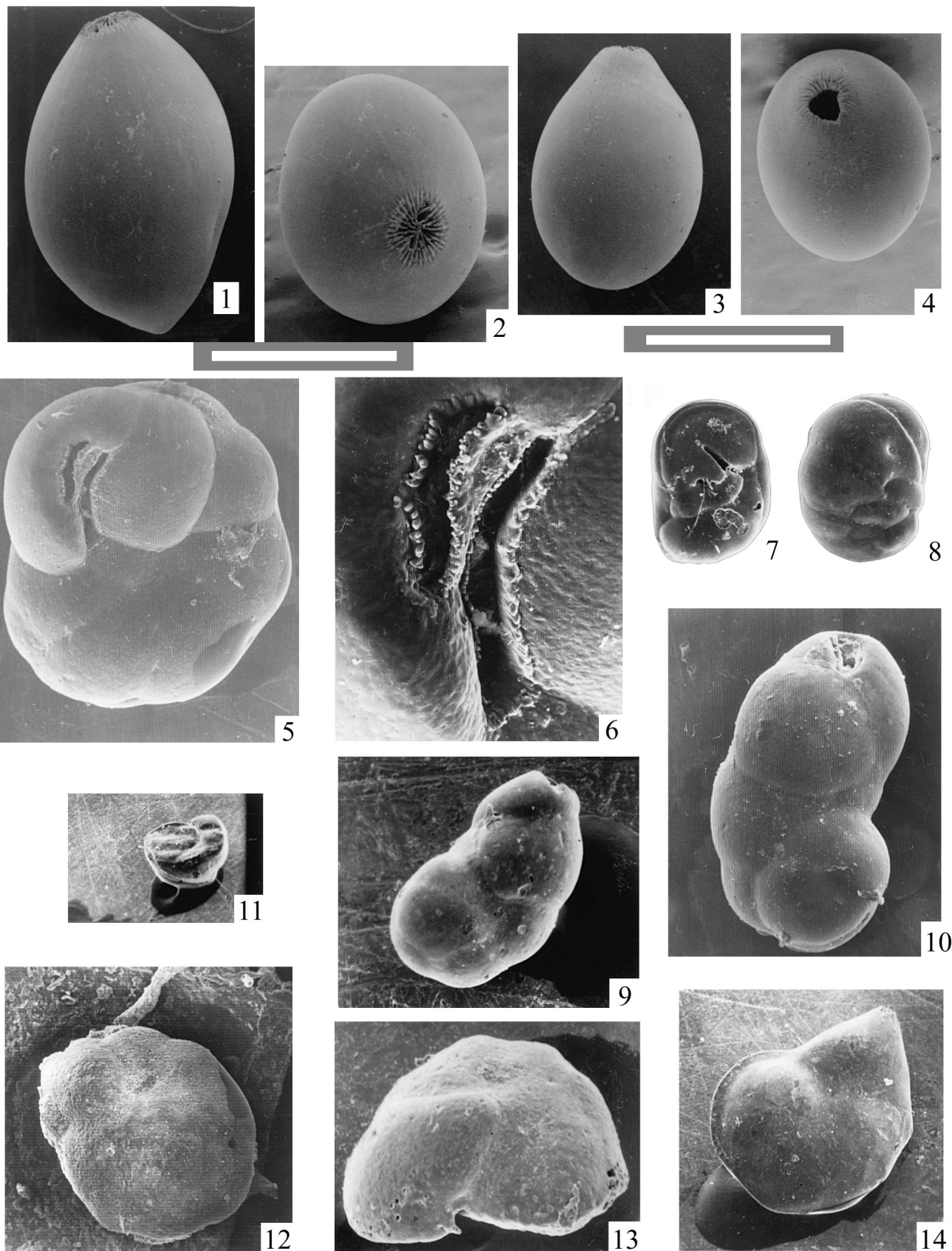
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## PLATE 4

Species collected on the shelf. Scale bar = 100µm.

