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# Benthic foraminiferal communities: distribution and ecology in Admiralty Bay, King George Island, West Antarctica

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**Abstract:** During the austral summer of 2002/2003 the author collected 38 marine and/or glacio-marine sediment samples from Admiralty Bay on King George Island (South Shetland Islands, West Antarctica). Recent "living" (Rose Bengal stained) and "dead" (subfossil) benthic foraminifera represented by 105 species belonging to 65 genera are recognized in samples from water depths of up to 520 m. They show large spatial variability. Four distinctive foraminiferal zones within the fjord of Admiralty Bay were recognized and analyzed in terms of environmental conditions. The zones are: restricted coves, open inlets, intermediate-, and deep-waters. The major environmental factors, which dictate foraminiferal distribution, are closely related to bathymetry and distance to open sea. Sediment composition and chlorophyll content appear to have minor influence on foraminiferal communities. Most diverse, deep-water faunas dominate water-depths below 200 m, which seems to be the lowest limit of atmospheric and meltwater influence. In waters shallower than 200 m, environmental features, affecting distribution of various benthic foraminiferal assemblages, appear to be sedimentation rate and hydrographic isolation. The results of this study gives promise to use the Admiralty Bay foraminiferal distribution pattern as a paleoenvironmental tool for shallow- to intermediate-water Quaternary marine research in fjord settings of the South Shetland Islands.

Key words: Antarctica, South Shetlands, Foraminifera, Recent.

## Introduction

Although the Recent Antarctic foraminifera research was initiated in XIX century, it flourished in the early part of the XX century (Mikhalevich 2004) and has been intensively carried on ever since, most recently by Fillon (1974), Anderson (1975), Osterman and Kellogg (1979), Ward and Webb (1986), Bernhard (1987), Ward *et al.* (1987), Mackensen *et al.* (1990), Ishman and Domack (1994), Violanti (1996), Mayer and Spindler (2000), Igarashi *et al.* (2001), and Mikhalevich (2004). Some work was also carried out in South Shetland Islands (Finger and

Lipps 1981; Li and Zhang 1986; Ishman and Domack 1994; Zhang 1994; Chang and Yoon 1995; Mayer 2000; Gaździcki and Majewski 2003).

## Setting

Admiralty Bay is the largest fjord-like bay in the South Shetland Islands (Fig. 1). Its total area is ~122 km$^2$, whereas total volume is over 24 km$^3$ (Robakiewicz and Rakusa-Suszczewski 1999). This fjord is composed of a >500 m deep main channel, which is wide-open to Bransfield Strait, and splits into three major inlets with water depths down to 100–200 m (see Battke 1990). The inlets are MacKellar and Martel to the north and Ezcurra to the west. Less than half of Admiralty Bay shore line is occupied by water-tide glaciers and ice falls, that have been retreating for at least the last few decades (Braun and Gossmann 2002). The bay's spectacular and diverse coastal and submarine morphology resulted from glacial processes, which took place mainly during the Pleistocene (Marsz 1983; Birkenmajer and Marsz 1999).

Within the bay, water temperatures and salinities are quite uniform both spatially and bathymetrically, which allows intense vertical water mixing (Szafrański and Lipski 1982; Lipski 1987). However during summer, the upper 15–35 m water-layer is a mixture of sea- and melt-waters (Sarukhanyan and Tokarczyk 1988). This upper water layer is characterized by strong, local variations in salinity (16–34‰) and temperature (–1.6–3°C) (Szafrański and Lipski 1982). The upper waters exhibit elevated oxygen (8 *vs.* 6 ml/l near the bottom) and reduced nutrient content (Samp 1980; Lipski 1987; Sarukhanyan and Tokarczyk 1988). Seasonal melt-water streams carry also large quantities of suspended mineral material (Pęcherzewski 1980), that is rapidly deposited when it reaches the bay. Winter freezing of Admiralty Bay is extremely variable (Kruszewski 2002). The bay freezes in 2 for every 3 years for up to 3 months. Its better sheltered inlets are frozen for considerably longer periods than the main channel.

Prevailing winds of WSW and NWN direction are the main forces driving water circulation. They push surface waters out to the open sea. The water budget is balanced by inflow of the uniform deep water from Bransfield Strait, predominantly along its SW margin (Pruszak 1980; Robakiewicz and Rakusa-Suszczewski 1999). A significant structural upwelling takes place over the submarine escarpment, intersecting Ezcurra Inlet near Point Thomas (Rakusa-Suszczewski 1980).

The lower limit of euphotic zone was estimated by Lipski (1987) at 15–45 m, with highest water transparency in the middle of the bay. However, macroalgal occurrences down to 90 m (Zieliński 1990) suggest deeper light penetration. Nutrient levels are high in the Admiralty Bay and they are not considered a limiting factor for primary production (Samp 1980; Lipski 1987). As compared with other Antarctic embayments, chlorophyll contents in Admiralty Bay are ten- to two-fold lower, suggesting reduced phytoplankton levels probably due to intense vertical mixing and water exchange with Bransfield Strait (Lipski 1987; Kopczyńska 1993).

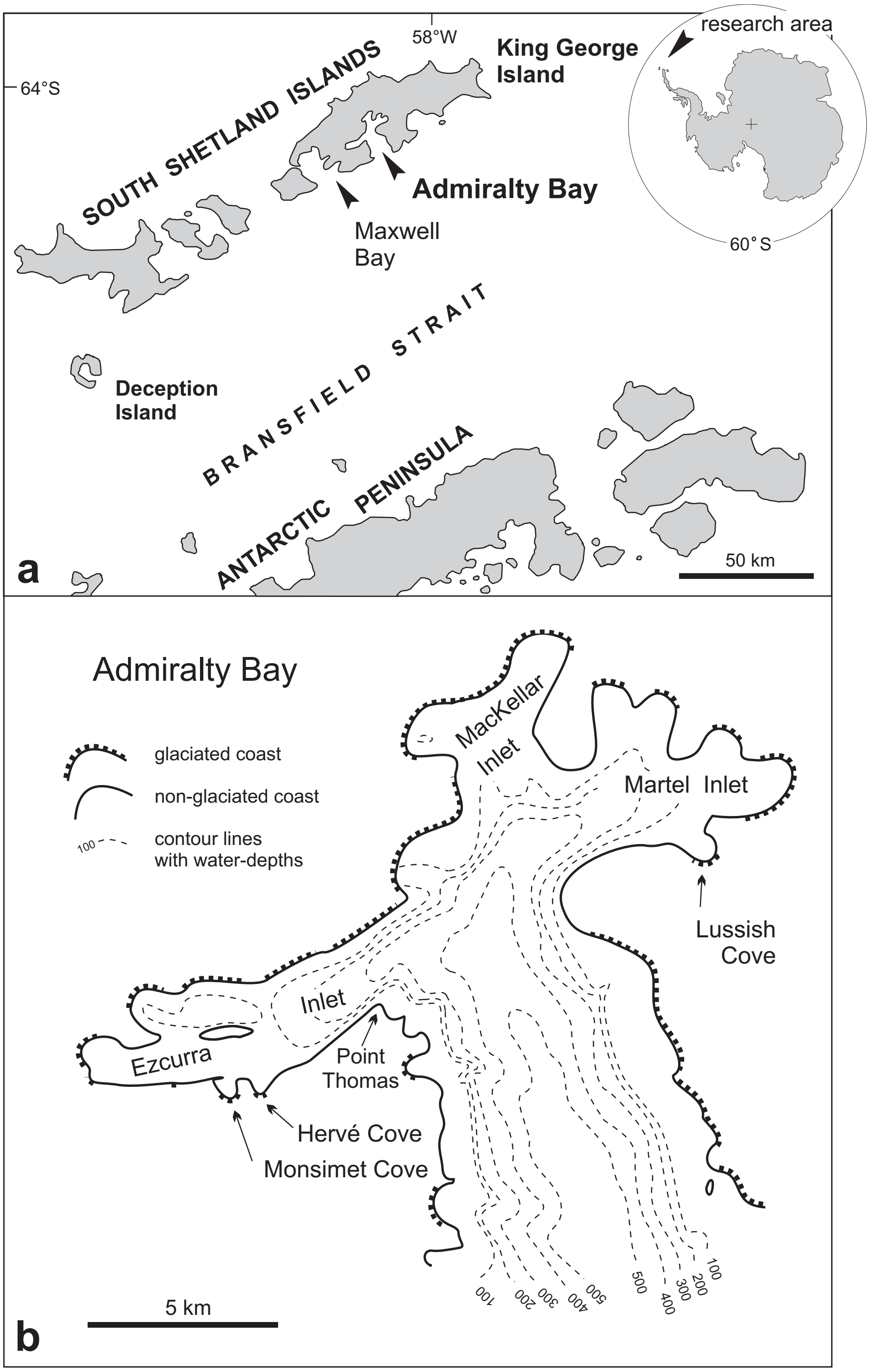


Fig. 1. Maps showing: (**a**) location of the area of research, (**b**) Admiralty Bay coastal types and batymetry.

Admiralty Bay of King George Island attracted considerable scientific attention from various nations over several decades. It has assumed a prominent place in the history of the Polish Antarctic research, being a natural research ground for 28 year-long Polish Antarctic expeditions to *Arctowski* Station. Despite broad ecological and biological studies (Rakusa-Suszczewski 1993), foraminiferal research in this area was rather random (Ishman and Domack 1994; Gaździcki and Majewski 2003). The present investigation rectifies this lack of attention.

## Methods

During the 27th Polish Antarctic Expedition to *Arctowski* Station, between November 30th 2002 and April 18th 2003, 38 short (up to 15 cm) undisturbed sediment cores were collected using a tube-sampler of 7 cm in diameter. The sampling stations were distributed throughout Admiralty Bay. Their water-depths ranged from 8 to 520 m (Table 1).

Immediately after sampling, sediment cores were sliced into ten 1 cm thick sections. Sediment was washed with sea water over a 125 µm sieve. The residue was stained with Rose Bengal (1g/l) and 70% ethanol diluted in sea water. A day after, the stained residue was washed in tap water and dried. In most subsamples, all "living" (stained) and "dead" foraminifera and ostracods (Majewski and Olempska 2005) were picked. Faunally-rich samples were divided using a dry microsplitter. All specimens were arranged by taxa on micropaleontological slides. The classification scheme of the Order Foraminiferida used here is that of Loeblich and Tappan (1988). All taxa recognized are listed in Appendix A. Their images are on Figs 9–26. The investigated foraminifer collection is housed at the Institute of Paleobiology of the Polish Academy of Sciences (Warszawa) under the catalogue number ZPAL F.45.

For presenting the datasets credibility, actual numbers of counted foraminiferal specimens (N) are indicated among results. Major taxa percentages, total faunal abundances (numbers of all foraminifera per 10 cm$^2$ of the sediment surface from the upper 10 cm of sediment), living-to-dead foraminiferal ratios, percentages of agglutinated forms, numbers of species (S), and Margalef's species richness are also presented. The species richness (d) was calculated according to the equation

$$d = (S-1)/\mathrm{Log}(N) ,$$

where N is a total number of foraminiferal specimens, and S is a number of foraminiferal species recorded at the analyzed station.

For better understanding of foraminiferal assemblages, the Principal Component statistical analysis was applied to "living" and "dead" data sets separately.

Table 1

List of stations and their environmental parameters

| Station number | Station location | | Water depth (m) | Distance to open sea (km) | Absorption per gram | Sediment mean size | Sediment sorting coefficient |
|---|---|---|---|---|---|---|---|
| 1 | Hervé Cove | | 8 | 11.8 | ? | ? | ? |
| 2 | Lussish Cove | | 20 | 14.3 | ? | 5.07 | 1.69 |
| 3 | 62°07.51'S | 58°25.60'W | 470 | 10.0 | 0.866 | 4.43 | 1.58 |
| 4 | 62°05.23'S | 58°29.25'W | 88 | 14.9 | 1.030 | 4.66 | 2.12 |
| 5 | 62°05.26'S | 58°28.30'W | 50 | 14.2 | 0.161 | 4.46 | 1.75 |
| 6 | 62°05.89'S | 58°26.57'W | 102 | 12.9 | 0.349 | 4.43 | 1.97 |
| 7 | 62°07.06'S | 58°28.27'W | 165 | 11.2 | ? | 4.57 | 1.73 |
| 8 | 62°08.71'S | 58°29.45'W | 290 | 9.0 | 0.342 | ? | ? |
| 9 | 62°10.30'S | 58°32.70'W | 57 | 12.2 | 0.261 | 4.63 | 1.95 |
| 10 | 62°10.80'S | 58°33.09'W | 8 | 12.7 | 0.892 | 4.27 | 1.69 |
| 11 | 62°10.50'S | 58°34.70'W | 63 | 13.8 | 0.359 | 4.97 | 1.96 |
| 12 | 62°10.65'S | 58°35.94'W | 74 | 15.2 | 0.259 | 2.97 | 3.25 |
| 13 | 62°10.76'S | 58°37.62'W | 47 | 16.2 | 0.145 | 4.75 | 2.18 |
| 14 | 62°10.39'S | 58°35.84'W | 19 | 14.8 | 0.472 | 4.41 | 2.24 |
| 15 | 62°10.18'S | 58°35.00'W | 49 | 14.0 | 0.312 | 2.97 | 3.15 |
| 16 | 62°10.03'S | 58°35.49'W | 84 | 14.2 | 0.279 | 5.14 | 1.55 |
| 17 | 62°09.87'S | 58°34.53'W | 103 | 13.8 | 0.213 | 4.20 | 2.39 |
| 18 | 62°09.55'S | 58°33.50'W | 123 | 12.5 | 0.436 | 3.21 | 3.09 |
| 19 | 62°04.27'S | 58°23.32'W | 83 | 15.7 | 0.376 | 3.94 | 2.60 |
| 20 | 62°04.41'S | 58°22.02'W | 34 | 15.6 | 0.241 | 4.66 | 2.32 |
| 21 | 62°04.55'S | 58°22.66'W | 39 | 15.5 | 0.616 | 5.03 | 1.71 |
| 22 | 62°05.06'S | 58°21.68'W | 51 | 15.0 | 0.347 | 4.32 | 2.58 |
| 23 | 62°05.33'S | 58°19.74'W | 68 | 15.3 | 0.372 | 5.05 | 1.96 |
| 24 | 62°04.72'S | 58°19.71'W | 87 | 16.2 | 0.271 | 5.07 | 1.74 |
| 25 | 62°04.99'S | 58°17.99'W | 90 | 16.7 | 0.148 | 5.07 | 1.74 |
| 26 | 62°05.89'S | 58°22.01'W | 220 | 13.2 | 0.301 | 5.05 | 1.88 |
| 27 | 62°05.39'S | 58°23.59'W | 20 | 13.3 | 0.157 | 2.00 | 2.59 |
| 28 | 62°06.30'S | 58°24.88'W | 294 | 11.3 | 0.565 | 4.62 | 2.33 |
| 29 | 62°07.04'S | 58°26.73'W | 370 | 11.1 | ? | 4.28 | 2.16 |
| 30 | 62°07.12'S | 58°27.77'W | 95 | 11.0 | 0.220 | 3.39 | 2.57 |
| 31 | 62°08.18'S | 58°23.05'W | 48 | 8.1 | 0.552 | 4.29 | 1.37 |
| 32 | 62°10.28'S | 58°22.12'W | 450 | 4.0 | 0.716 | 5.11 | 1.64 |
| 33 | 62°12.35'S | 58°24.14'W | 86 | 0.3 | 0.948 | 3.88 | 2.08 |
| 34 | 62°12.11'S | 58°23.50'W | 292 | 0.5 | ? | 4.00 | 1.95 |
| 35 | 62°09.96'S | 58°26.13'W | 220 | 5.5 | ? | 3.09 | 2.84 |
| 36 | 62°09.55'S | 58°25.73'W | 480 | 5.8 | 0.266 | 4.18 | 2.12 |
| 37 | 62°09.20'S | 58°24.59'W | 510 | 6.2 | 0.232 | 4.54 | 2.14 |
| 38 | 62°11.04'S | 58°23.26'W | 520 | 2.2 | 0.292 | 4.50 | 1.67 |

Raw and statistically treated foraminiferal results were compared with environmental data by calculation of Pearson's *r* correlation coefficients.

At 32 stations a few grams of surface-sediment were taken for chlorophyll content. These analyses were conducted at *Arctowski* Station laboratory on SPEKOL 1100, Quantitative Analysis Version 3.2. Standard grain-size analysis of sediment was conducted at 36 stations on >63 μm fractions. Mean grain size (M) and graphic standard deviation (σ), understood as sorting coefficient, were calculated according to the following equations:

$$M = (\Phi 16 + \Phi 50 + \Phi 84)/3$$

$$\sigma = (\Phi 84 + \Phi 16)/4 + (\Phi 95 + \Phi 5)/6.6\ ,$$

where Φn are grain sizes for different percentages taken from cumulative curves calculated for various stations.

**Rose Bengal staining**. — This method allows differentiation between "living" and "dead" foraminifera (Walton 1952). In this study, "living" foraminifera were identified among transparent calcareous foraminifera, porcellaneous, as well as among multi-chamber (polythalamous) agglutinated species thanks to nondestructive observations. The criterion used to distinguish "living" specimens among polythalamous transparent or semitransparent calcareous and agglutinated species was the presence of brightly red or violet coloration fully filling at least the last chamber (see also Corliss 1991; Silva *et al.* 1996). Special attention was given to exclude specimens in which colorization was due to secondary changes and those with only inner-chamber colorization. Porcellaneous "living" foraminifera were identified by a presence of darkly-stained "tongue" of protoplasm spilling out through the test opening.

In case of one-chamber (monothalanous) agglutinated taxa as well as *Miliamina arenacea* the staining technique failed due to the overwhelming presence of secondarily stained specimens. As the result, all specimens belonging to these taxa were included into the "dead" foraminiferal dataset.

## Results

**Foraminiferal results**. — At all stations, 3735 "living" and 55254 "dead" foraminifera were recognized. They represent 105 taxa at the species level, belonging to 65 genera (see Appendix A and Figs 9–26). Only 12 out of 379 sub-samples revealed no specimens. Summary counts for the 38 stations of "living" (Rose Bengal stained) and "dead" foraminifera are presented on Appendices B and C. They show percentages of species prepared for the Principal Component statistical analysis. For the data selection methods refer to the Principal Component Analysis section. "Dead" and "living", or total fauna abundances (numbers of specimens per 10 $cm^2$ of the sediment surface from the 0–10 cm core interval) of

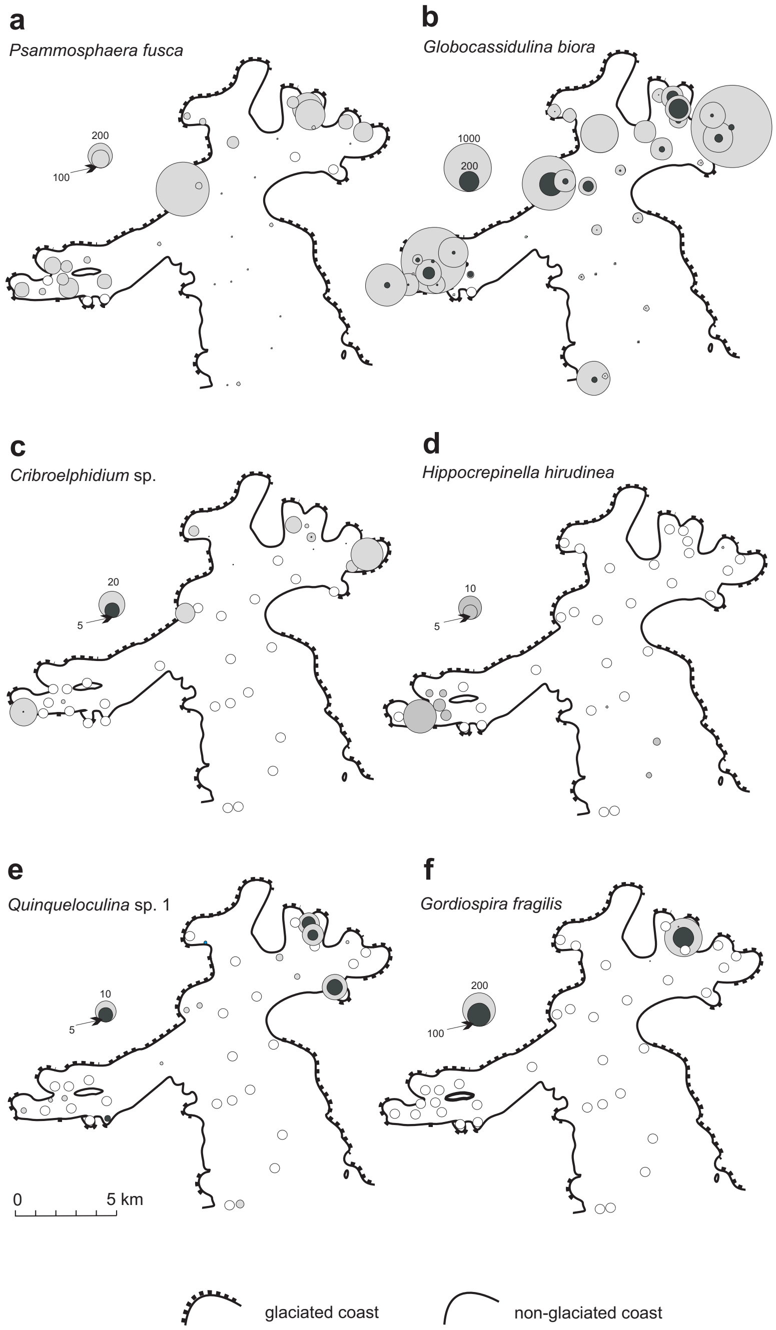


Fig. 2. Distribution maps of selected near-shore species. Number of specimens of particular taxa per 10 cm$^2$ of sediment in the upper 10 cm of sediment are expressed by circle surface. Where two gray shadows are marked, the dark indicates "living" standing stock; whereas, the bright "dead" abundance. Where one color is used, it expresses undivided total abundances. White circles indicate no specimens of particular taxon at the station. See Fig. 5b for station numbers, bathymetric contours, and coast types.