- |   |  |
|---|--|
| <p>1-4 <i>Glandulina antarctica</i> Parr, 1, 2 - (microsphaeric form), side and apertural view, "Polarstern", 1996, Station 14; 3, 4 - (megalosphaeric form), side and apertural view, collected by diver A. Pushkin, Mawson Sea, Fish Tail Bay.</p> <p>5-6 <i>Anticleina biora</i> Crespin, 5, apertural view (×200); 6, double aperture (×600); collected by diver A. Pushkin, Mawson Sea, Fish Tail Bay.</p> <p>7-8 <i>Robertina chapmani</i> Heron-Allen and Earland (×80), 7, apertural view; 8, side view, "Polarstern", 1996, Station 2.</p> | <p>9-10 <i>Cassidulinoides parkerianus</i> (Brady), 9 - (×200), "Polarstern", Station 5; 10 - (×250), collected by diver A. Pushkin, Mawson Sea, Fish Tail Bay.</p> <p>11-12 <i>Cibicides antarcticus</i> (Saidova), 11 - (×24), "Polarstern", Station 12; 12, (×120) (attached, with the arenaceous tubes of the cyst) collected by diver A. Pushkin, Mawson Sea, Fish Tail Bay.</p> <p>13 <i>Cibicides refulgens</i> Montfort (×70), "Polarstern", 1996, Station 24.</p> <p>14 <i>Lenticulina antarctica</i> Parr (×35), "Polarstern", 1996, Station 24.</p> |
|---|--|