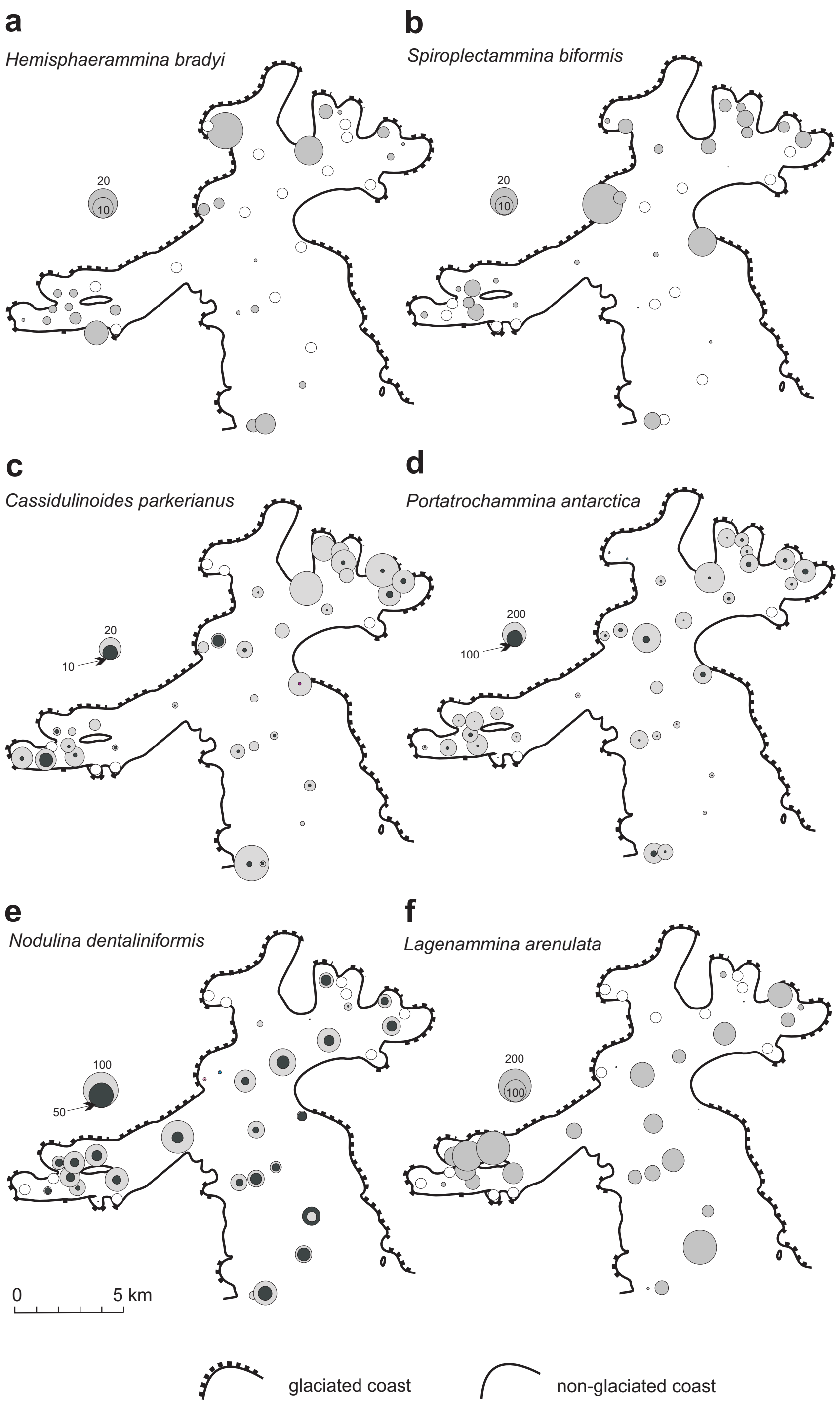


Fig. 3. Distribution maps of selected near-shore and cosmopolitan species. See Fig. 2 for scale explanation, Fig. 5b for station numbers, bathymetric contours, and coast types.

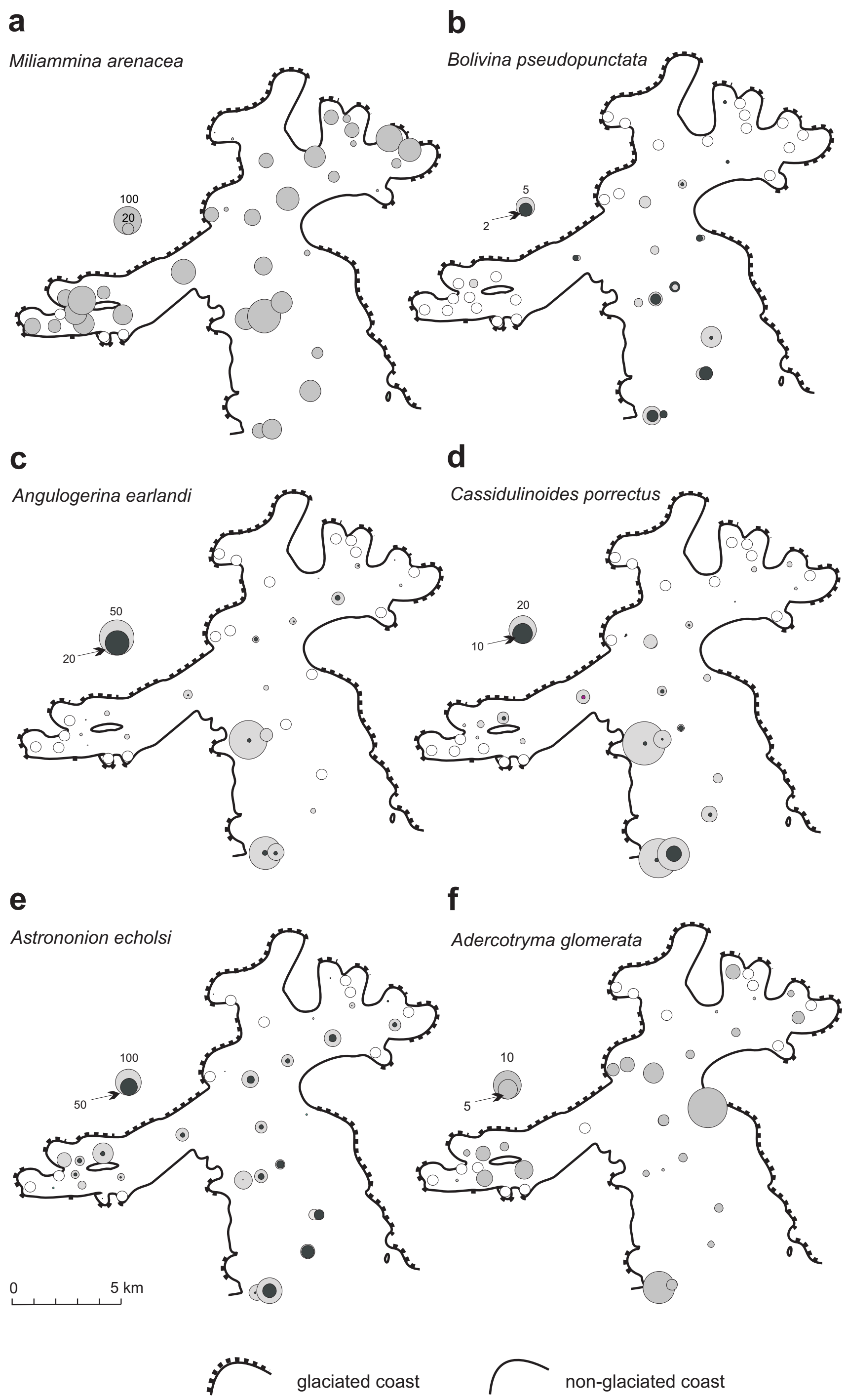


Fig. 4. Distribution maps of selected cosmopolitan and deep-water species. See Fig. 2 for scale explanation, Fig. 5b for station numbers, bathymetric contours, and coast types.

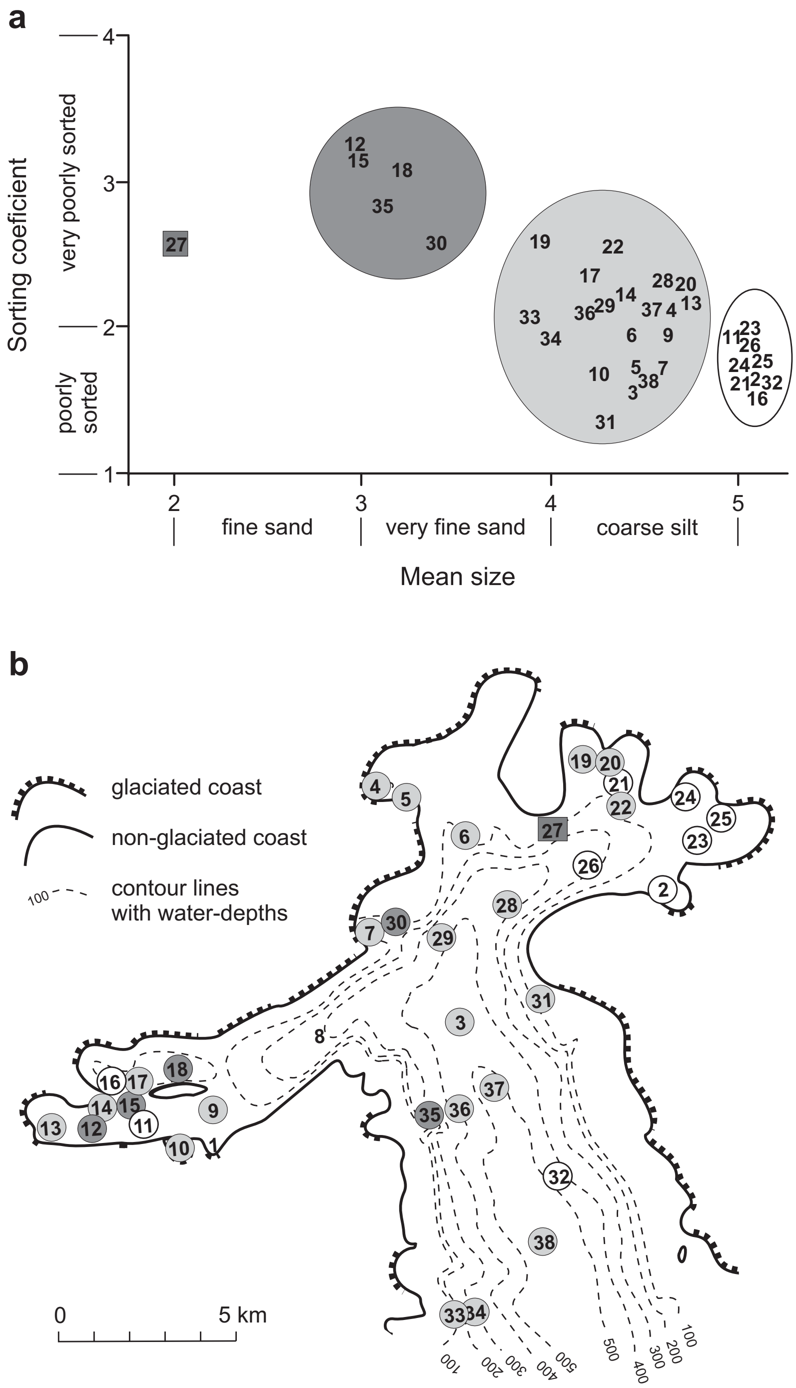


Fig. 5. Results of grain-size analysis: (**a**) sediment mean size *vs.* sorting coefficient plot with three clusters of values marked by different shades of gray, (**b**) map showing distribution of sediment samples grouped in the three clusters and marked by the same shades of gray as on (a).

the prominent taxa are plotted on Figs 2–4. These plots represent a great variety of distribution patterns; from inner-fjord (Fig. 2) to outer-fjord restricted (Fig. 4b, d). There are some that show no clear pattern whatsoever (Fig. 4e–f). The foraminiferal distribution patterns are discussed in detail in further sections.

**Sediment composition and chlorophyll content**. — Figure 5a shows the relation between mean grain size (M) and sorting coefficient (σ) for the sediment samples from various stations. All analyzed sediment samples represented poorly to very poorly sorted sediments with various numbers of larger dropstones. Practically all were fine sands to coarse silts. The results clustered in three broad groups (Fig. 5a), rather evenly distributed throughout the bay (Fig. 5b). It appears that the sediment-composition patterns in Admiralty Bay are either chaotic or very complicated.

Similarly, chlorophyll content of surface sediment, expressed by absorption per gram, does not show clear spatial or bathymetrical distribution patterns (Fig. 6). Moreover, the broad sampling time interval, between November 30th and April 18th, could have complicated these patterns.

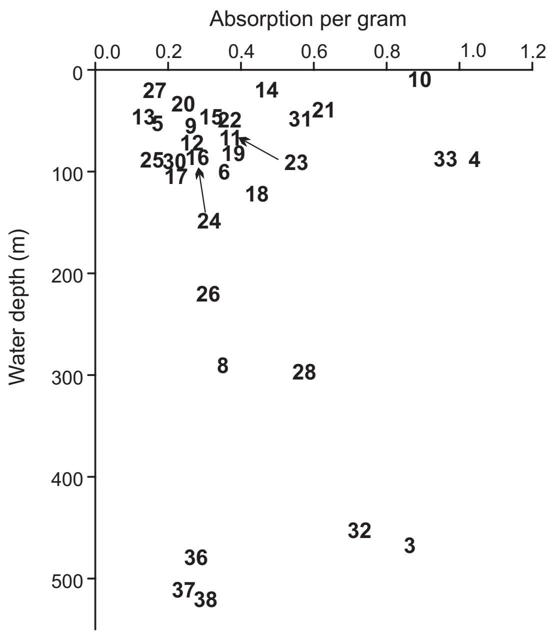


Fig. 6. Chlorophyll content, expressed by absorption per gram *vs.* station bathymetrical depth.

## Interpretation

**Principal Component Analysis**. — To explain the foraminiferal assemblage distribution, the foraminiferal relative frequencies were treated in a Q-mode

Table 2

PC scores and percent of total variance explained resulted from 5-factor principal component analysis performed on the "living" foraminiferal dataset. Scores indicating statistically most important taxa are **in bold**, scores suggesting accessory species are *in italics*

| "LIVING" | PC 1 | PC 2 | PC 3 | PC 4 | PC5 |
|---|---|---|---|---|---|
| % of total variance explained | 41.07 | 17.27 | 15.99 | 11.7 | 5.094 |
| ***Nodulina dentaliniformis*** | –0.410 | **1.372** | **5.106** | –0.146 | –0.028 |
| *Nodulina subdentaliniformis* | –0.244 | –0.169 | *0.360* | –0.092 | –0.140 |
| *Nodulina kerguelensis* | –0.150 | *0.462* | –0.035 | –0.357 | –0.171 |
| *Reophax scorpiurus* | –0.247 | –0.370 | –0.096 | –0.287 | –0.214 |
| *Reophax pilulifer* | –0.231 | –0.319 | –0.210 | –0.285 | –0.253 |
| *Labrospira jeffreysii* | –0.111 | 0.147 | –0.329 | –0.186 | –0.345 |
| *Adercotryma glomerata* | –0.227 | –0.411 | –0.116 | –0.023 | –0.198 |
| *Spiroplectammina biformis* | –0.147 | –0.541 | –0.009 | –0.005 | –0.221 |
| ***Portatrochammina antarctica*** | 0.129 | –0.049 | –0.118 | **5.268** | –0.084 |
| *Portatrochammina bipolaris* | –0.182 | 0.149 | –0.115 | 0.103 | –0.384 |
| *Atlantinella atlantica* | –0.094 | –0.133 | –0.430 | –0.242 | –0.371 |
| *Gordiospira fragilis* | 0.057 | –0.579 | –0.132 | –0.634 | –0.368 |
| ***Quinqueloculina* sp. 1** | –0.343 | –0.312 | –0.137 | –0.147 | **4.991** |
| *Pyrgo elongata* | –0.161 | –0.443 | –0.116 | –0.352 | –0.235 |
| *Pyrgo bulloides* | –0.279 | –0.388 | –0.245 | 0.025 | –0.219 |
| *Oolina felsinea* | –0.238 | –0.474 | –0.080 | –0.301 | –0.228 |
| *Fissurina* sp. 2 | –0.233 | –0.361 | –0.134 | –0.298 | –0.246 |
| *Pseudofissurina mccullochae* | –0.240 | –0.449 | –0.091 | –0.317 | –0.231 |
| *Bolivina pseudopunctata* | –0.256 | 0.164 | –0.239 | 0.028 | –0.269 |
| *Angulogerina earlandi* | –0.188 | –0.401 | –0.007 | –0.199 | –0.268 |
| *Cassidulinoides parkerianus* | –0.067 | –0.907 | *0.623* | 0.645 | –0.363 |
| *Cassidulinoides porrectus* | –0.220 | 0.171 | –0.310 | –0.168 | –0.267 |
| ***Globocassidulina biora*** | **5.352** | –0.137 | 0.268 | –0.296 | 0.233 |
| *Fursenkoina fusiformis* | –0.199 | –0.265 | –0.257 | –0.252 | –0.218 |
| *Rosalina globularis* | –0.169 | –0.363 | –0.175 | –0.204 | –0.239 |
| *Cibicides refulgens* | 0.000 | *0.544* | –0.584 | –0.192 | –0.548 |
| *Nonionella iridea* | –0.241 | –0.386 | –0.095 | –0.319 | –0.239 |
| ***Astrononion echolsi*** | 0.024 | **4.882** | –1.371 | –0.081 | –0.007 |
| *Astrononion antarcticum* | –0.220 | –0.115 | –0.382 | –0.238 | –0.287 |
| *Pullenia subcarinata* | –0.152 | 0.131 | –0.397 | –0.131 | –0.345 |
| *Cribroelphidium* sp. | –0.212 | –0.449 | –0.149 | –0.317 | –0.233 |

(Varimax rotated) principal component (PC) analysis. "Dead" and "living" foraminiferal datasets were treated separately. The second included all calcareous and polythalamous agglutinated taxa without *Miliammina arenacea*.

Table 3

PC scores and percent of total variance explained resulted from 6–factor principal component analysis performed on the "dead" foraminiferal dataset. Scores indicating statistically most important taxa are **in bold**, scores suggesting accessory species are *in italics*

| "DEAD" | PC 1 | PC 2 | PC 3 | PC 4 | PC 5 | PC 6 |
|---|---|---|---|---|---|---|
| % of total variance explained | 42.93 | 13.86 | 13.15 | 12.67 | 9.321 | 3.166 |
| *Rhabdammina* sp. | –0.123 | –0.313 | –0.229 | –0.276 | –0.139 | 0.195 |
| ***Lagenammina arenulata*** | –0.345 | 0.066 | –0.062 | **5.699** | –0.189 | 0.019 |
| *Armorella spherica* | –0.140 | –0.203 | –0.181 | –0.161 | –0.516 | 0.202 |
| ***Psammosphaera fusca*** | –0.752 | –0.503 | **5.643** | –0.273 | –0.367 | 0.010 |
| ***Hemisphaerammina bradyi*** | 0.024 | –0.365 | –0.273 | –0.194 | –0.385 | **–5.790** |
| ***Miliammina arenacea*** | –0.154 | –0.733 | *0.459* | 0.364 | **4.047** | –0.196 |
| *Hormosinella* sp. | –0.231 | 0.196 | 0.116 | 0.015 | –0.463 | 0.211 |
| *Nodulina dentaliniformis* | –0.147 | –0.491 | 0.144 | –0.023 | **2.366** | –0.065 |
| *Nodulina subdentaliniformis* | –0.076 | –0.457 | –0.238 | 0.101 | –0.233 | 0.195 |
| *Nodulina kerguelensis* | –0.125 | –0.248 | –0.235 | –0.046 | –0.637 | 0.201 |
| *Reophax pilulifer* | –0.126 | –0.309 | –0.229 | –0.304 | –0.241 | 0.203 |
| *Labrospira jeffreysii* | –0.187 | –0.188 | –0.067 | –0.063 | –0.097 | 0.189 |
| *Adercotryma glomerata* | –0.209 | 0.040 | –0.177 | –0.063 | –0.785 | 0.207 |
| *Spiroplectammina biformis* | –0.222 | *0.243* | –0.006 | –0.161 | –0.846 | 0.056 |
| *Paratrochammina bartmani* | –0.118 | –0.045 | –0.341 | –0.327 | 0.248 | 0.249 |
| *Paratrochammina lepida* | –0.107 | –0.244 | –0.286 | –0.217 | –0.252 | 0.218 |
| ***Portatrochammina antarctica*** | –0.836 | **5.549** | 0.291 | –0.234 | *0.593* | –0.266 |
| *Portatrochammina bipolaris* | –0.157 | –0.088 | –0.303 | –0.262 | 0.176 | 0.199 |
| *Atlantinella atlantica* | –0.134 | –0.164 | –0.271 | –0.136 | –0.467 | 0.210 |
| *Gordiospira fragilis* | –0.157 | –0.328 | 0.034 | –0.186 | –0.654 | 0.233 |
| *Quinqueloculina* sp. 1 | 0.091 | –0.452 | –0.247 | –0.227 | –0.568 | 0.246 |
| *Pyrgo elongata* | –0.122 | –0.285 | –0.191 | –0.137 | –0.618 | 0.205 |
| *Bolivina pseudopunctata* | –0.105 | –0.292 | –0.259 | 0.009 | –0.602 | 0.219 |
| *Angulogerina earlandi* | –0.107 | –0.094 | –0.412 | –0.697 | *0.724* | 0.242 |
| *Cassidulinoides parkerianus* | –0.171 | *0.761* | –0.062 | –0.095 | –0.644 | 0.260 |
| *Cassidulinoides porrectus* | –0.111 | –0.155 | –0.408 | –0.553 | *0.692* | 0.239 |
| ***Globocassidulina biora*** | **5.747** | *0.674* | 0.669 | 0.175 | –0.001 | 0.108 |
| *Fursenkoina fusiformis* | –0.103 | –0.250 | –0.237 | –0.115 | –0.610 | 0.211 |
| *Rosalina globularis* | –0.102 | –0.028 | –0.341 | –0.077 | –0.457 | 0.235 |
| *Cibicides lobatulus* | –0.123 | –0.272 | –0.228 | –0.090 | –0.617 | 0.199 |
| *Cibicides refulgens* | –0.181 | *0.436* | –0.647 | –0.249 | 0.332 | 0.265 |
| *Nonionella iridea* | –0.112 | –0.299 | –0.228 | –0.075 | –0.533 | 0.211 |
| *Astrononion echolsi* | 0.004 | –0.301 | –0.511 | 0.042 | **2.015** | 0.202 |
| *Astrononion antarcticum* | –0.135 | –0.291 | –0.189 | –0.189 | –0.436 | 0.206 |
| *Pullenia subcarinata* | –0.054 | –0.308 | –0.365 | –0.802 | *0.818* | 0.251 |
| *Cribroelphidium* sp. | –0.094 | –0.264 | –0.135 | –0.174 | –0.654 | 0.218 |

For these analyses new datasets were constructed of species that exceeded 2% of the assemblage composition in at least one station. In case of "dead" assemblages, six rare but frequently occurring species (*Nodulina kerguelensis*, *Atlantinella atlantica, Pyrgo elongata*, *Fursenkoina fusiformis*, *Cibicides lobatulus*, and *Astrononion antarcticum*) were added. The procedure was chosen, because it reduced the variables to a manageable number with no significant loss of information. In this way, the author left 31 species (variables) for "living" (Appendix B) and 36 for "dead" (Appendix C) datasets. Moreover, data from station 1 were excluded from the "dead" dataset, due to very low foraminiferal numbers.

After careful selection, 5-factor PC model was chosen as the best fit for "living" and 6-factor model as the one that most precisely describes assemblage variation within the "dead" foraminiferal dataset. The Principal Component (PC) scores (Tables 2, 3) show the contribution of the selected variables ("living" and "dead" foraminiferal taxa) to each PC factor. Taxa, which favor similar environmental conditions, may show high scores on one PC, indicating their participation in one assemblage. All PCs are well defined by mostly single, statistically most important taxa (score numbers marked on Tables 2 and 3 in bold) and at most few accessory species, characterized by significantly lower score values in the PC analysis (score numbers in italics). For the clarity of further discussion, the calculated PCs, which are mathematical models of real assemblages, will be named after their statistically most important taxa, LA for "living" assemblages and DA for "dead" assemblages. Geographic distribution of these assemblages is based of their PC loading values (Table 4) and is plotted on Figs 7 and 8.

Five major distinguished PCs explain 91.1% of the total variance of the "living" foraminiferal dataset (Table 2). They are *Globocassidulina biora* LA (41.1% of total variance explained), then *Astrononion echolsi* LA (17.3%), which includes three accessory species: *Nodulina dentaliniformis, Cibicides refulgens*, and *Nodulina kerguelensis.* The third most important PC is *Nodulina dentaliniformis* LA (16.0% of total variance explained), accessory species are *Cassidulinoides parkerianus* and *Nodulina subdentaliniformis*, fourth *Portatrochammina antarctica* LA (11.7%) again with *C. parkerianus* as accessory, and fifth *Quinquelocullina* sp. 1 LA (5.1%).

Six PCs explains 95.1% of "dead" foraminiferal dataset total variance (Table 3). They are: again *Globocassidulina biora* DA (42.9% of total variance explained) with no accessory taxa, *Portatrochammina antarctica* DA (13.9%) with *C. parkerianus, G. biora*, *C. refulgens*, and *S. biformis*. The third PC is *Psammosphaera fusca* DA (12.9% of total variance explained) with *G. biora* and *M. arenacea* as accessory species, fourth *Lagenammina arenulata* DA (12.7%) with *M. arenacea*, and sixth *Hemispaerammina bradyi* DA (3.2%). The fifth "dead" PC (9.3% of total variance explained) is characterized by three important species: *Miliammina arenacea*, *Nodulina dentaliniformis*, and *Astrononion echolsi*

Table 4

PC loading values of "living" and "dead" PC assemblages. Highest loadings, marked **in bold**, were used for construction of Figs 7 and 8

| Sta-tion | "LIVING" | | | | | "DEAD" | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | PC 1 | PC 2 | PC 3 | PC 4 | PC 5 | PC 1 | PC 2 | PC 3 | PC 4 | PC 5 | PC 6 |
| 1 | –0.092 | –0.029 | –0.048 | –0.019 | **0.949** | | | | | | |
| 2 | 0.227 | –0.063 | –0.010 | –0.042 | **0.908** | **0.953** | 0.083 | 0.108 | 0.020 | 0.002 | 0.029 |
| 3 | 0.074 | **0.907** | 0.288 | –0.084 | –0.059 | 0.528 | 0.387 | 0.100 | **0.640** | 0.377 | 0.003 |
| 4 | **0.917** | –0.057 | 0.039 | 0.250 | 0.023 | **0.938** | 0.126 | 0.315 | 0.017 | –0.012 | 0.019 |
| 5 | | | | | | **0.849** | 0.105 | 0.351 | –0.002 | –0.037 | –0.367 |
| 6 | 0.009 | –0.037 | –0.021 | **0.978** | –0.037 | **0.950** | 0.156 | 0.260 | 0.022 | 0.037 | 0.016 |
| 7 | **0.993** | –0.025 | 0.053 | –0.044 | 0.042 | 0.641 | 0.046 | **0.756** | –0.011 | –0.035 | 0.012 |
| 8 | 0.102 | 0.559 | **0.779** | 0.018 | –0.025 | 0.022 | –0.053 | 0.189 | 0.442 | **0.790** | 0.000 |
| 9 | **0.961** | 0.062 | 0.252 | –0.012 | 0.032 | 0.114 | 0.151 | **0.657** | 0.620 | 0.341 | –0.024 |
| 10 | | | | | | 0.027 | 0.013 | –0.021 | –0.017 | –0.045 | **–0.996** |
| 11 | **0.634** | 0.073 | 0.589 | 0.469 | –0.012 | 0.501 | 0.527 | **0.619** | 0.207 | 0.196 | –0.025 |
| 12 | 0.296 | –0.082 | 0.391 | **0.447** | –0.052 | **0.816** | 0.494 | 0.251 | 0.048 | 0.109 | 0.001 |
| 13 | **0.992** | –0.045 | 0.058 | 0.008 | 0.035 | **0.952** | 0.117 | 0.274 | 0.023 | 0.016 | 0.019 |
| 14 | | | | | | **0.958** | 0.135 | 0.192 | 0.016 | –0.018 | –0.160 |
| 15 | **0.989** | 0.021 | 0.122 | 0.026 | 0.040 | **0.829** | 0.276 | 0.338 | 0.297 | 0.174 | 0.005 |
| 16 | **0.942** | 0.034 | 0.319 | 0.058 | 0.032 | 0.196 | 0.250 | **0.750** | 0.483 | 0.237 | 0.008 |
| 17 | **0.721** | 0.428 | 0.485 | –0.056 | 0.018 | **0.962** | 0.160 | 0.155 | 0.144 | 0.047 | 0.015 |
| 18 | **0.622** | 0.512 | 0.575 | –0.044 | 0.015 | **0.817** | 0.179 | 0.132 | 0.506 | 0.106 | 0.022 |
| 19 | 0.081 | 0.289 | **0.929** | 0.047 | 0.000 | 0.451 | **0.644** | 0.545 | 0.054 | 0.158 | –0.026 |
| 20 | **0.992** | –0.031 | 0.045 | 0.008 | 0.096 | 0.411 | 0.150 | **0.888** | –0.031 | –0.031 | 0.005 |
| 21 | **0.673** | –0.101 | 0.014 | –0.115 | –0.014 | 0.487 | 0.106 | **0.852** | –0.027 | –0.026 | 0.017 |
| 22 | **0.931** | 0.003 | 0.055 | 0.344 | 0.028 | **0.746** | 0.619 | 0.212 | –0.002 | 0.089 | 0.000 |
| 23 | **0.942** | 0.134 | 0.278 | 0.022 | 0.022 | **0.939** | 0.250 | 0.128 | 0.151 | 0.081 | 0.021 |
| 24 | **0.679** | 0.097 | 0.468 | 0.547 | 0.006 | **0.757** | 0.369 | 0.357 | 0.345 | 0.156 | –0.002 |
| 25 | **0.884** | –0.042 | 0.039 | 0.456 | 0.024 | **0.968** | 0.166 | 0.180 | 0.030 | 0.018 | 0.016 |
| 26 | **0.819** | 0.477 | 0.271 | 0.073 | 0.015 | **0.834** | 0.219 | 0.089 | 0.442 | 0.173 | 0.027 |
| 27 | 0.148 | –0.012 | –0.016 | **0.967** | –0.010 | 0.534 | **0.795** | 0.140 | –0.009 | 0.157 | –0.066 |
| 28 | 0.146 | **0.615** | 0.722 | 0.057 | –0.048 | 0.375 | 0.562 | 0.102 | 0.339 | **0.589** | 0.002 |
| 29 | **0.712** | 0.196 | –0.056 | 0.138 | –0.093 | 0.349 | **0.741** | 0.035 | 0.348 | 0.217 | 0.019 |
| 30 | **0.882** | –0.076 | 0.136 | 0.348 | 0.000 | **0.870** | 0.398 | 0.280 | 0.010 | 0.017 | 0.002 |
| 31 | 0.168 | 0.080 | 0.549 | **0.759** | –0.011 | 0.218 | **0.911** | 0.234 | –0.030 | 0.061 | –0.008 |
| 32 | –0.040 | **0.733** | 0.665 | 0.011 | –0.014 | 0.494 | 0.164 | 0.093 | **0.694** | 0.377 | 0.049 |
| 33 | **0.841** | 0.001 | –0.006 | 0.479 | 0.018 | **0.920** | 0.314 | 0.088 | –0.020 | 0.106 | 0.033 |
| 34 | –0.048 | **0.893** | 0.048 | 0.010 | –0.116 | 0.019 | 0.321 | –0.048 | 0.136 | **0.733** | 0.050 |
| 35 | 0.350 | 0.279 | **0.758** | 0.321 | –0.058 | 0.081 | 0.565 | –0.014 | 0.179 | **0.626** | 0.044 |
| 36 | 0.034 | **0.699** | 0.688 | 0.007 | 0.020 | –0.043 | 0.009 | 0.092 | 0.429 | **0.789** | –0.009 |
| 37 | –0.008 | **0.933** | 0.146 | 0.030 | 0.031 | 0.007 | 0.059 | 0.046 | **0.908** | 0.374 | 0.002 |
| 38 | –0.016 | **0.940** | 0.227 | –0.009 | 0.032 | –0.059 | –0.018 | 0.007 | **0.966** | 0.211 | 0.004 |

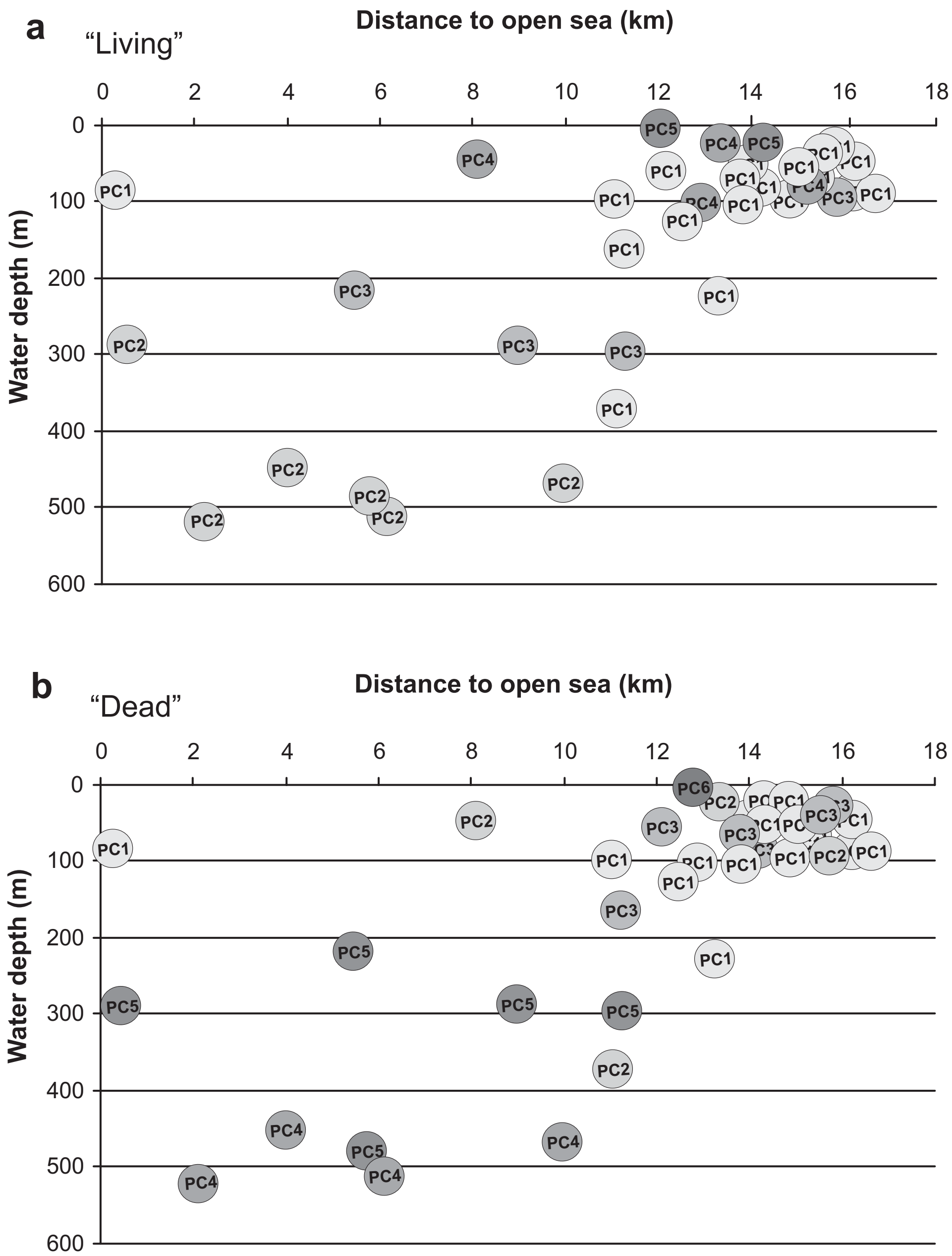


Fig. 7. Plots showing distribution of (**a**) "living" and (**b**) "dead" PCs in terms of their water-depth and distance to open sea. See Fig. 8 for the PCs assemblage names as introduced in this paper.

together with four accessory taxa: *P. subcarinata*, *A. earlandi*, *C. porrectus*, and *P. antarctica*. For simplicity, it is further referred to as *Miliammina arenacea* DA.

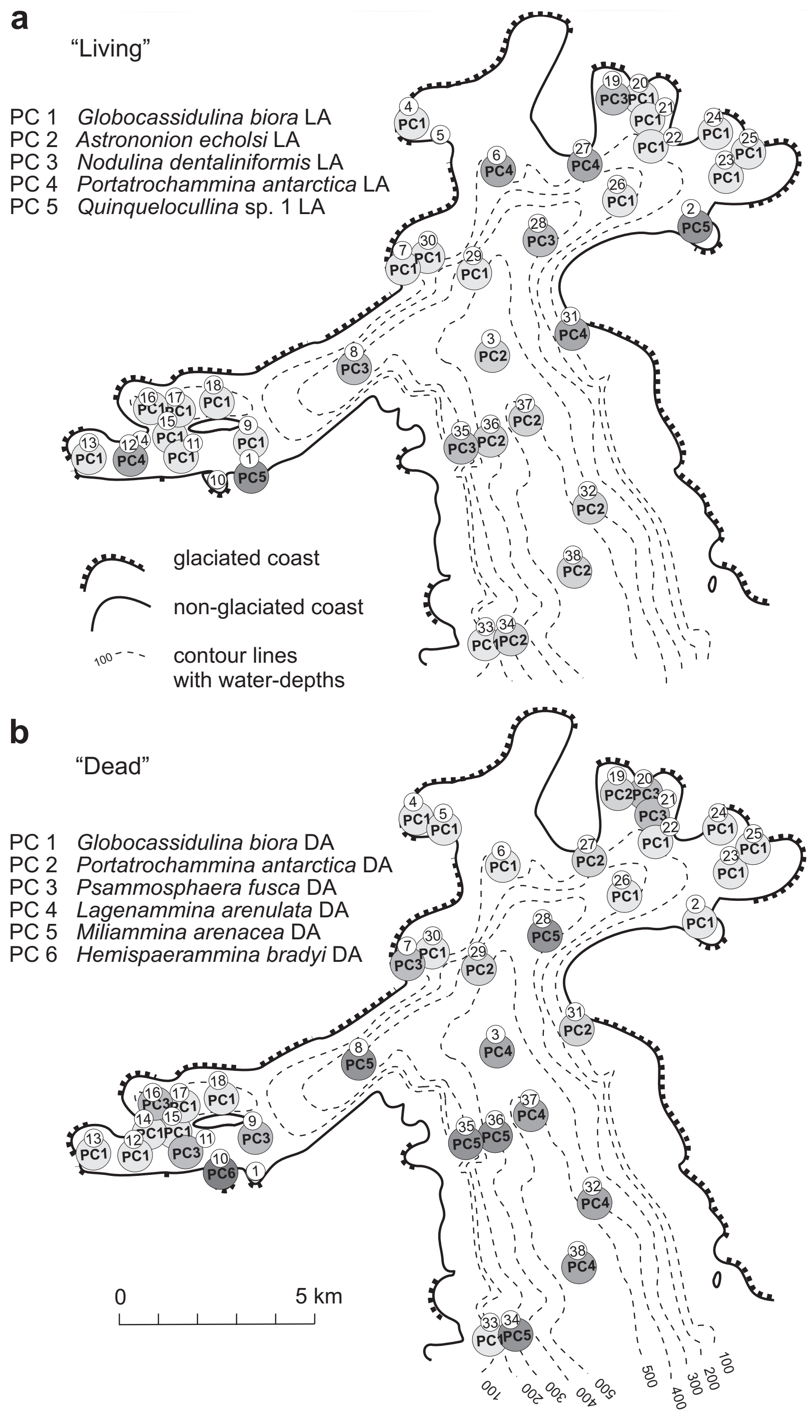


Fig. 8. Maps showing geographic distribution of (**a**) "living" and (**b**) "dead" PCs within Admiralty Bay. Note the PCs assemblage names as introduced in this paper.

**Environmental interpretation of the faunal results**. — In order to depict relations between the foraminiferal data and environmental variables, correlation coefficients (*r*) were calculated for both "living" and "dead" foraminiferal datasets (Tables 5, 6). Water depth, distance to open sea, chlorophyll content expressed by absorption per gram, as well as mean grain size and sorting coefficient of sediment were considered against selected taxa percentages, the faunal PC-loadings, total foraminiferal abundances, living-to-dead foraminiferal ratio, percent agglutinated forms, number of species (S), and species richness (d). The correlation coefficients (*r*) 0.6 and greater are considered here as reasonable after Mackensen *et al.* (1995); however, *r* values not lower than 0.5 are also discussed and referred to as "weak correlation". Both are marked in bold on Tables 5 and 6.

In general, the correlation coefficients between foraminiferal occurrences, chlorophyll content and sediment parameters are rather low, showing that there is not a strict linear relationship between the fauna and the two elements of environment. However, a number of taxa shows correlation with geographic distribution expressed by water depth and distance to open sea (Tables 5, 6). Moreover, some environmental predispositions of the investigated foraminifera can be derived from geographical distribution of single taxa (Figs 2–4) and PC assemblages

Table 5

Correlation coefficients (*r*) calculated from 31 most frequently occurring "living" benthic foraminiferal species, LAs, environmental parameters, and faunal characteristics against the environmental and faunal parameters. The correlation coefficient approaches 1.0 and –1.0 as the positive and negative correlation increases

| parameters / taxa and parameters | water depth (m) | distance to open sea (km) | absorption per gram | sediment mean size | sediment sorting coefficient | standing stock (N/10 cm sq.) | living-to-dead ratio ×10 | percent agglutinated forms | number of species | species richness |
|---|---|---|---|---|---|---|---|---|---|---|
| *Nodulina dentaliniformis* | 0.4 | –0.2 | 0.2 | –0.1 | 0.0 | –0.3 | –0.2 | **0.5** | **0.6** | **0.5** |
| *Nodulina subdentaliniformis* | 0.3 | –0.4 | 0.2 | 0.0 | –0.1 | –0.2 | –0.1 | 0.4 | 0.4 | 0.4 |
| *Nodulina kerguelensis* | **0.6** | –0.2 | 0.2 | 0.2 | 0.1 | –0.2 | –0.1 | 0.3 | 0.3 | 0.4 |
| *Reophax scorpiurus* | 0.5 | –0.4 | –0.1 | 0.0 | 0.1 | –0.1 | –0.1 | 0.2 | 0.5 | 0.4 |
| *Reophax pilulifer* | 0.2 | –0.4 | –0.3 | –0.2 | –0.2 | 0.1 | 0.0 | 0.0 | 0.5 | 0.3 |
| *Labrospira jeffreysii* | 0.4 | –0.3 | 0.0 | 0.1 | 0.1 | 0.1 | –0.1 | 0.1 | 0.4 | **0.5** |
| *Adercotryma glomerata* | –0.1 | –0.3 | 0.2 | 0.0 | 0.0 | –0.1 | –0.1 | 0.2 | 0.1 | 0.2 |
| *Spiroplectammina biformis* | –0.2 | 0.1 | 0.3 | 0.1 | 0.0 | –0.2 | –0.1 | 0.1 | –0.2 | 0.0 |
| *Portatrochammina antarctica* | –0.3 | 0.2 | 0.2 | –0.1 | 0.2 | –0.3 | –0.2 | **0.5** | –0.3 | –0.2 |
| *Portatrochammina bipolaris* | 0.3 | **–0.5** | –0.3 | 0.1 | 0.2 | 0.1 | –0.1 | 0.3 | **0.5** | **0.5** |