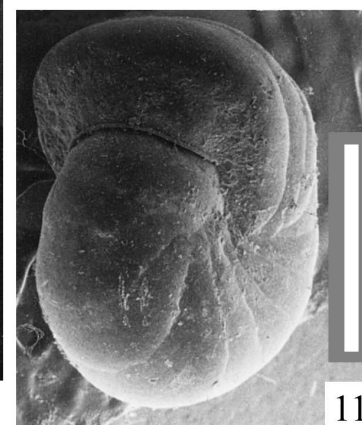
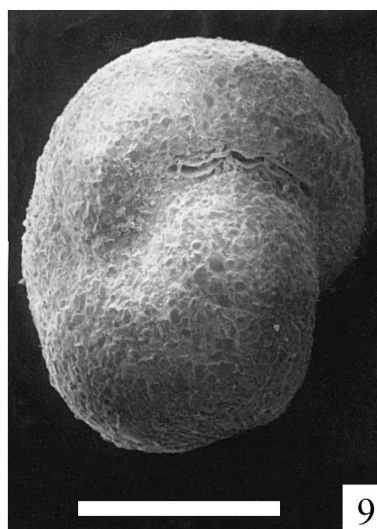
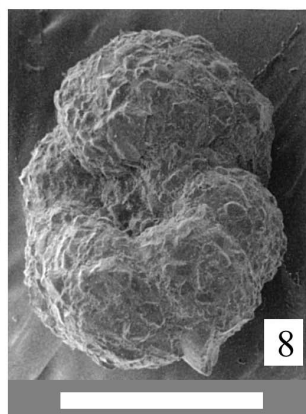
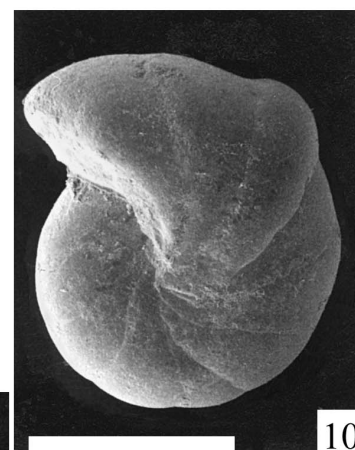
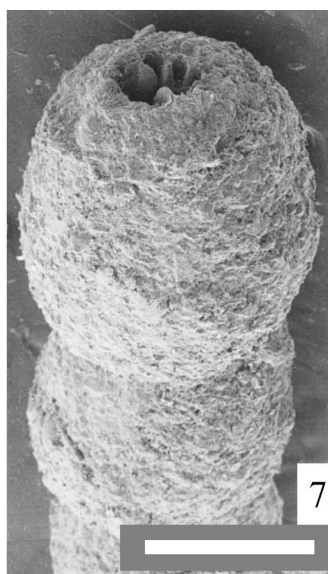
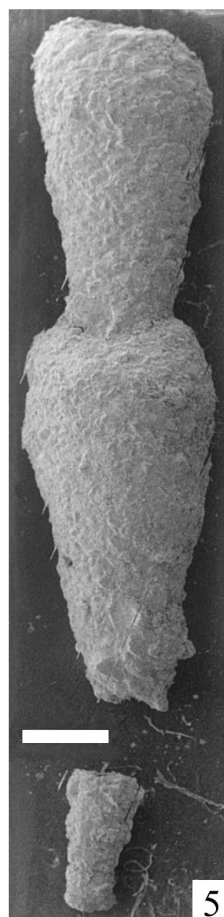
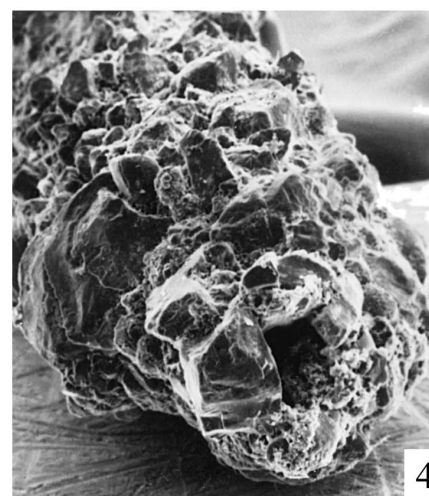
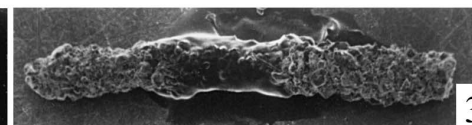
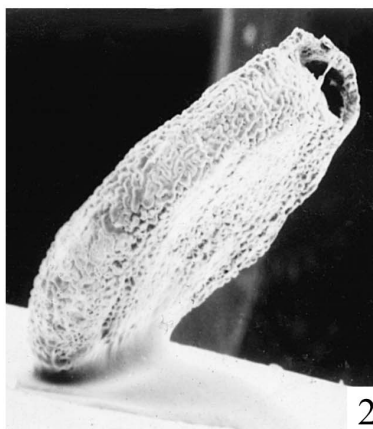
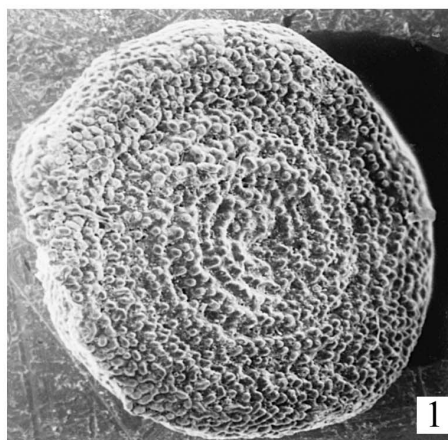
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## PLATE 5

Species collected on the shelf (1, 2) and at the upper part of the bathyal zone (3-11). Scale bar = 100µm.

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| <p>1-2 <i>Spirillina plana</i> Wiesner (×70), "Polarstern", 1996, Station 24; 1, side view; 2, peripheral view.</p> <p>3-4 <i>Rhabdammina antarctica</i> Saidova, 3, test view (×10), 4, apertural view (×150) "Polarstern", 1996, Station 18.</p> <p>5 <i>Pseudonodosinella margaritaria</i> (Rhumbler) <i>elongata</i> Saidova, "Polarstern", 1996, Station 24.</p> <p>6-7 <i>Nodosinum gaussicum</i> (Rhumbler), 6, test view; 7, apertural view, "Polarstern", 1996, Station 30.</p> | <p>8 <i>Haplophragmoides umbilicatum</i> Pearcey, "Polarstern", 1996, Station 30.</p> <p>9 <i>Cribrostomoides antarcticus</i> Saidova, "Polarstern", 1996, Station 30.</p> <p>10-11 <i>Cyclammina orbicularis</i> Brady <i>asellina</i> Rhumbler, 10, side view, 11, apertural view of another specimen, "Polarstern", 1996, Station 30.</p> |
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