Table 5 continued

| parameters / taxa and parameters | water depth (m) | distance to open sea (km) | absorption per gram | sediment mean size | sediment sorting coefficient | standing stock (N/10 cm sq.) | living-to-dead ratio ×10 | percent agglutinated forms | number of species | species richness |
|---|---|---|---|---|---|---|---|---|---|---|
| *Atlantinella atlantica* | 0.2 | –0.1 | –0.4 | 0.1 | 0.1 | 0.3 | 0.0 | 0.0 | 0.2 | 0.3 |
| *Gordiospira fragilis* | –0.1 | 0.2 | 0.1 | 0.1 | 0.0 | **0.7** | 0.2 | 0.1 | –0.2 | –0.2 |
| *Quinqueloculina* sp. 1 | –0.2 | 0.1 | **–0.5** | –0.4 | **–0.5** | –0.1 | **0.8** | –0.4 | –0.4 | –0.3 |
| *Pyrgo elongata* | –0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.0 | –0.1 | –0.1 | 0.0 | 0.0 |
| *Pyrgo bulloides* | –0.1 | 0.1 | 0.1 | 0.1 | 0.0 | –0.1 | –0.1 | 0.3 | –0.1 | –0.1 |
| *Oolina felsinea* | –0.1 | 0.2 | 0.1 | 0.1 | 0.1 | –0.1 | –0.1 | 0.3 | 0.0 | 0.0 |
| *Fissurina* sp. 2 | 0.3 | –0.2 | 0.0 | 0.0 | 0.0 | –0.1 | –0.1 | 0.1 | 0.1 | 0.3 |
| *Pseudofissurina mccullochae* | 0.1 | –0.1 | 0.1 | **–0.6** | **–0.6** | –0.1 | 0.0 | 0.1 | 0.3 | 0.2 |
| *Bolivina pseudopunctata* | **0.6** | **–0.6** | 0.2 | 0.0 | –0.1 | –0.1 | –0.1 | 0.2 | –0.1 | –0.1 |
| *Angulogerina earlandi* | 0.1 | –0.4 | –0.2 | –0.1 | 0.1 | –0.1 | –0.1 | 0.1 | 0.4 | 0.4 |
| *Cassidulinoides parkerianus* | –0.2 | 0.2 | 0.1 | –0.1 | 0.3 | –0.2 | –0.1 | 0.0 | –0.1 | 0.0 |
| *Cassidulinoides porrectus* | **0.5** | **–0.7** | –0.2 | –0.1 | 0.0 | –0.1 | –0.1 | 0.1 | **0.6** | **0.6** |
| *Globocassidulina biora* | **–0.5** | **0.5** | 0.0 | 0.3 | 0.3 | 0.3 | –0.2 | **–0.6** | –0.5 | **–0.5** |
| *Fursenkoina fusiformis* | 0.3 | –0.3 | –0.1 | 0.0 | –0.2 | 0.1 | –0.1 | –0.1 | 0.2 | 0.2 |
| *Rosalina globularis* | 0.0 | –0.4 | 0.2 | –0.4 | –0.3 | 0.0 | –0.1 | 0.0 | 0.4 | 0.4 |
| *Cibicides refulgens* | 0.4 | –0.2 | –0.3 | –0.1 | –0.2 | 0.2 | 0.0 | 0.0 | 0.4 | 0.5 |
| *Nonionella iridea* | 0.3 | –0.1 | 0.2 | –0.1 | –0.2 | –0.1 | –0.1 | 0.1 | 0.2 | 0.3 |
| *Astrononion echolsi* | **0.9** | **–0.6** | 0.1 | 0.1 | –0.1 | –0.1 | –0.1 | 0.1 | **0.6** | **0.5** |
| *Astrononion antarcticum* | 0.1 | –0.4 | –0.4 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.4 | 0.3 |
| *Pullenia subcarinata* | 0.3 | **–0.6** | –0.3 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | **0.6** | **0.6** |
| *Cribroelphidium* sp. | –0.1 | 0.2 | 0.0 | 0.1 | 0.0 | 0.0 | –0.1 | –0.3 | –0.2 | –0.2 |
| *G. biora* LA | **–0.5** | **0.5** | 0.1 | 0.3 | 0.3 | 0.2 | –0.2 | –0.5 | –0.3 | –0.3 |
| *A. echolsi* LA | **0.9** | **–0.6** | 0.1 | 0.0 | –0.1 | –0.1 | –0.1 | 0.2 | **0.7** | **0.6** |
| *N. dentaliniformis* LA | 0.3 | –0.1 | 0.2 | –0.1 | 0.0 | –0.3 | –0.3 | **0.5** | **0.5** | 0.5 |
| *P. antarctica* LA | –0.3 | 0.1 | 0.2 | 0.0 | 0.2 | –0.3 | –0.3 | **0.5** | –0.2 | –0.1 |
| *Quinqueloculina* sp. 1 LA | –0.3 | 0.1 | –0.4 | –0.3 | –0.5 | –0.2 | **0.7** | **–0.5** | –0.4 | –0.4 |
| water depth (m) | | **–0.6** | 0.0 | 0.1 | –0.1 | 0.0 | –0.1 | 0.2 | **0.7** | **0.6** |
| distance to open sea (km) | | | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | –0.2 | **–0.7** | **–0.6** |
| absorption per gram | | | | 0.2 | 0.2 | –0.2 | –0.4 | 0.4 | 0.1 | 0.1 |
| sediment mean size | | | | | **0.5** | 0.2 | **–0.5** | 0.0 | –0.1 | 0.0 |
| sediment sorting coefficient | | | | | | 0.0 | **–0.6** | 0.1 | 0.0 | 0.0 |
| standing stock (N/10 cm sq.) | | | | | | | 0.2 | –0.2 | –0.1 | –0.1 |
| living-to-dead ratio ×10 | | | | | | | | –0.3 | –0.2 | –0.2 |
| percent agglutinated | | | | | | | | | 0.3 | 0.4 |

Table 6

Correlation coefficients (*r*) calculated from 36 most frequently occurring "dead" benthic foraminiferal species, DAs, environmental parameters, and faunal characteristics against the environmental and faunal parameters. The correlation coefficient approaches 1.0 and –1.0 as the positive and negative correlation increases

| taxa and parameters / parameters | water depth (m) | distance to open sea (km) | absorption per gram | sediment mean size | sediment sorting coefficient | abundance (N/10 cm sq.) | living–to–dead ratio ×10 | percent agglutinated forms | number of species | species richness |
|---|---|---|---|---|---|---|---|---|---|---|
| *Rhabdammina* sp. | 0.4 | **–0.6** | –0.3 | –0.1 | 0.0 | 0.0 | 0.1 | 0.2 | **0.5** | **0.6** |
| *Lagenammina arenulata* | **0.7** | –0.4 | 0.1 | 0.0 | –0.1 | –0.1 | 0.1 | **0.5** | 0.5 | **0.5** |
| *Armorella spherica* | 0.0 | –0.2 | 0.0 | –0.2 | –0.3 | –0.2 | 0.1 | 0.2 | 0.2 | 0.3 |
| *Psammosphaera fusca* | –0.4 | 0.4 | 0.0 | 0.2 | 0.0 | 0.2 | 0.3 | 0.1 | –0.4 | –0.4 |
| *Hemisphaerammina bradyi* | –0.2 | 0.1 | 0.2 | 0.0 | –0.1 | –0.2 | –0.2 | 0.3 | –0.4 | –0.3 |
| *Miliammina arenacea* | **0.7** | –0.4 | 0.0 | –0.3 | –0.3 | –0.2 | 0.0 | **0.5** | **0.6** | **0.6** |
| *Hormosinella* sp. | 0.0 | 0.1 | 0.2 | –0.1 | 0.1 | –0.2 | 0.0 | 0.3 | 0.2 | 0.2 |
| *Nodulina dentaliniformis* | 0.4 | –0.3 | 0.1 | **–0.5** | **–0.5** | –0.2 | 0.0 | **0.5** | 0.5 | **0.5** |
| *Nodulina subdentaliniformis* | **0.6** | –0.5 | 0.2 | –0.2 | –0.4 | –0.2 | 0.3 | 0.3 | 0.4 | 0.4 |
| *Nodulina kerguelensis* | **0.7** | –0.2 | 0.0 | 0.2 | 0.0 | –0.1 | 0.1 | 0.2 | 0.4 | 0.5 |
| *Reophax pilulifer* | 0.3 | –0.5 | –0.4 | –0.2 | –0.1 | 0.0 | 0.2 | 0.1 | 0.4 | 0.5 |
| *Labrospira jeffreysii* | 0.4 | –0.2 | 0.0 | –0.2 | –0.2 | –0.1 | 0.0 | 0.4 | 0.3 | 0.4 |
| *Adercotryma glomerata* | –0.1 | –0.2 | 0.2 | 0.0 | –0.1 | –0.1 | 0.0 | 0.2 | 0.0 | 0.1 |
| *Spiroplectammina biformis* | –0.3 | 0.0 | 0.1 | 0.0 | –0.1 | –0.1 | 0.0 | 0.1 | –0.2 | –0.2 |
| *Paratrochammina bartmani* | 0.3 | **–0.8** | –0.2 | –0.1 | 0.1 | 0.0 | 0.0 | 0.1 | **0.6** | **0.6** |
| *Paratrochammina lepida* | **0.5** | **–0.8** | –0.2 | 0.0 | 0.1 | –0.1 | 0.1 | 0.1 | **0.6** | **0.7** |
| *Portatrochammina antarctica* | –0.2 | 0.1 | 0.0 | –0.2 | 0.3 | –0.1 | –0.1 | 0.2 | 0.2 | 0.2 |
| *Portatrochammina bipolaris* | **0.6** | **–0.6** | –0.4 | 0.0 | 0.0 | –0.1 | 0.1 | 0.3 | **0.7** | **0.7** |
| *Atlantinella atlantica* | **0.6** | **–0.5** | –0.3 | 0.1 | 0.0 | –0.1 | 0.3 | 0.2 | **0.5** | **0.6** |
| *Gordiospira fragilis* | –0.1 | 0.1 | 0.1 | 0.1 | –0.1 | 0.0 | **0.8** | 0.1 | –0.1 | –0.1 |
| *Quinqueloculina* sp. 1 | –0.2 | 0.1 | –0.4 | 0.1 | –0.1 | –0.2 | 0.1 | –0.4 | –0.4 | –0.4 |
| *Pyrgo elongata* | –0.1 | 0.1 | 0.0 | 0.0 | –0.2 | 0.0 | 0.0 | –0.1 | 0.2 | 0.2 |
| *Bolivina pseudopunctata* | **0.5** | –0.5 | 0.2 | 0.1 | –0.1 | –0.2 | 0.3 | 0.1 | 0.2 | 0.3 |
| *Angulogerina earlandi* | 0.2 | –0.5 | –0.3 | –0.2 | 0.1 | 0.0 | –0.1 | 0.0 | **0.6** | **0.5** |
| *Cassidulinoides parkerianus* | –0.2 | 0.0 | 0.2 | –0.1 | 0.2 | –0.1 | 0.0 | 0.1 | 0.1 | 0.1 |
| *Cassidulinoides porrectus* | 0.4 | **–0.7** | –0.3 | –0.3 | 0.0 | 0.0 | 0.0 | 0.1 | **0.6** | **0.6** |
| *Globocassidulina biora* | **–0.6** | **0.6** | 0.0 | 0.2 | 0.2 | 0.4 | –0.3 | **–0.9** | **–0.6** | **–0.6** |
| *Fursenkoina fusiformis* | 0.1 | **–0.5** | 0.2 | –0.1 | –0.1 | 0.0 | 0.1 | –0.1 | 0.3 | 0.3 |
| *Rosalina globularis* | 0.3 | –0.3 | –0.2 | –0.1 | 0.0 | 0.0 | 0.2 | 0.0 | 0.3 | 0.3 |
| *Cibicides lobatulus* | **0.6** | –0.4 | 0.2 | 0.1 | 0.0 | –0.2 | 0.0 | 0.2 | 0.4 | 0.4 |
| *Cibicides refulgens* | 0.4 | –0.3 | –0.5 | 0.0 | 0.0 | 0.0 | 0.2 | 0.1 | 0.3 | 0.4 |

Table 6 continued

| parameters / taxa and parameters | water depth (m) | distance to open sea (km) | absorption per gram | sediment mean size | sediment sorting coefficient | abundance (N/10 cm sq.) | living–to–dead ratio ×10 | percent agglutinated forms | number of species | species richness |
|---|---|---|---|---|---|---|---|---|---|---|
| *Nonionella iridea* | 0.4 | –0.4 | 0.1 | –0.1 | –0.2 | –0.2 | 0.3 | 0.2 | 0.2 | 0.3 |
| *Astrononion echolsi* | **0.7** | **–0.7** | –0.1 | –0.1 | –0.2 | –0.2 | 0.2 | 0.3 | **0.7** | **0.7** |
| *Astrononion antarcticum* | 0.3 | **–0.6** | –0.3 | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | **0.5** | **0.6** |
| *Pullenia subcarinata* | 0.2 | **–0.7** | –0.3 | –0.1 | 0.0 | 0.1 | 0.1 | 0.0 | **0.5** | **0.6** |
| *Cribroelphidium* sp. | –0.2 | 0.4 | 0.1 | 0.2 | 0.1 | 0.1 | –0.2 | –0.3 | –0.3 | –0.4 |
| *G. biora* DA | **–0.5** | **0.5** | 0.1 | 0.2 | 0.3 | 0.3 | –0.2 | **–0.9** | –0.4 | **–0.5** |
| *P. antarctica* DA | –0.2 | 0.0 | –0.1 | –0.1 | 0.3 | –0.1 | –0.1 | 0.1 | 0.2 | 0.2 |
| *P. fusca* DA | –0.4 | 0.5 | 0.1 | 0.2 | 0.0 | 0.1 | 0.2 | 0.2 | –0.4 | –0.4 |
| *L. arenulata* DA | **0.8** | –0.4 | 0.1 | 0.0 | –0.2 | –0.2 | 0.1 | **0.5** | **0.5** | **0.5** |
| *M. arenacea* DA | **0.7** | **–0.6** | –0.2 | –0.4 | –0.3 | –0.2 | 0.1 | 0.4 | **0.7** | **0.8** |
| *H. bradyi* DA | 0.2 | –0.1 | –0.2 | 0.0 | 0.1 | 0.3 | 0.2 | –0.3 | 0.4 | 0.3 |
| water depth (m) | | **–0.7** | –0.1 | 0.0 | –0.2 | –0.1 | 0.2 | 0.4 | **0.6** | **0.7** |
| distance to open sea (km) | | | 0.1 | 0.2 | 0.2 | 0.1 | –0.2 | –0.3 | **–0.6** | **–0.7** |
| absorption per gram | | | | 0.0 | –0.1 | –0.3 | –0.1 | 0.2 | –0.1 | –0.1 |
| sediment mean size | | | | | 0.2 | 0.1 | 0.2 | –0.2 | –0.2 | –0.2 |
| sediment sorting coefficient | | | | | | 0.1 | –0.1 | –0.3 | 0.0 | 0.0 |
| abundance (N/10 cm sq.) | | | | | | | 0.0 | –0.3 | 0.1 | –0.1 |
| living-to-dead ratio ×10 | | | | | | | | 0.2 | 0.1 | 0.1 |
| percent agglutinated | | | | | | | | | 0.3 | 0.4 |

(Figs 7, 8). Distribution and relation to environmental variables of "living" (LA) and "dead" assemblages (DA) is discussed below.

## Description of living assemblages

***Globocassidulina biora* LA**. — The PC assemblage is practically synonymous with its only statistically significant species *G. biora* (Table 2). No other taxa present either high PC scores (Table 2) nor significant correlation (Table 5) with *G. biora* LA. Nevertheless, this foraminifera alone comprises over one third of the total fauna investigated, being by far the most numerous species. It is definitely most abundant in inner parts of the Admiralty Bay, frequently dominating the shallow-water near-shore environments located close to the ice front. "Living" specimens of *Globocassidulina biora* were present at practically all stations (Fig. 2B).

Although far less abundant than in shallow waters, they were commonly encountered also at deep-water stations. Weak correlation of both *G. biora* percentages and LA loadings, with water depth and distance to open sea (Table 5), confirm preferred shallow-water and inner-fjord habitats.

***Astrononion echolsi* LA**. — This assemblage is restricted only to deeper parts of the main channel of the Admiralty Bay; 300 m and deeper (Fig. 7a). This is also indicated by strong correlation between both *A. echolsi* and LA loadings with increased water depths ($r = 0.9$) and near open-sea conditions ($r = 0.6$) (Table 5). Accessory species of this assemblage are *N. dentaliniformis*, *C. refulgens*, and *N. kerguelensis* (Table 2). Moreover, *C. porrectus* and *B. pseudopunctata* show weak positive correlation with this LA (data not presented in this paper). All the taxa are restricted to rather deep waters (Figs 3, 4). They are absent in glacier-proximal settings. *Astrononion echolsi* LA, as the only LA, clearly correlates with high number of taxa and species richness (Table 5), indicating maximal faunal diversities in deep-water outer fjord.

***Nodulina dentaliniformis* LA**. — This LA mainly occupies central regions of the fjord, where three major inlets enter the main channel (Fig. 8a). It appears to prefer intermediate water depths of 200–300 m; however, it was also encountered at station 19 at 83 m water-depth (Fig. 7a). This LA shows weak positive correlation with percent agglutinated forams and number of species (Table 5). Accessory species are *C. parkerianus* and *N. subdentaliniformis* (Table 2), which are absent at the shallowest, inner-most locations.

***Portatrochammina antarctica* LA**. — This is a shallow-water LA, restricted to upper 100 m (Fig. 7a). In Martel and Mackellar inlets, it is characteristic of near-shore but rather outer parts of these inlets; however, in Ezcurra Inlet it was encountered inside rather far inner-fjord Goulden Cove (Fig. 8a). Its accessory species is *C. parkerianus* (Table 2), which, similarly like the major species of the *Portatrochammina antarctica* LA, was encountered throughout the bay with the exception of the shallowest, inner-most locations (Fig. 3c–d). This LA shows weak positive correlation only with percent agglutinated forams (Table 5), which may simply mirror its dominance by arenaceous *Portatrochammina antarctica*.

***Quinqueloculina* sp. 1 LA**. — This LA was encountered at the shallowest (8 and 20 m) and most restricted locations within Hervé and Lussish coves (Figs 7a, 8a), that are isolated from waters of the open fjord by underwater moraine ridges. *Quinqueloculina* sp. 1 LA and its most important taxon, correlate with high live-to-dead ratio (Table 5), which may suggest high sedimentation rate preferences of this taxon. Moreover, weak negative correlation between *Quinqueloculina* sp. 1 and chlorophyll content and sorting coefficient suggest preference for relatively low-food and rather poorly than very poorly-sorted sediment. Overall weak negative correlation between both mean size and the sorting coefficient of sediment on one side and live-to-dead ratio on the other, throughout the Admiralty Bay (Table 5), suggests a presence of higher living-to-dead ratios in relatively coarse and better-sorted sediments, which could have been deposited more rapidly.

## Description of dead assemblages

***Globocassidulina biora* DA**. — Similarly as *Globocassidulina biora* LA, the *G. biora* DA is also dominated by the single species (Table 3). It is even more restricted to shallow waters, usually 100 m or shallower, and inner- rather than outer-fjord settings (Figs 7b, 8b). Weak correlation with water depth and distance to open sea supports this observation (Table 6). However, dominance of *Globocassidulina biora* DA at 86 m deep station 33, located right at the fjord mouth, suggests that the DA geographic distribution pattern may be rather due to the fjord morphology, with broad shallow areas dominating the inner-fjord inlets. This leaves water-depth as the most important factor affecting distribution of this DA. *Globocassidulina biora* DA shows strong negative correlation with percent agglutinated (–0.9) and weak also negative correlation with species richness (Table 6), which is expected with the strong dominance of this DA by the single, most numerous, and calcareous foraminiferal species.

***Portatrochammina antarctica* DA**. — This is a complex DA with *C. parkerianus, G. biora*, and *C. refulgens* as accessory taxa (Table 3). It tends to occupy terminal portions of the main channel at its junction with the branching inlets, with the exception of station 19, which is located close to glacial terminus in Martel Inlet, but still at 83 m water depth (Fig. 8b). This DA was not observed in western-most Ezcurra Inlet. Three out of four locations of this DA are at water depths 100 m or less, with one at almost 400 m (Fig. 7b). *Portatrochammina antarctica* DA does not show even weak correlation with any environmental factors observed (Table 6), which together with rather patchy distribution suggests the intermediate character of this assemblage. This DA seems to correspond with *Portatrochammina antarctica* LA which shows somewhat similar distribution.

***Psammosphaera fusca* DA**. — The accessory species of this DA are *G. biora* and *M. arenacea* (Table 3). Similarly as with *Lagenammina arenulata* DA discussed below, this assemblage has no direct LA counterpart, because its dominant species was not considered in the living foraminiferal dataset. It occupies depths shallower than 100 m (Fig. 7b); however, at station 7 it was encountered at 165 m water depth, although still very close to glacial terminus (Fig. 8b). *Psammosphaera fusca* DA occupies inner-fjord regions. *Psammosphaera fusca* is the second most common inner-fjord taxon, less numerous in near-shore samples than *G. biora* only (Fig. 2a–b). *Psammosphaera fusca* DA shows negative correlation values in respect to species richness (Table 6), suggesting low-diversity foraminiferal communities; however, probably slightly more diverse than the *Globocassidulina biora* DA. The *P. fusca* DA also has a higher life-to-dead ratio than *G. biora* DA (Table 6), which may suggest more intense sedimentation rates.

***Lagenammina arenulata* DA**. — Its accessory species is *M. arenacea* (Table 3); however, it shows some degrees of correlation with *A. echolsi*, *N. kerguelensis*, *N. subdentaliniformis*, and *N. dentaliniformis* (data not presented in this paper), characteristic also for the next DA. Moreover, weak positive correlation with the *Miliammina arenacea* DA suggests broad similarities of the two DAs. The *Lagenammina arenulata* DA is clearly restricted only to the deepest parts of the central channel and water-depths below 400 m (Figs 7b, 8b). It is weakly correlated with high number of species and species richness (Table 6). However, it is important to mention that *L. arenulata* dominating this DA occurs in similar numbers in very deep waters below 400 m and in some shallow-water settings within the inlets (Fig. 3f). This may suggest either complex environmental preferences or polyspecific character of this taxon. Simple monothalamous morphology of this species suggests that the second option is more likely.

***Miliammina arenacea* DA**. — It is a complex DA with *Miliammina arenacea*, *Nodulina dentaliniformis*, and *Astrononion echolsi* as major species, and four accessory taxa: *P. subcarinata*, *A. earlandi*, *C. porrectus*, and *P. antarctica* (Table 3). Moreover, *P. bipolaris*, *P. lepida, R. pilulifer*, *L. jeffreysii*, *N. subdentaliniformis*, *A. antarcticum*, and *P. subcarinata* show correlation with this DA (data not presented in this paper). *Miliammina arenacea* DA occupies slopes of the main channel between 200 and 300 m; however, at station 36 it was encountered at 480 m water-depth (Figs 7b, 8b). Correlation values (Table 6) also suggest that this DA preferred deep-water and rather outer-fjord habitats. *Miliammina arenacea* DA exhibit the highest positive correlation with specific richness among all faunal assemblages.

***Hemispaerammina bradyi* DA**. — This assemblage was present at station 10 only, which is located at 8 m water-depth (Fig. 8b). It is inside a small cove additionally separated from the fjord by underwater moraine. This DA is a highly specialized assemblage dominated by large monothalamous *Hemispaerammina bradyi* overgrowing small bivalves (Fig. 10.1).

**"Living" *vs.* "dead" assemblages (LA *vs.* DA)**. — Although "living" foraminiferal datasets comprised of calcareous and only polythalamous agglutinated taxa without *Miliammina arenacea* and "dead" datasets comprise of all foraminifera including undivided ("living" and "dead") monothalamous agglutinated and *M. arenacea*, there are clear parallels between PC results based on the two datasets. *Globocassidulina biora* DA is a clear counterpart of *Globocassidulina biora* LA. They are dominated by the same single species (Tables 2, 3) and have similar distribution (Fig. 7). Deep water *Astrononion echolsi* LA and *Nodulina dentaliniformis* LA correspond to *Lagenammina arenulata* DA and *Miliammina arenacea*

DA. They include broadly similar species (Tables 2, 3), are characterized by high specific diversities (Tables 5, 6), and are all restricted to waters deeper than 200 m (Fig. 7). Similarly *Portatrochammina antarctica* DA corresponds to *Portatrochammina antarctica* LA, which both show somewhat similar distribution (Fig. 8) and do not correlate with any environmental factors discussed (Tables 5, 6). Both *Quinquelocullina* sp. 1 LA and *Hemispaerammina bradyi* DA, although characterized by different taxa, are constrained to shallow-water coves of rather restricted water-exchange with the open fjord (Fig. 8).

The only typically "dead" assemblage is *Psammosphaera fusca* DA, which is dominated by the single species that was not present in the "living" dataset. This is a strictly near-shore DA (Fig. 8b), which among "living" foraminiferas was artificially incorporated into *Globocassidulina biora* LA.

## Benthic foraminiferal zonation in Admiralty Bay

The comparison of "living" and "dead" taxa distribution with ecological data revealed clear zonation patterns of benthic foraminifera inhabiting Admiralty Bay.

**Restricted coves**. — Monsimet Cove, Hervé Cove, Lussish Cove (Fig. 1) are typically separated from the open fjord by under-water moraine ridges, which promotes most unstable (atmospheric and melt-water influenced) hydrographic conditions. Their water depths seldom exceed 20 m. Total foraminiferal numbers are low, typically well below 100 specimens per 10 $cm^2$, diversities are low, and live-to-dead ratios high (Appendices B and C). Typical species are *Quinquelocullina* sp. 1 and *Hemispaerammina bradyi* (larger variance), at some locations associated by *Globocassidulina biora* (Fig. 2b).

**Open inlets**. — Ezcurra Inlet, Martel Inlet, Mackellar Inlet (Fig. 1) can be up to 250 m deep, but are usually shallower than 100 m. Total standing stocks and "dead" abundances of the inlet faunas exceeds those of deeper waters. *Globocassidulina biora* and *Psammosphaera fusca* clearly dominate low-diverse assemblages. They are both present throughout the bay; however, they reach the greatest abundances in shallow waters, well inside the inlets (Fig. 2a–b). *Psammosphaera fusca* may prefer higher sedimentation rates and/or slightly more diverse communities than *G. biora.* Other important taxa flourishing in the inlets are: *Quinqueloculina* sp. 1, *H. hirudinea*, *C. parkerianus*, *S. biformis*, and to some extent *H. bradyi* (smaller variance), see Figs 2e–d and 3a–c. Among the inlet faunas, *Cribroelphidium* sp. deserves special mention (Fig. 2c). This taxon was found quite commonly and in considerable numbers only in immediate proximity of water-tide glaciers. Thus, it appears to be a valuable glacier-proximity indicator, similarly as *Cribroelphidium excavatum clavatum* from Arctic fjords (Hald and Korsun 1997). The inlet zone may developed thanks to more intense freezing, iceberg grounding, and freshwater injections, which result in large quantities of suspended material, as compared to the main channel. On the other hand, presence of the typical *G. biora* dominated assemblage at station 33, located right at the mouth of Admiralty Bay (Fig. 8b), may suggest greater impact of bathymetry and near-shore sedimentation on foraminiferal communities than water chemistry and extension of winter sea-ice.

**Intermediate zone**. — It occupies terminal portion of the main channel at its junction with the branching inlets. Water depths are ~100 m as well as shallower and occasionally deeper. This is one of near-shore zones; however, it maintains evident open-water conditions. The geographic limits of this zone are not clearly cut. Foraminiferal diversities and total abundances are of middle values. The typical foraminiferal taxa are *P. antarctica* and *C. parkerianus*, together with less important *C. refulgens*, *S. biformis*, and *G. biora*. The major species for this zone are in fact distributed more or less evenly throughout shallower and/or deeper settings (Figs 2b, 3b–d). The key element characterizing the intermediate zone appears to be the relatively high proportion between *P. antarctica* and *C. parkerianus* on one side to *G. biora* and *P. fusca* on the other, with significant presence of both deep- and shallow-water taxa. There are not obvious correlation with any environmental factor analyzed (refer to *P. antarctica* LA and DA in Tables 5, 6), which together with rather poorly defined geographic extent (see *P. antarctica* LA and DA on Figs 7, 8) of this zone suggests its transitional, possibly ephemeral, environmental conditions.

**Deep-water zone**. — It occupies the main channel of Admiralty Bay below 200 m water depth. Oceanic waters have unlimited access to this portion of the fjord, providing the most stable and fully marine hydrographic conditions. In general, the deep-water faunas are characterized by the highest diversities, whereas their total abundances place closer to the middle values. PC analysis showed clearly that this zone splits into lower (below 400 m) and upper (200–400 m) subzones (Fig. 7). For the upper part, steep slopes, which drop from eastern and western shores of the outer bay, dominate. They may be influenced by intense near-shore sedimentation and underwater slumping. The lower subzone is relatively flat, which suggests a more stable and slower sedimentation (Fig. 8). Among "living" foraminifera, lower subzone communities are more diverse, whereas among "dead" upper subzone assemblages show the highest diversities (Tables 5, 6). Faunal differences between them are subtle and not always easy to grasp, probably due to *post mortem* downward transport of sediment containing foraminifera. As a matter of fact, both subzones are populated by similar foraminiferal associations. In both, *A. echolsi*, *N. dentaliniformis*, *N. subdentaliniformis*, *B. pseudopunctata*, *N. kerguelensis*, *P. lepida*, *L. jeffreysii*, and *A. antarcticum* occur in similar abundances. However, *M. arenacea*, *C. porrectus*, *A. earlandi*, *P. subcarinata*, and *P. bipolaris* are more common in the upper portion of the main channel (Figs 3, 4). On the other hand, the lower subzone is characterized by noticeable increase in *L. arenulata* (Fig. 3f).

## Discussion

Formerly, Antarctic workers (Uchio 1960; McKnight 1962; Bandy and Echols 1964; Pflum 1966; Herb 1971; Osterman and Kellogg 1979) routinely attributed various foraminiferal assemblages to different bathymetric zones. More recently, broader sampling areas and increasing technical capabilities promoted use of a wide range of oceanographic parameters, which allows assignment of foraminiferal assemblages to different water masses (Anderson 1975; Ishman and Domack 1994; Mackensen *et al*. 1995; Harloff and Mackensen 1997; Mikhalevich 2004). Nevertheless, Murray (1991) summarized that depth-related distribution of major modern foraminiferal associations in marine Antarctica is remarkably uniform thanks to latitudinal oceanic circulation in this realm.

As mentioned in the previous section, the deep-water foraminiferal zone in Admiralty Bay extends below 200 m water-depth. It is not associated with major water mass transition, which is suggested by uniform water temperatures and salinities within the bay (Szafrański and Lipski 1982; Lipski 1987). It is noteworthy that many Antarctic workers put bathymetric border between different faunas at ~200 m water-depth (*e.g.* McKnight 1962; Bandy and Echols 1964; Pflum 1966; Herb 1971; Milam and Anderson 1981), therefore it appears that this depth has regional range and may match lowest limit of atmospheric and meltwater influence. Hydrographical profiles presented by Rakusa-Suszczewski (1996) seem to support this thesis.

One question left to answer is the geographic extent of recently investigated foraminiferal communities. The presence of foraminiferal zonation documented here for Admiralty Bay is rather typical for climatically dynamic polar-fjord setting. Similar benthic distribution was observed in the fjords of Arctic Spitsbergen (Hald and Korsun 1997). Even though different species occur in low-latitude Arctic, they appear to have ecological and morphological equivalents in recently investigated Antarctic fjords.

In Antarctica, Maxwell Bay, located between Nelson Island and King George Island (Fig. 1), has foraminiferal assemblages analogous to those found in Admiralty Bay, regardless of nomenclature differences between various authors. This faunal similarity suggests widespread occurrence of described assemblages. Both Chang and Yoon (1995) and Mayer (2000) recognized the shallow-water *G. biora–P. fusca* assemblage. Moreover, "Biotope B" of Chang and Yoon (1995), which occurs below 65.5 m appears to correspond to combined *N. dentaliniformis* LA – *P. antarctica* LA and *P. antarctica* DA – *M. arenacea* DA associations from Admiralty Bay. The well defined depth-limit of "Biotope B" appears to result from detail sampling of a single transect in much restricted Marian Cove. Unfortunately, the detailed foraminiferal record from the caldera of Deception Island (Finger and Lipps 1981) is environmentally too unique to enable comparison with recent data.

Ishman and Domack (1994) placed the South Shetland Islands and Palmer Archipelago within one realm of a single foraminiferal assemblage, named after *Fursenkoina* spp. They reported the existence of much different, agglutinated-taxa dominated, assemblages far south in Marguerite Bay. According to the same authors, the South Shetlands are recently under influence of Weddell Sea Transitional Water with Carbonate Compensation Depth (CCD) below 900 m. This position of CCD may explain high abundances of calcareous foraminifera throughout Admiralty Bay (Appendices B, C), and lack of arenaceous-dominated deep-water assemblages. However, Domack and Ishamn (1994) clearly differentiated between Admiralty Bay, as characterized by estuarine circulation, and Palmer Archipelago together with neighboring Danco Coast, which are much more stable oceanographically. This oceanographic dissimilarity may suggest the existence of different foraminiferal communities in more southern fjord-locations. Thus, it would be risky to extrapolate the Admiralty Bay foraminiferal zonation as a paleoceanographic tool far beyond the South Shetlands, without further field studies.

## Conclusions

1. Discrete benthic foraminiferal assemblages dominate four distinctive zones within Admiralty Bay; restricted coves, open inlets, intermediate, and deep-water zone. The same or similar communities appear to inhabit similar environments also in other parts of the South Shetland Islands.

2. The major environmental factors, which dictate foraminiferal distribution, are closely related to bathymetry and distance to open sea. Sediment composition and chlorophyll content appear to have minor influence on foraminiferal assemblages.

3. Most diverse, deep-water faunas dominate water-depths below 200 m, which seems to be the lowest limit of atmospheric and meltwater influence.

4. In waters shallower than 200 m, environmental features, affecting distribution of various benthic foraminiferal assemblages, appear to be sedimentation rate and hydrographic isolation; however, in large part they remain unclear.

5. The results of this study gives promise to use the Admiralty Bay foraminiferal distribution pattern as a paleoenvironmental tool for shallow- to intermediate-water Quaternary marine research in fjord settings of the South Shetland Islands.

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**Appendix A.** Taxonomic appendix.

This list includes all taxa found in Admiralty Bay during recent studies arranged in alphabetical order. References and some taxonomical notes are included. All taxa are illustrated on Figs 9–26, where station numbers and depth intervals of particular specimens are indicated. Station*1-3 refer to location from Gaździcki and Majewski (2003).

*Adercotryma glomerata* (Brady, 1878). Finger and Lipps (1981, pl. 1, fig. 11).
*Angulogerina earlandi* Parr, 1950. Igarashi *et al.* (2001, pl. 11, fig. 7).
*Ammodiscus incertus* (d'Orbigny, 1839). Violanti (1996, pl. 3, fig. 6).
*Ammodiscus incertus discoideus* Cushman, 1917. Finger and Lipps (1981, pl. 1, fig. 9).
*Ammopemphix quadrupla* (Wiesner, 1931). Earland (1934, pl. 2, fig. 3).
*Ammovertellina* sp.
*Armorella spherica* Heron-Allen *et* Earland, 1929. Earland (1933, pl. 7, figs 16–23). Frequently does not possess characteristic appendages. However, it still clearly differs from *P. fusca* by thinner and brighter finely-agglutinated wall, composed of quartz grains predominantly.
*Astrammina rara* Rhumbler, 1931. Bowser *et al.* (1995, pl. 1, fig. 1).
*Astrononion antarcticum* Parr, 1950. Igarashi *et al.* (2001, pl. 12, fig. 10).
*Astrononion echolsi* Kennett, 1967. Finger and Lipps (1981, pl. 3, fig. 6).
*Atlantinella atlantica* (Parker, 1952). Wollenburg and Mackensen (1998, pl. 1, figs 13–15).
*Bolivina pseudopunctata* Höglund, 1947. Ishman and Domack (1994, pl. 2, fig. 5).
*Cassidulinoides parkerianus* (Brady, 1881). Finger and Lipps (1981, pl. 2, fig. 8).
*Cassidulinoides porrectus* (Heron-Allen *et* Earland, 1932). Igarashi *et al.* (2001, pl. 10, fig. 11).
*Cibicides lobatulus* (Walker *et* Jacob, 1798). Osterman and Kellogg (1979, pl. 1, figs 1–3).
*Cibicides* cf. *lobatulus* (Walker *et* Jacob, 1798) differs from *C. lobatulus* by less regular chamber arrangement. By this feature, it resembles *Lobatula lobatula* (Walker *et* Jacob 1789) as pictured by Wollenburg and Mackensen (1998, pl. 4, figs 12–14).
*Cibicides refulgens* de Montfort, 1808. Finger and Lipps (1981, pl. 3, fig. 1).
*Cornuspira involvens* (Reuss, 1850). Finger and Lipps (1981, pl. 2, fig. 1).
*Cornuspira* sp.
*Cribroelphidium* sp.
*Crithionina* sp.
*Dentalina communis* (d'Orbigny, 1826). Violanti (1996, pl. 6, fig. 12).
*Fissurina crebra* (Matthes, 1939). Milam and Anderson (1981, pl. 6, fig. 4).
*Fissurina* cf. *trigonomarginata* (Parker *et* Jones, 1865). The specimen pictured differs from *Fissurina trigonomarginata* pictured by Ward and Webb (1986, pl. 2, fig. 6) by much thicker outline.
*Fissurina* sp. 1
*Fissurina* sp. 2
*Fursenkoina fusiformis* (Williamson, 1858). It represents quite a range in degree of test elongation, as pictured among others by Finger and Lipps (1981, pl. 2, fig. 7), Ishman and Domack (1994, pl. 2, fig. 7), and Violanti (1996, pl. 9, figs 14–15).
*Glandulina antarctica* Parr, 1950. Violanti (1996, pl. 8, fig. 16).

*Globocassidulina biora* (Crespin, 1960). Finger and Lipps (1981, pl. 4, figs 6–7). Some authors (Finger and Lipps 1981; Violanti 1996) tend to distinguish *G. biora* from *G. rossensis* basing on apertural morphology. However, the multi-aperture abnormal specimen pictured on Fig. 23.8 shows quite a variety of apertural shapes in *G. biora* itself.

?*Globofissurella* sp. Igarashi *et al.* (2001, pl. 7, fig. 2).

*Glomospira gordialis* (Jones *et* Parker, 1860). Violanti (1996, pl. 3, fig. 9).

*Glomospira* sp.

*Gordiospira fragilis* (Heron-Allen *et* Earland, 1932). Milam and Anderson (1991, pl. 5, fig. 4).

*Hemisphaerammina bradyi* (Loeblich *et* Tappan, 1957). Violanti (1996, pl. 2, fig. 13). There appear to be two types. “Large” variance (Fig. 10.1) was found only in station 10 (isolated Monsimet Cove), were it grown over small bivalves, whereas “small” variance (Fig. 10.3) is common in more open inlets.

*Hippocrepinella hirudinea* (Heron-Allen *et* Earland, 1932). Finger and Lipps (1981, pl. 1, fig. 2).

*Hormosinella ovicula gracilis* (Earland, 1933). Violanti (1996, pl. 3, fig. 15).

*Hormosinella* sp.

*Hyalinonetrion gracillima* (Seguenza, 1862). Zhang (1994, pl. 4, figs 1–2).

*Labrospira jeffreysii* (Williamson, 1858). Zhang (1994, pl. 2, figs 15–16).

*Labrospira wiesneri* Parr, 1950. Milam and Anderson (1991, pl. 2, fig. 6). It differs clearly from *L. jeffreysii* by very finely agglutinated test-walls.

*Lagena* cf. *heronalleni*. Differs from *Lagena heronalleni* Earland, 1934 (pl. 6, figs 55–57) by presence of single or paired thin ribs between the main chain-rib structures.

*Lagena squamososulcata* Heron-Allen *et* Earland, 1922 (pl. 5, fig. 15).

*Lagena subacuticosta* Parr, 1950. Violanti (1996, pl. 7, fig. 1).

*Lagenammina arenulata* (Skinner, 1961). Igarashi *et al.* (2001, pl. 1, fig. 12). There appear to be three types that differ in size. Among the three types, percentage of cement increases with greater size. Distribution map of this species (Fig. 3f) also suggests a presence of at least two types; shallow- and deep-water.

*Laryngosigma hyalascidia* Loeblich *et* Tappan, 1953. Ward and Webb (1986, pl. 11, fig. 4).

*Lenticulina* sp.

*Miliammina arenacea* (Chapman, 1916). Finger and Lipps (1981, pl. 1, fig. 10).

*Miliammina lata* Heron-Allen *et* Earland, 1930. Violanti (1996, pl. 3, fig. 12).

*Nodulina dentaliniformis* (Brady, 1884). Violanti (1996, pl. 3, figs 16–17).

*Nodulina kerguelensis* (Parr, 1950). Igarashi *et al.* (2001, pl. 2, fig. 14).

*Nodulina subdentaliniformis* (Parr, 1950). Violanti (1996 pl. 3, fig. 18).

*Nonionella bradii* (Chapman, 1916). Violanti (1996, pl. 10, figs 8, 13).

*Nonionella iridea* Herron-Allen *et* Earland, 1932. Schmiedl (1995, pl. 3, figs 15–16).

*Oolina felsinea* (Fornasini, 1894). Igarashi *et al.* (2001, pl. 8, fig. 2).

*Oolina globosa caudigera* (Wiesner, 1931). Igarashi *et al.* (2001, pl. 8, fig. 1).

*Oolina lineata* (Williamson, 1848). Anderson (1975, pl. 7, fig. 16) specimen is devoid of apertural tube pictured by McKnight (1962, pl. 19, fig. 118) and Violanti (1996, pl. 7, fig. 14).

*Parafissurina fusiformis* (Wiesner, 1931). As also pictured by Finger and Lipps (1981, pl. 2, fig. 5), Violanti (1996, pl. 8, fig. 8), and Igarashi *et al.* (2001, pl. 9, fig. 5), it represents quite a range of test elongation.

*Paratrochammina (Lepidoparatrochammina) bartmani* (Hedley, Hurdle *et* Burdett, 1967). Igarashi *et al.* (2001, pl. 3, fig. 10).

*Paratrochammina (Lepidoparatrochammina) lepida* Brönnimann *et* Whittaker, 1988. Igarashi *et al.* (2001, pl. 3, fig. 11).

*Patellina corrugata* Williamson, 1858. Igarashi *et al.* (2001, pl. 1, fig. 4).

*Pelosina* sp.

*Planispirinoides* sp.

*Portatrochammina antarctica* (Parr, 1950). Milam and Anderson (1991, pl. 4, fig. 3). *Portatrochammina antarctica* is regarded by some as synonymous with *P. malovensis* (Finger and Lipps 1981). However, Igarashi *et al.* (2001) and Violianti (1996) believe otherwise. Igarashi *et al.* (2001) considered two species established by Parr; *P. antarctica* and *P. wiesneri*, as two subspecies of *P. antarctica*. Here they are not differentiated.

*Portatrochammina bipolaris* (Brönnimann *et* Whittaker, 1980). Igarashi *et al.* (2001, pl. 4, fig. 7).

*Portatrochammina* cf. *bipolaris* Brönnimann *et* Whittaker, 1980. It is clearly recognizable from *P. bipolaris* by more spherical and well visible inner chambers on the spiral test-side.

*Procerolagena gracilis* (Williamson, 1848). Zhang (1994, pl. 4, fig. 3).

*Proteonina decorata* Earland, 1933 (pl. 1, figs 28–29). As also noted by Earland (1933), it is easily distinguished by great contrast between large, exclusively black sediment grains surrounded by abundant, almost white cementation.

*Psammosphaera fusca* Schulze, 1875. Igarashi *et al.* (2001, pl. 1, fig. 11).

*Psammosphaera rustica* Heron-Allen *et* Earland, 1912. Earland (1933, pl. 1, fig. 27).

?*Psammosphaera* sp.

*Pseudobulimina chapmani* (Heron-Allen *et* Earland, 1922). Igarashi *et al.* (2001, pl. 10, fig. 4).

*Pseudofissurina mccullochae* Jones, 1984. Igarashi *et al.* (2001, pl. 10, fig. 3).

*Pullenia subcarinata* (d'Orbigny, 1839). Fillon (1974, pl. 6, figs 7–8).

*Pullenia* cf. *subcarinata* (d'Orbigny, 1839). The shape of this single specimen resembles *Pullenia bulloides* (d'Orbigny, 1826); however, its presence together with large population of *P. subcarinata*, which also represents large variety of test-shape, suggests it should be placed with the latter.

*Pyrgo bulloides* (d'Orbigny, 1826). Herb (1971, pl. 1, fig. 9).

*Pyrgo depressa* (d'Orbigny, 1826). Igarashi *et al.* (2001, pl. 6, fig. 8).

*Pyrgo elongata* (d'Orbigny, 1826). Igarashi *et al.* (2001, pl. 6, fig. 7).

*Pyrgo* sp.

*Quinqueloculina* cf. *seminulum* (Linné, 1758) *sensu* Collins *et al.* (1996, pl. 1, fig. 4).

*Quinqueloculina weaveri* Rau, 1948. Corliss (1991, pl. 1, fig. 10).

*Quinqueloculina* sp. 1.

*Quinqueloculina* sp. 2.

*Quinqueloculina* sp. 3.

*Quinqueloculina* sp. 4.

?*Quinqueloculina* sp.

*Recurvoides contortus* Earland, 1934. Violanti (1996, pl. 4, figs 10–11).

*Reophax pilulifer* Brady, 1884. Herb (1971, pl. 10, figs 3–5).

*Reophax scorpiurus* de Montfort, 1808. Violanti (1996, pl. 4, fig. 3).

*Reophax* sp.

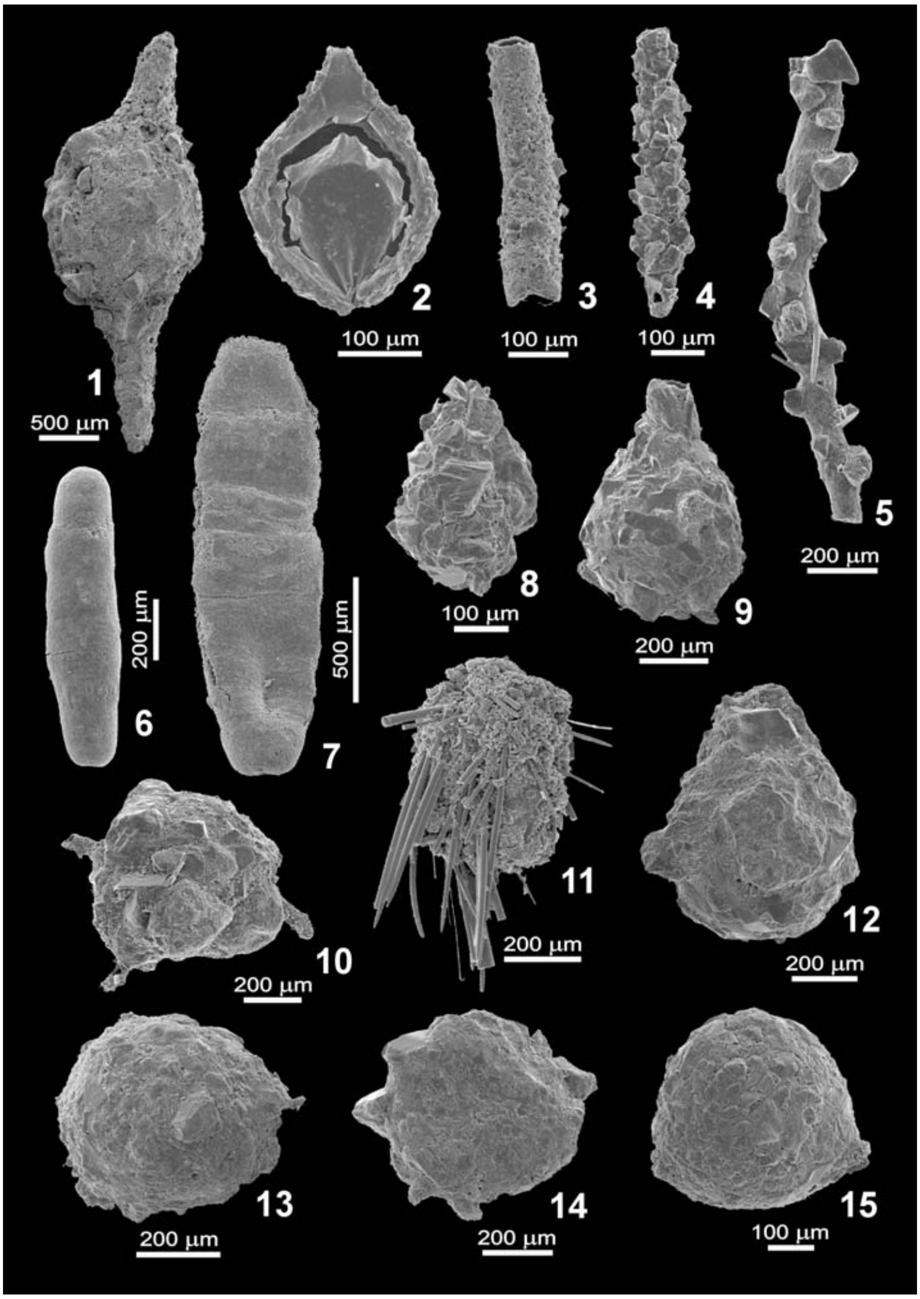


Fig. 9. **1**. *Pelosina* sp.; 8, 0–1 cm. **2**. *Vanhoefenella gaussi* Rhumbler, 1905; 36, 6–7 cm. **3–5**. *Rhabdammina* sp.; 28, 2–3 cm, 9, 0–1 cm, 34, 2.5–5 cm. **6–7**. *Hippocrepinella hirudinea* (Heron-Allen *et* Earland, 1932); 11, 0–1 cm. **8–9**, **12**. *Lagenammina arenulata* (Skinner, 1961); station*1, 9, 7–8 cm, 9, 4–5 cm. **10**. *Astrammina rara* Rhumbler, 1931; 8, 1–2 cm. **11**. *Psammosphaera rustica* Heron-Allen *et* Earland, 1912; 36, 1–2 cm. **13**. *Psammosphaera fusca* Schulze, 1875; station*1. **14–15**. *Armorella spherica* Heron-Allen *et* Earland, 1929; 8, 9–10 cm, 6, 0–1 cm.

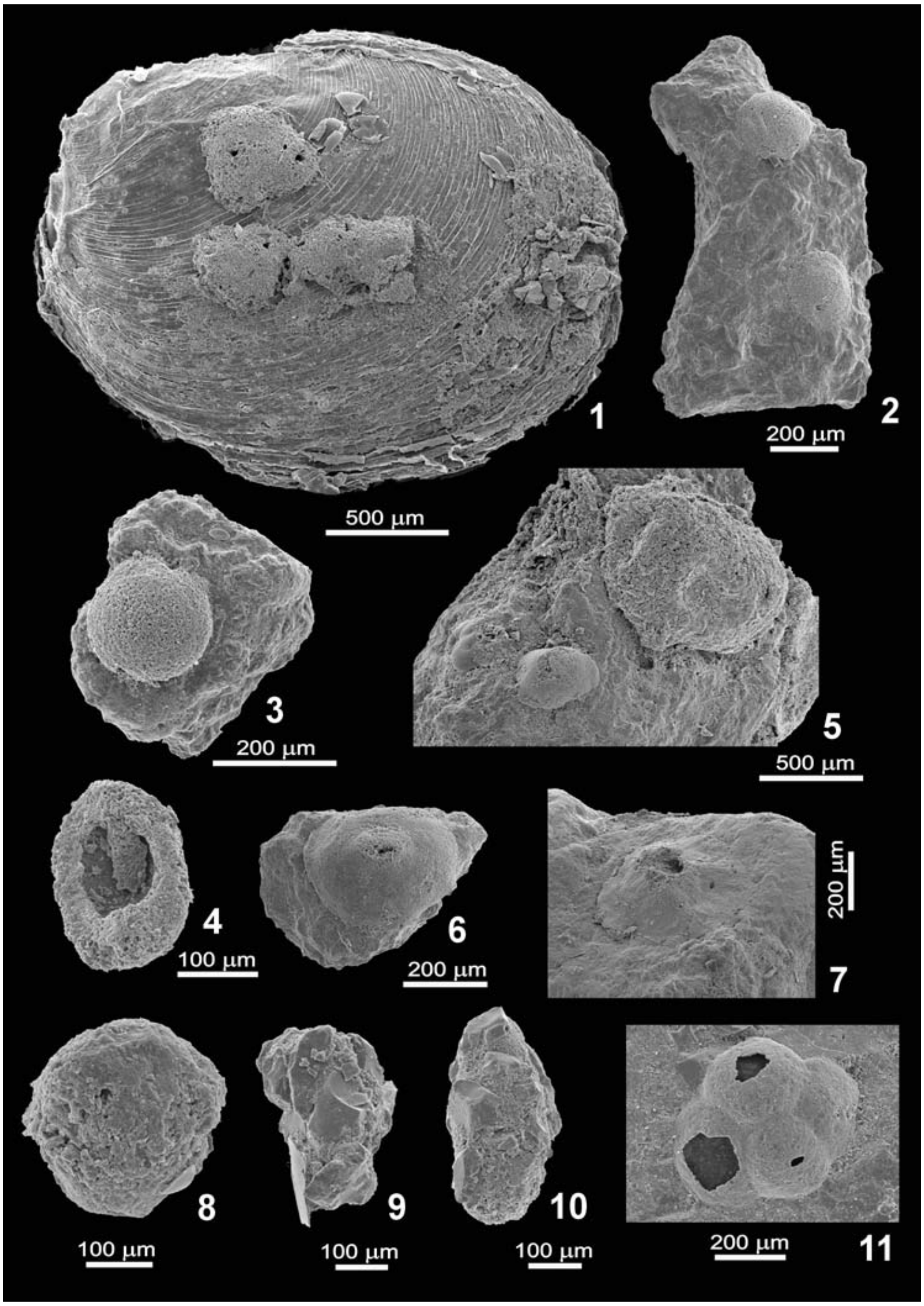


Fig. 10. **1**–**5**. *Hemisphaerammina bradyi* (Loeblich *et* Tappan, 1957); 10, 4–5 cm, 5, 7–8 cm, 5, 4–5 cm, 27, 10–15 cm, 36, 5–6 cm. **6**–**7**. *Tholosina centroforata* Rhumbler, 1935; 16, 0–1 cm, 34, 0–2.5 cm. **8**. *Crithionina* sp.; 7, 0–1 cm. **9.** ?*Psammosphaera* sp.; 32, 0–1 cm. **10**. *Proteonina decorata* Earland, 1933; 35, 1–2 cm. **11**. *Ammopemphix quadrupla* (Wiesner, 1931); 34, 2.5–5 cm.

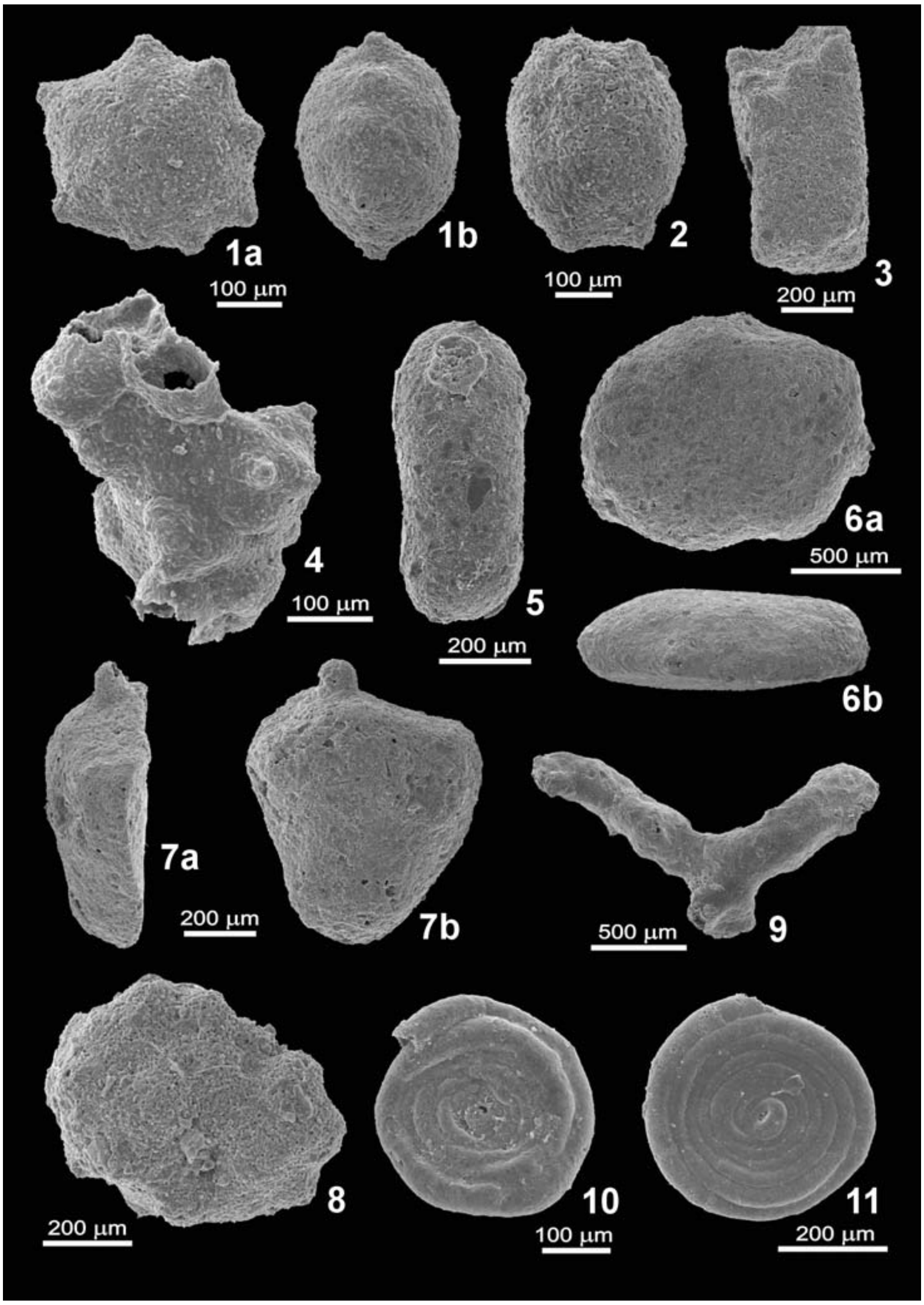


Fig. 11. **1–2**, **4**. *Thurammina corrugata* Earland, 1934; 38, 1–2 cm, 37, 3–4 cm, 38, 4–5 cm. **3**. *Thurammina* cf. *corrugata* Earland, 1934; 35, 4–5 cm. **5–6**. *Webbinella limosai* Earland, 1933; 35, 4–5 cm, 4, 6–7 cm. **7**. *Webbinella* cf. *limosai* Earland, 1933; 18, 7–8 cm. **8**. *Webbinella* cf. *limosai* Earland, 1933; 36, 4–5 cm. **9**. *Saccorhiza* sp.; 16, 0–1 cm. **10**. *Ammodiscus incertus* (d'Orbigny, 1839); 9, 2–3 cm. **11**. *Ammodiscus incertus discoideus* Cushman, 1917; 38, 5–6 cm.

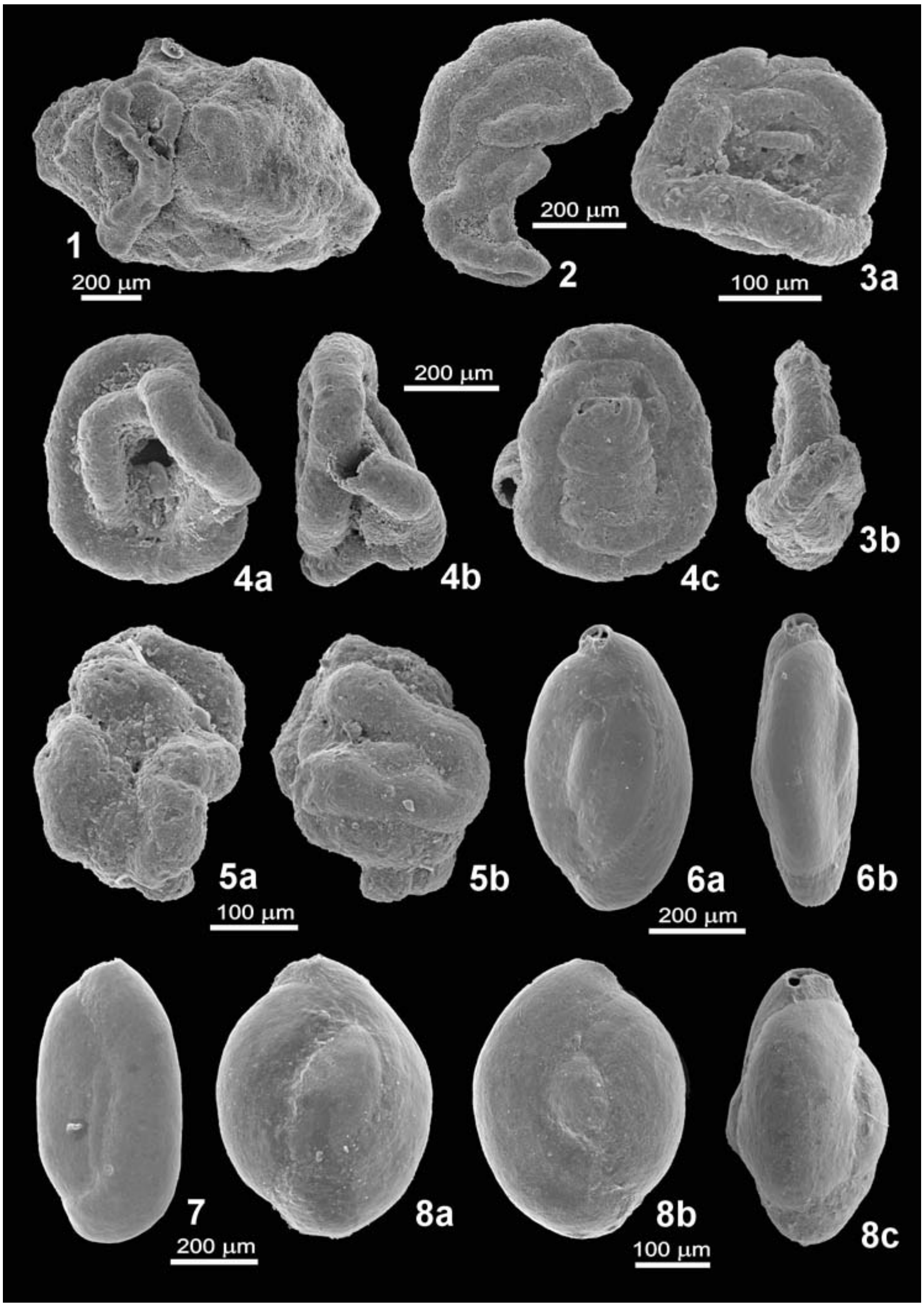


Fig. 12. **1**–**2**. *Tolypammina vagans* (Brady, 1879); 8, 2–3 cm, 32, 3–4 cm. **3**. *Ammovertellina* sp.; 34, 0–2.5 cm. **4**. *Glomospira gordialis* (Jones *et* Parker, 1860); 36, 1–2 cm. **5**. ?*Glomospira* sp.; 37, 3–4 cm. **6**–**7**. *Miliammina arenacea* (Chapman, 1916); station*1. **8**. *Miliammina lata* Heron-Allen *et* Earland, 1930; 24, 0–1 cm.

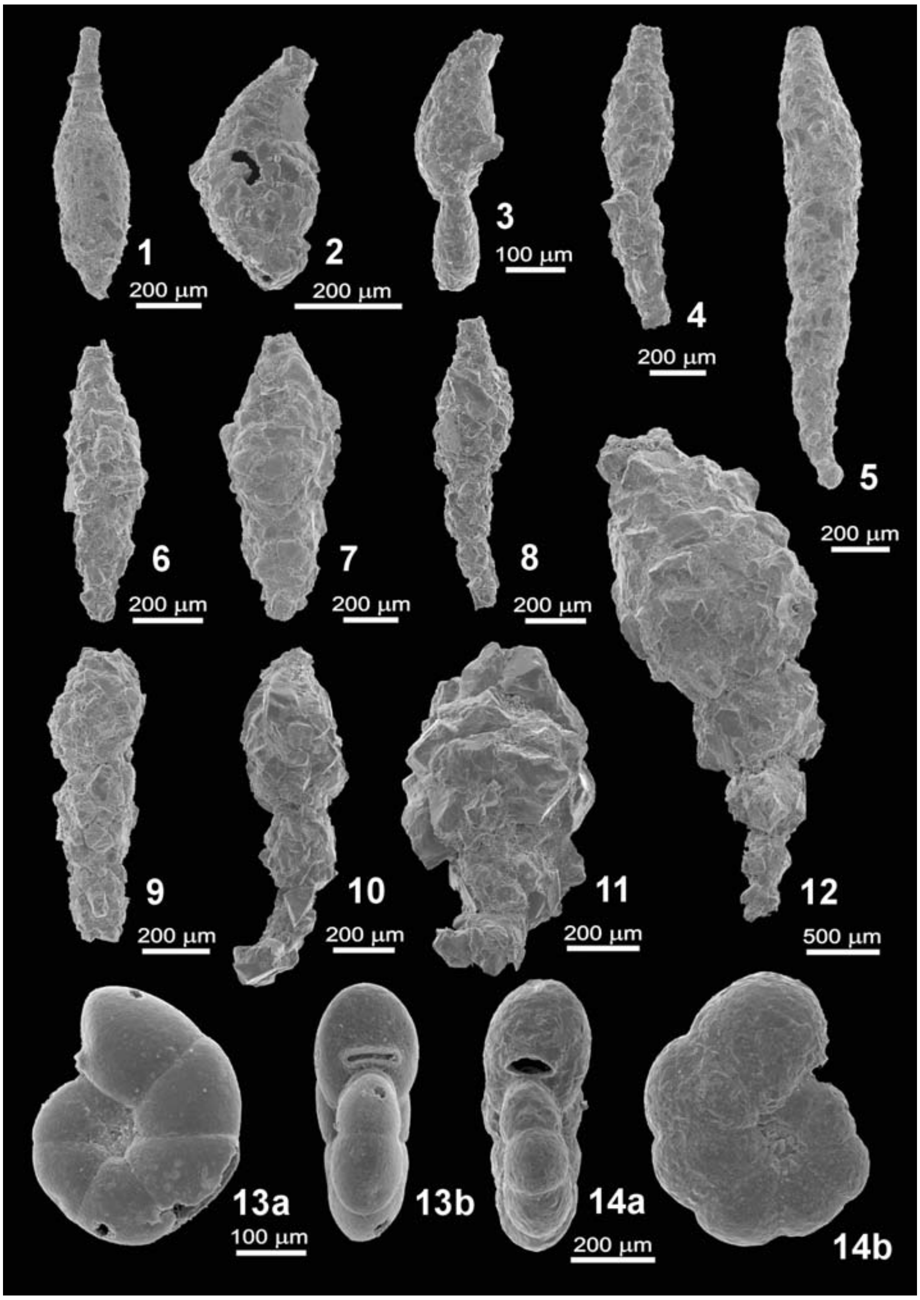


Fig. 13. **1**. *Hormosinella ovicula gracilis* (Earland, 1933); 35, 2–3 cm. **2–3**. *Hormosinella* sp.; 9, 6–7 cm, 11, 3–4 cm. **4–5**. *Nodulina dentaliniformis* (Brady, 1884); 36, 2–3 cm, 8, 2–3 cm. **6–7**. *Nodulina subdentaliniformis* (Parr, 1950); 17, 0–1 cm, 36, 2–3 cm. **8**. *Nodulina kerguelensis* (Parr, 1950); 9, 0–1 cm. **9.** *Reophax* sp.; 6, 1–2 cm. **10**. *Reophax scorpiurus* de Montfort, 1808; 36, 2–3 cm. **11–12**. *Reophax pilulifer* Brady, 1884; 8, 9–10 cm, 8, 1–2 cm. **13**. *Labrospira wiesneri* Parr, 1950; 32, 4–5 cm. **14**. *Labrospira jeffreysii* (Williamson, 1858); 19, 6–7 cm.

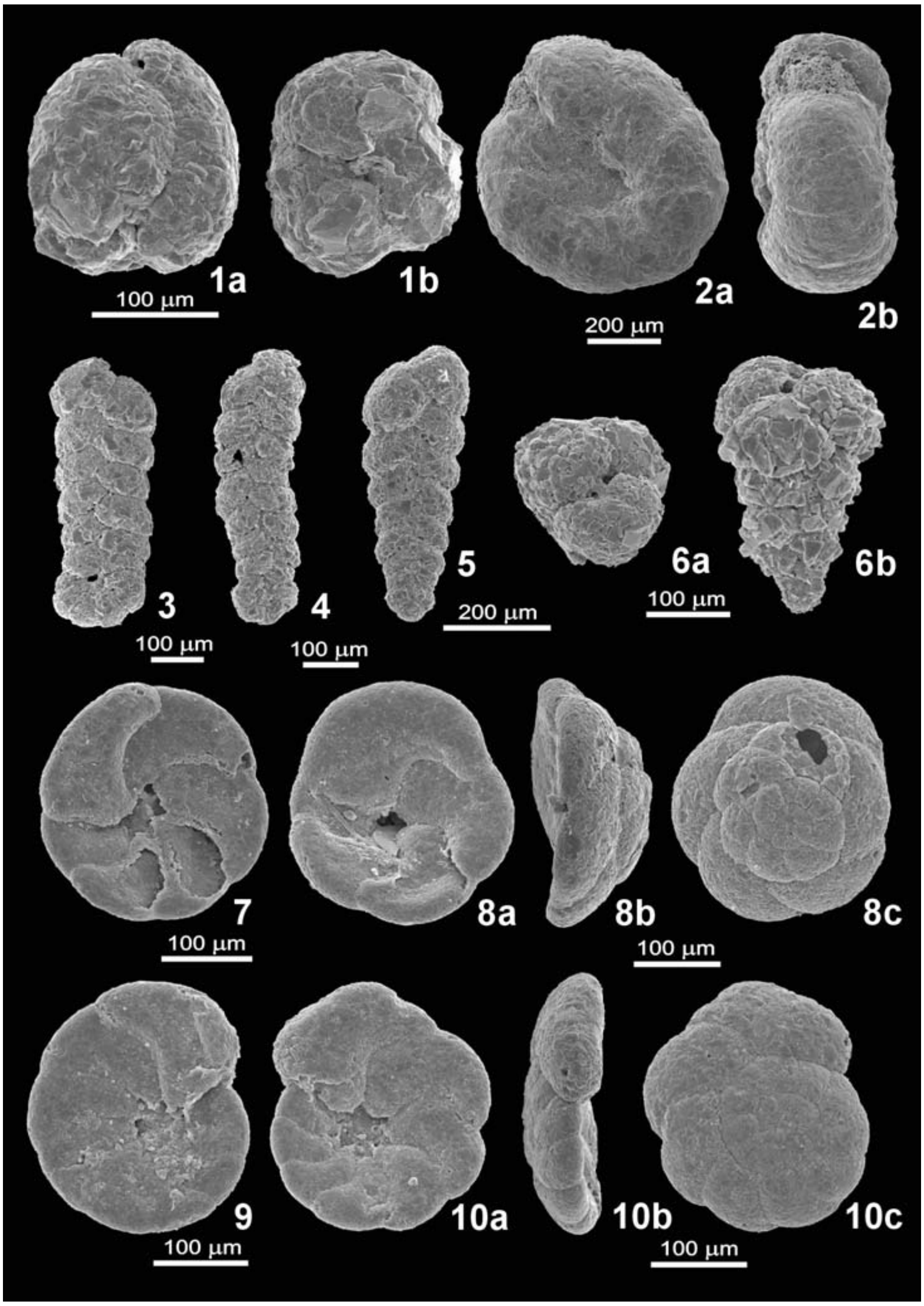


Fig. 14. **1**. *Adercotryma glomerata* (Brady, 1878); 30, 1–2 cm. **2**. *Recurvoides contortus* Earland, 1934; 34, 2.5–5 cm. **3–5**. Spiroplectammina biformis (Parker *et* Jones, 1865); station*1, 9, 2–3 cm, 7, 9–10 cm. **6**. *Rhumblerella* sp.; 3, 5–6 cm. **7–8**. *Paratrochammina (Lepidoparatrochammina) bartmani* (Hedley, Hurdle *et* Burdett, 1967); 12, 5–6 cm, 16, 4–5 cm. **9–10**. *Paratrochammina (Lepidoparatrochammina) lepida* Brönnimann *et* Whittaker, 1988; 9, 7–8 cm, 18, 3–4 cm.

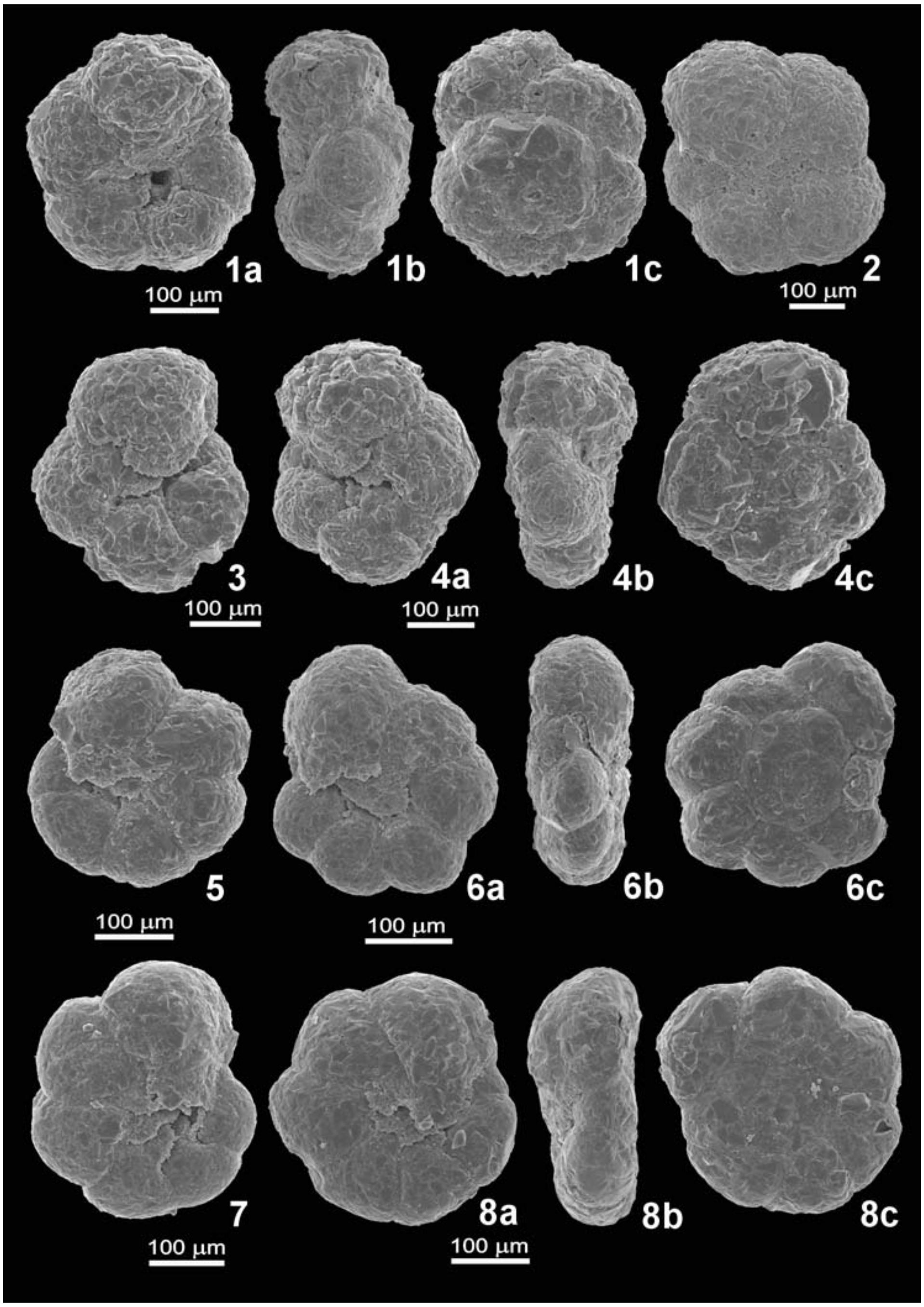


Fig. 15. **1–4**. *Portatrochammina antarctica* (Parr, 1950); 7, 9–10 cm, station*1, 13, 7–8 cm, 5, 8–9 cm. **5–6**. *Portatrochammina* cf. *bipolaris* Brönnimann *et* Whittaker, 1980; 3, 6–7 cm, 38, 3–4 cm. **7–8**. *Portatrochammina bipolaris* (Brönnimann *et* Whittaker, 1980); 9, 6–7 cm, 32, 8–9 cm.

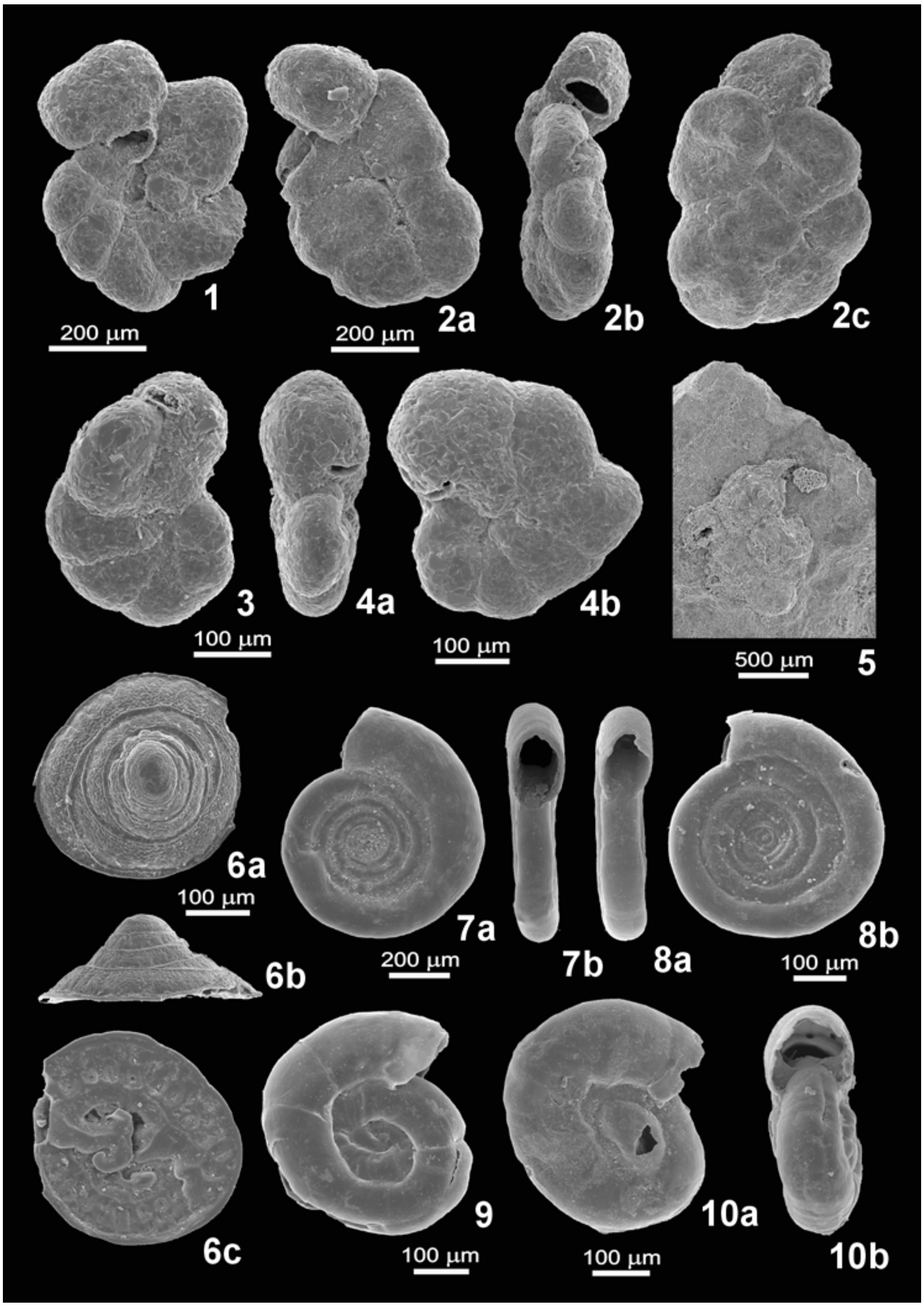


Fig. 16. **1**–**4**. *Atlantinella atlantica* (Parker, 1952); 31, 0–1 cm, 22, 1–2 cm, 36, 4–5 cm, 22, 1–2 cm. **5**. *Sorosphaera* sp.; 36, 1–2 cm. **6**. *Patellina corrugata* Williamson, 1858; 11, 3–4 cm. **7.** *Cornuspira* sp.; 9, 2–3 cm. **8**. *Cornuspira involvens* (Reuss, 1850); 23, 0–1 cm. **9**–**10**. *Gordiospira fragilis* (Heron-Allen *et* Earland, 1932); 21, 0–1 cm.

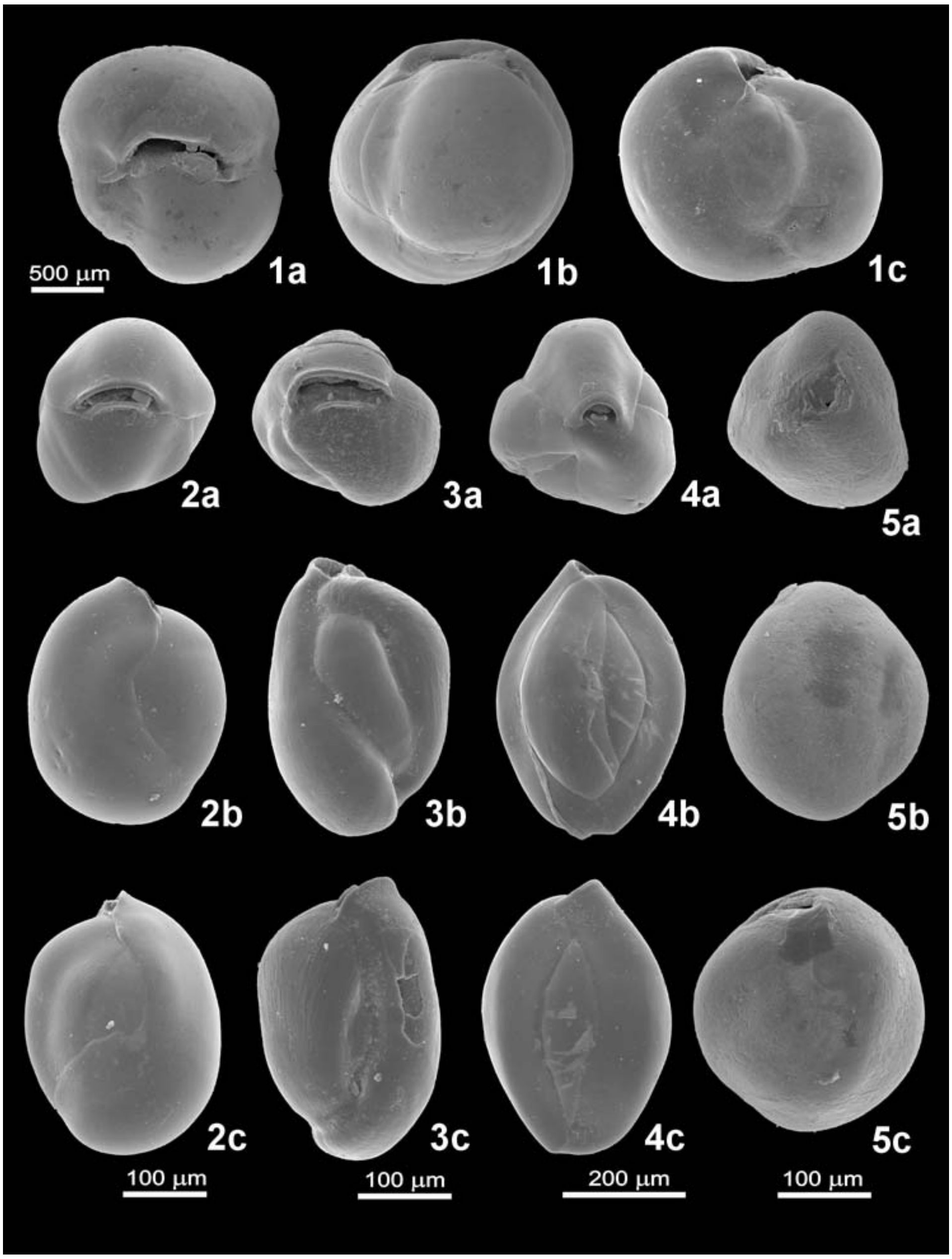


Fig. 17. **1**. *Planispirinoides* sp.; 26, 0–1 cm. **2**. *Quinqueloculina* sp. 4; 36, 0–1 cm. **3**. *Quinqueloculina* cf. *seminulum* (Linné, 1758); 38, 0–1 cm. **4**. *Quinqueloculina weaveri* Rau, 1948; 38, 0–1 cm. **5**. ?*Quinqueloculina* sp.; 29, 0–2.5 cm.

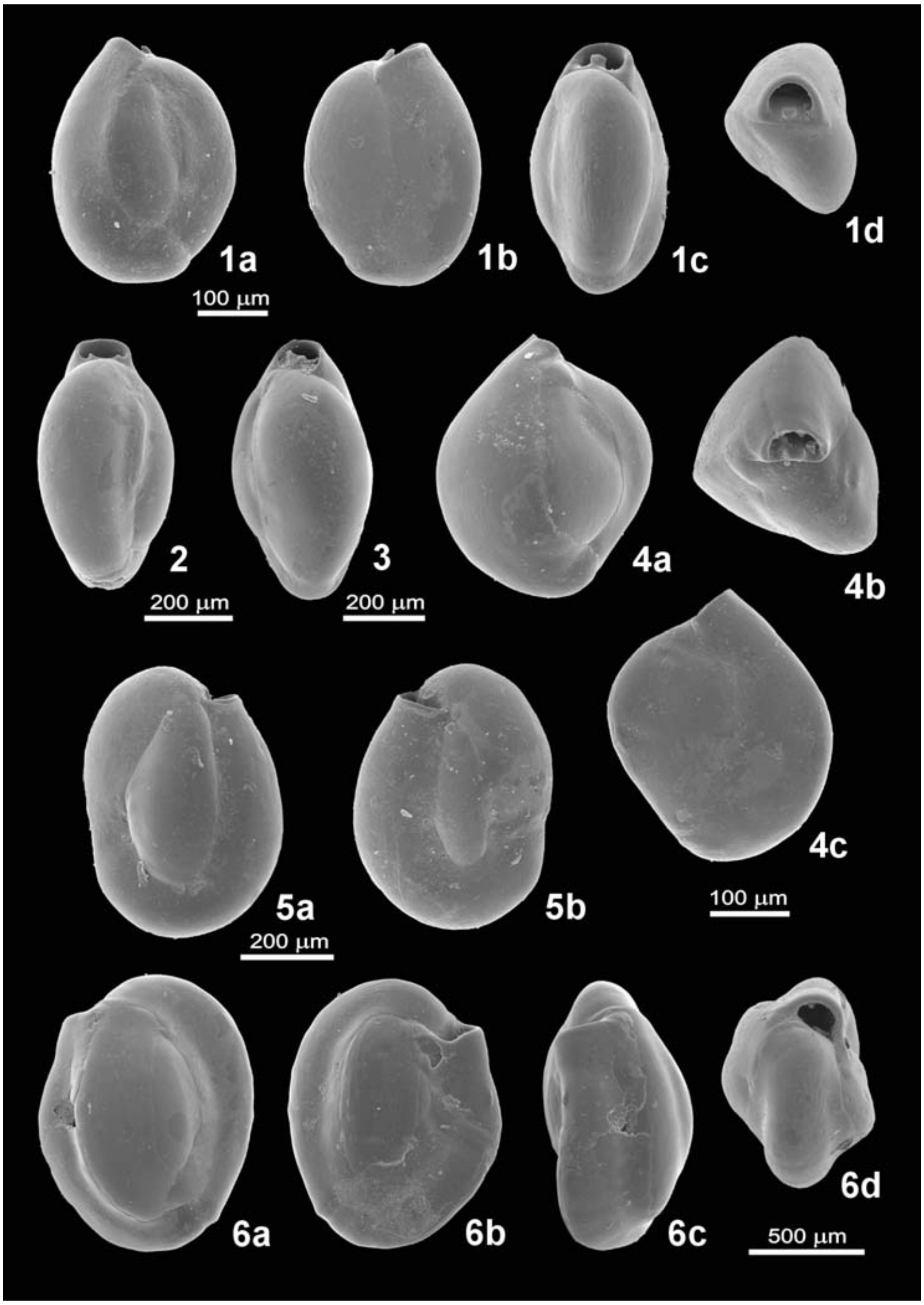


Fig. 18. **1**–**3**. Quinqueloculina sp. 1; 2, 0–1 cm, 5, 10–15 cm, 20, 0–1 cm. **4**. Quinqueloculina sp. 2; 33, 0–1 cm. **5**–**6**. Quinqueloculina sp. 3; 5, 8–9 cm, 38, 0–1 cm.

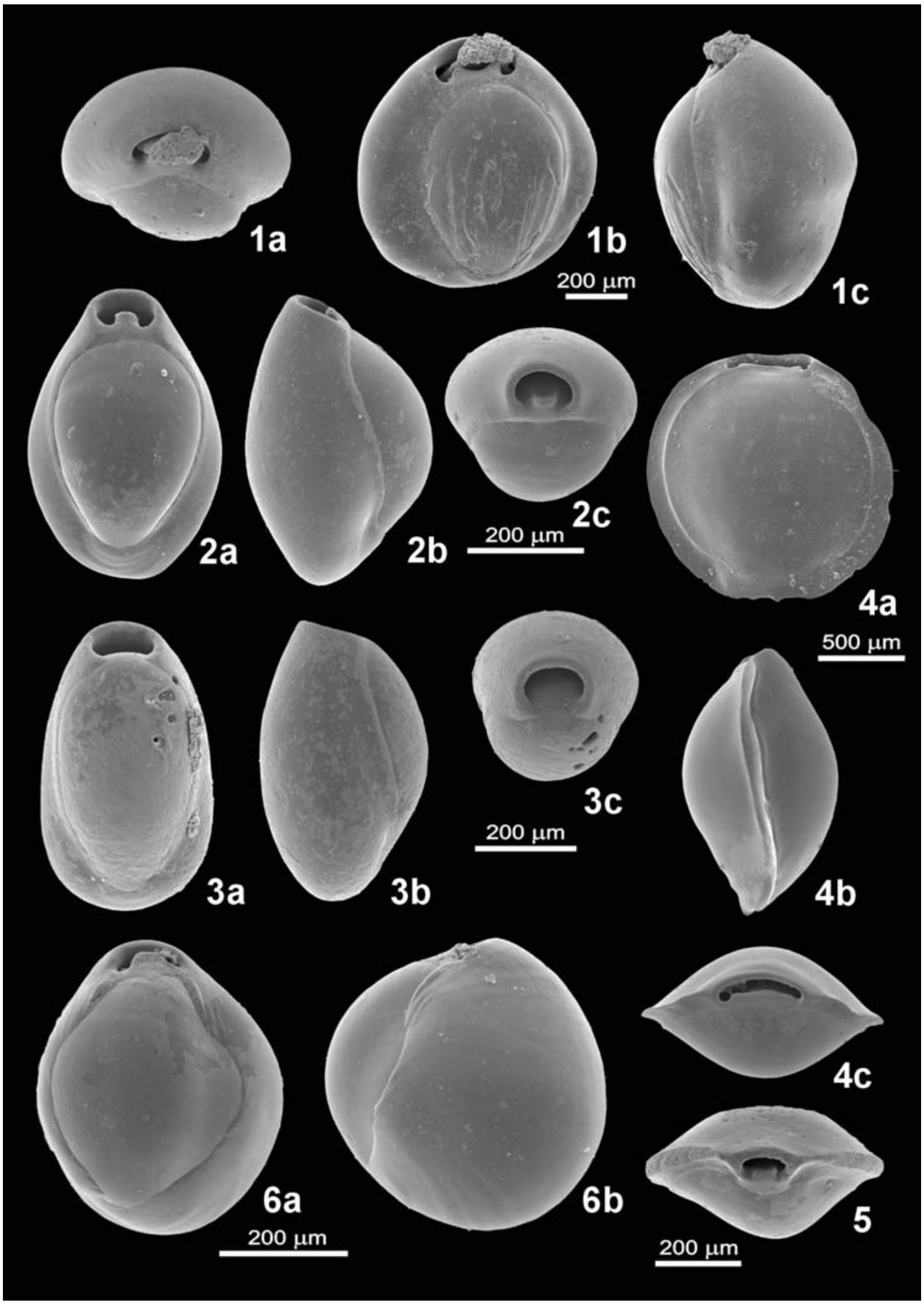


Fig. 19. **1**. *Pyrgo bulloides* (d'Orbigny, 1826); 6, 0–1 cm. **2**. *Pyrgo elongata* (d'Orbigny, 1826); 33, 10–15 cm. **3**. *Pyrgo* sp.; 33, 10–15 cm. **4–5**. *Pyrgo depressa* (d'Orbigny, 1826); 8, 0–1 cm, 34, 2.5–5 cm. **6**. ? *Sigmoilina* sp.; 34, 2.5–5 cm

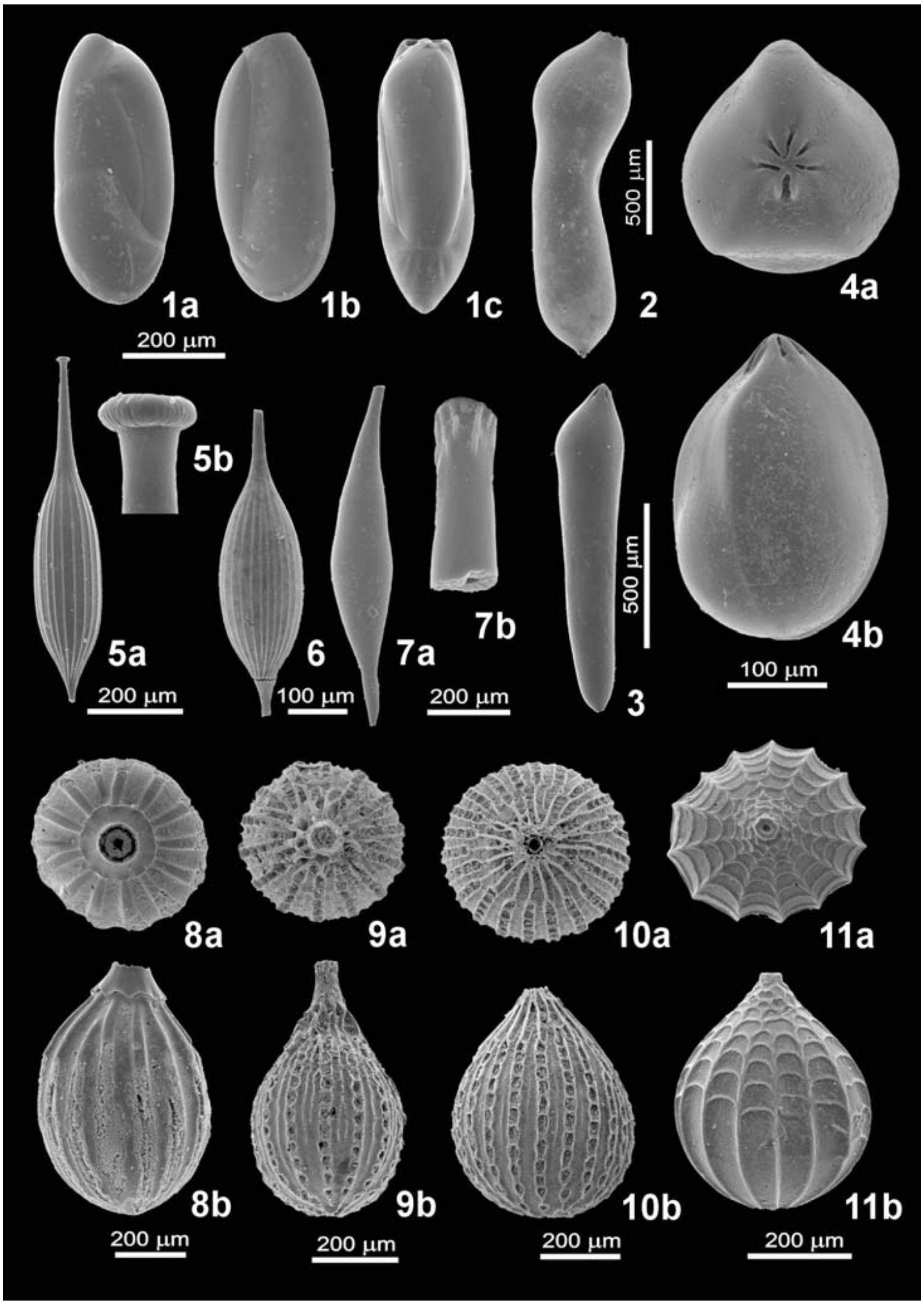


Fig. 20. **1**. *Triloculinella antarctica* (Kennett, 1967); 28, 2–3 cm. **2–3**. *Dentalina communis* (d'Orbigny, 1826); 18, 5–6 cm, 23, 8–9 cm. **4**. *Lenticulina* sp.; 36, 6–7 cm. **5–6**. *Procerolagena gracilis* (Williamson, 1848); 25, 2–3 cm, station*1. **7**. *Hyalinonetrion gracillima* (Seguenza, 1862); 33, 8–9 cm. **8**. *Lagena subacuticosta* Parr, 1950; 35, 9–10 cm. **9–10**. *Lagena* cf. *heronalleni* Earland, 1934; 35, 5–6 cm, 33, 1–2 cm. **11**. *Lagena squamososulcata* Heron-Allen *et* Earland, 1922; 26, 3–4 cm.

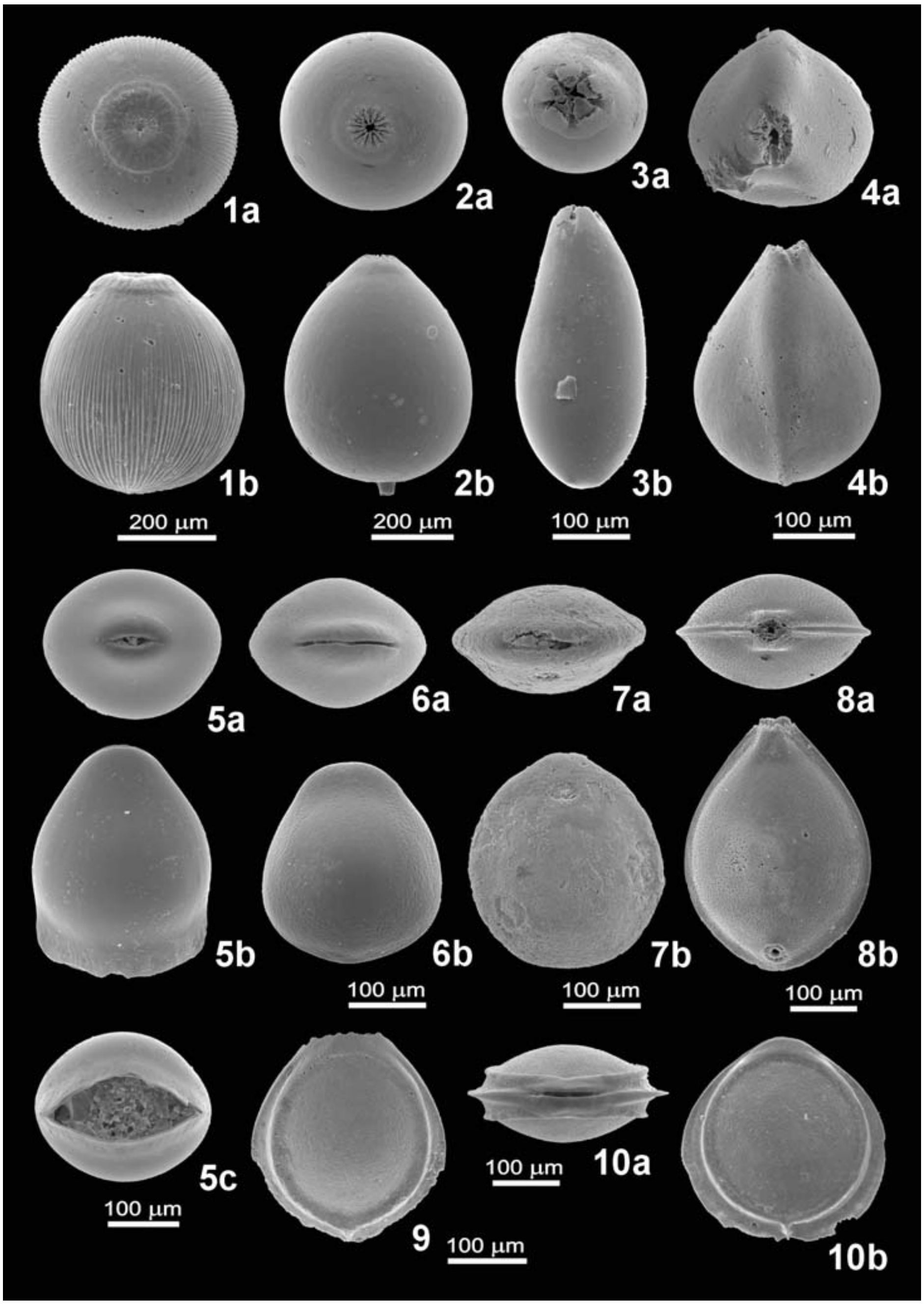


Fig. 21. **1**. *Oolina lineata* (Williamson, 1848); 34, 2.5–5 cm. **2**. *Oolina globosa caudigera* (Wiesner, 1931); 25, 3–4 cm. **3**. *Oolina felsinea* (Fornasini, 1894); 19, 0–1 cm. **4**. *Fissurina* cf. *trigono-marginata* (Parker *et* Jones, 1865); 36, 2–3 cm. **5**. *Fissurina* sp. 1; 38, 0–1 cm. **6**. *Fissurina* sp. 2; 26, 3–4 cm. **7**. ?*Globofissurella* sp.; 33, 8–9 cm. **8**. *Fissurina crebra* (Matthes, 1939); 35, 0–1 cm. **9**–**10**. *Pseudofissurina mccullochae* Jones, 1984; 35, 0–1 cm, 38, 2–3 cm.

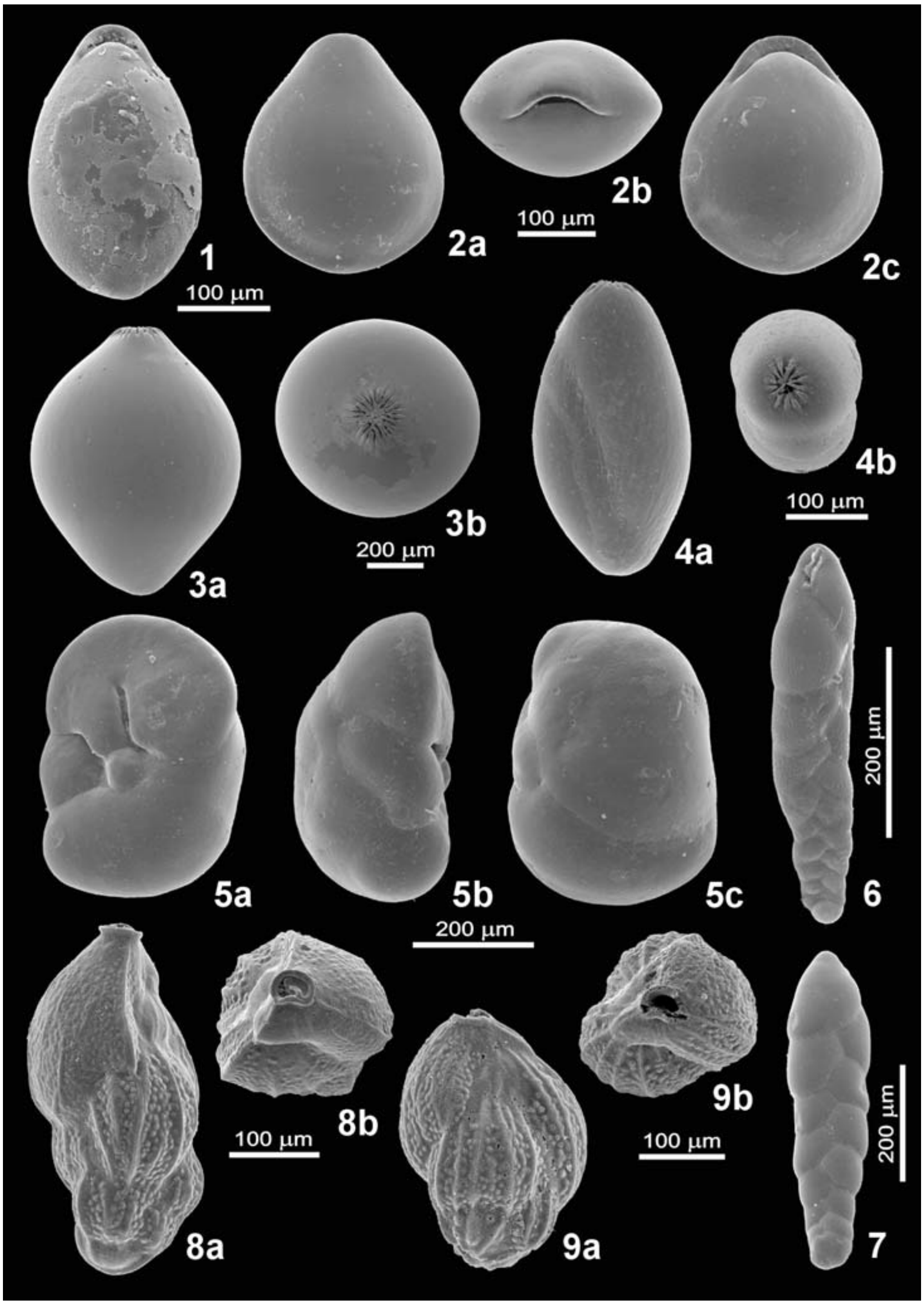


Fig. 22. **1**–**2**. *Parafissurina fusiformis* (Wiesner, 1931); 35, 1–2 cm, 36, 3–4 cm. **3**. *Glandulina antarctica* Parr, 1950; 34, 2.5–5 cm. **4**. *Laryngosigma hyalascidia* Loeblich *et* Tappan, 1953; 27, 5–6 cm. **5**. *Pseudobulimina chapmani* (Heron-Allen *et* Earland, 1922); 34, 2.5–5 cm. **6**–**7**. *Bolivina pseudopunctata* Höglund, 1947; 28, 4–5 cm, 28, 3–4 cm. **8**–**9**. *Angulogerina earlandi* Parr, 1950; 3, 5–6 cm, 8, 9–10 cm.

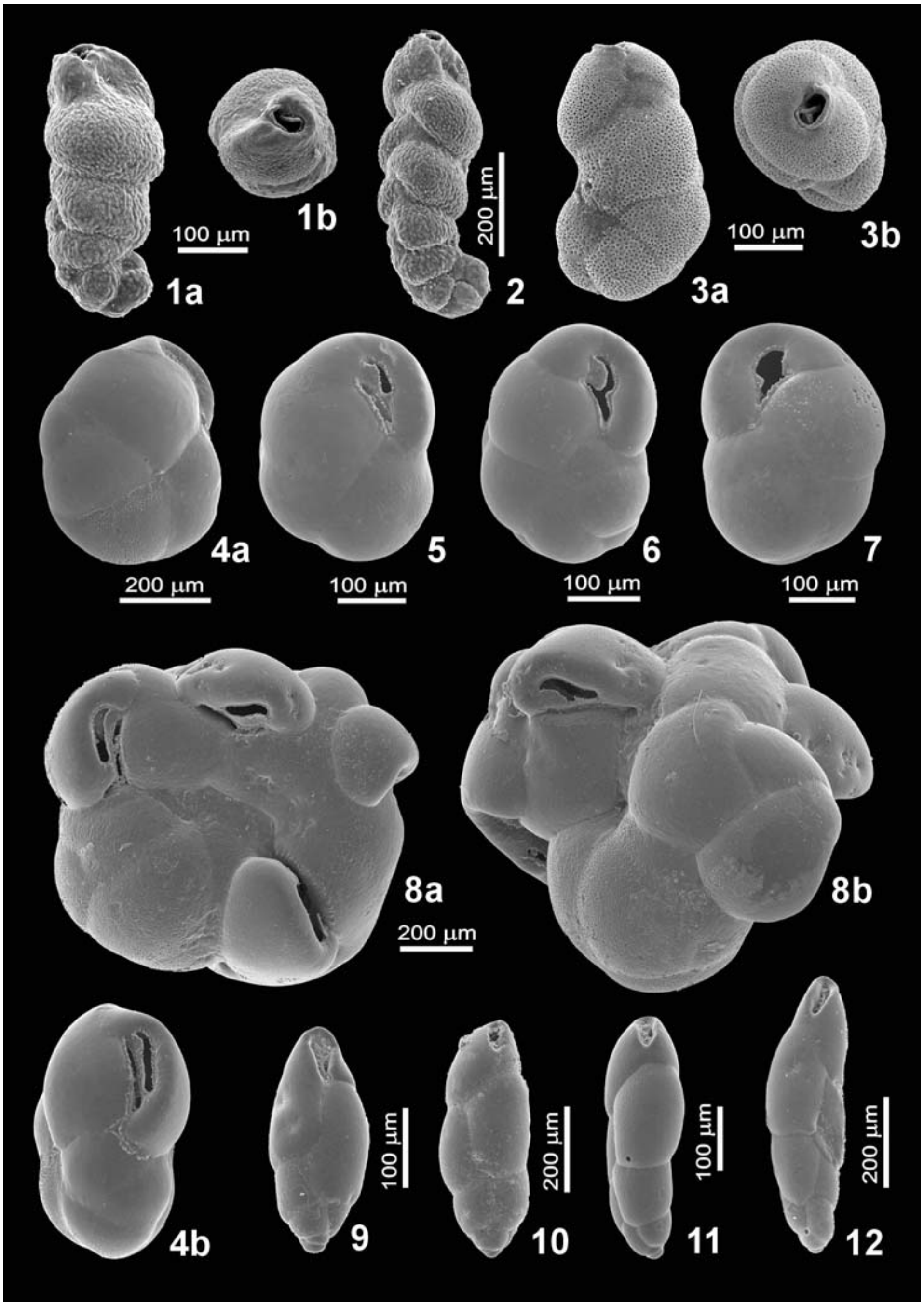


Fig. 23. **1–2**. *Cassidulinoides parkerianus* (Brady, 1881); 12, 9–10 cm, 17, 0–1 cm. **3**. *Cassidulinoides porrectus* (Heron-Allen *et* Earland, 1932); 8, 3–4 cm. **4–8**. *Globocassidulina biora* (Crespin, 1960); station*3 (4–7), 21, 4–5 cm (abnormal specimen). **9–12**. *Fursenkoina fusiformis* (Williamson, 1858); 17, 8–9 cm, 7, 0–1 cm, 15, 8–9 cm, 19, 7–8 cm.

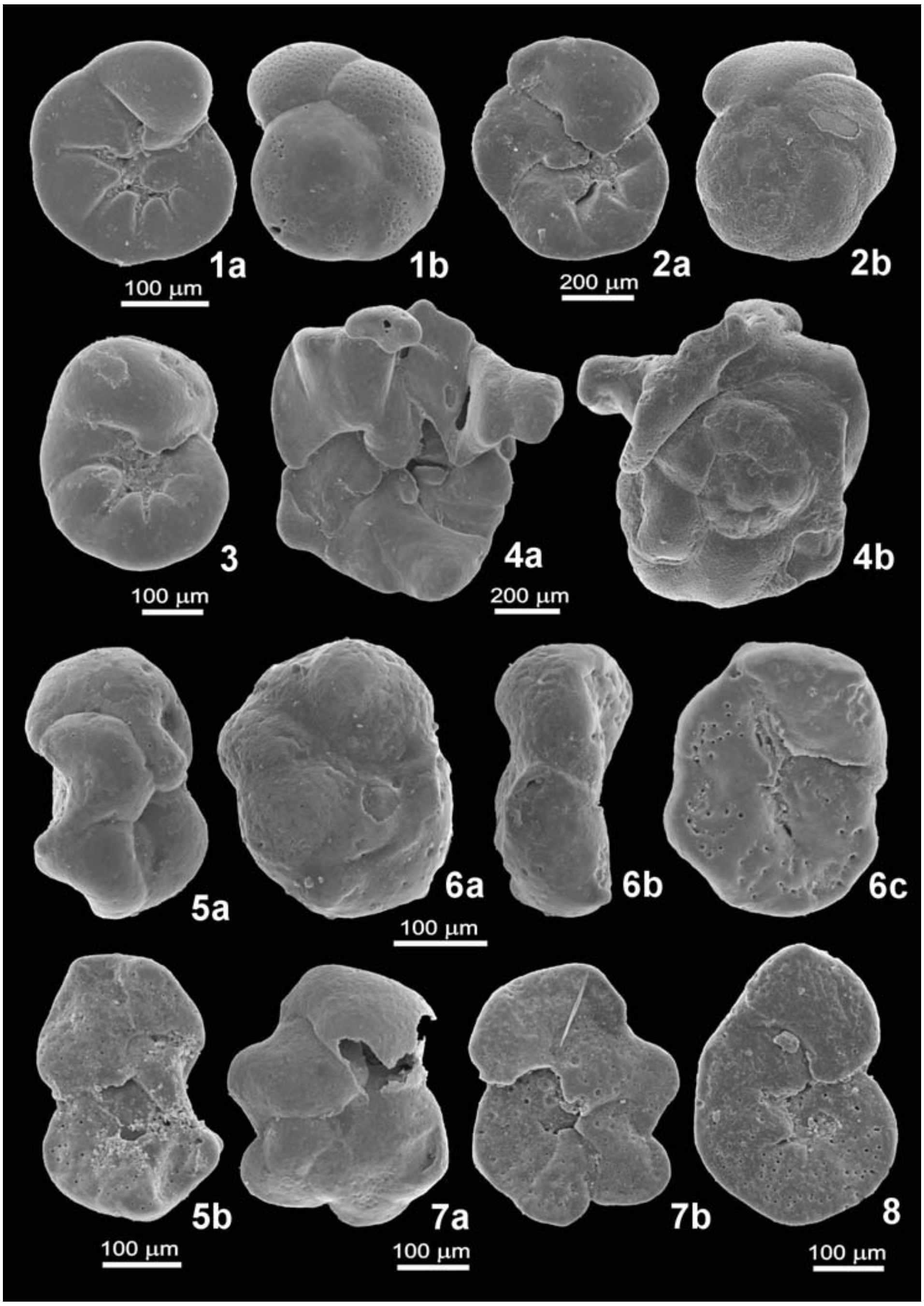


Fig. 24. **1**–**4**. *Rosalina globularis* d'Orbigny, 1826; 18, 8–9 cm, 18, 10–15 cm, 3, 1–2 cm, 30, 8–9 cm. **5**–**6**. *Cibicides* cf. *lobatulus* (Walker *et* Jacob, 1798); 3, 5–6 cm, 3, 3–4 cm, **7**–**8**. *Cibicides lobatulus* (Walker *et* Jacob, 1798); 26, 4–5cm, 22, 2–3 cm.

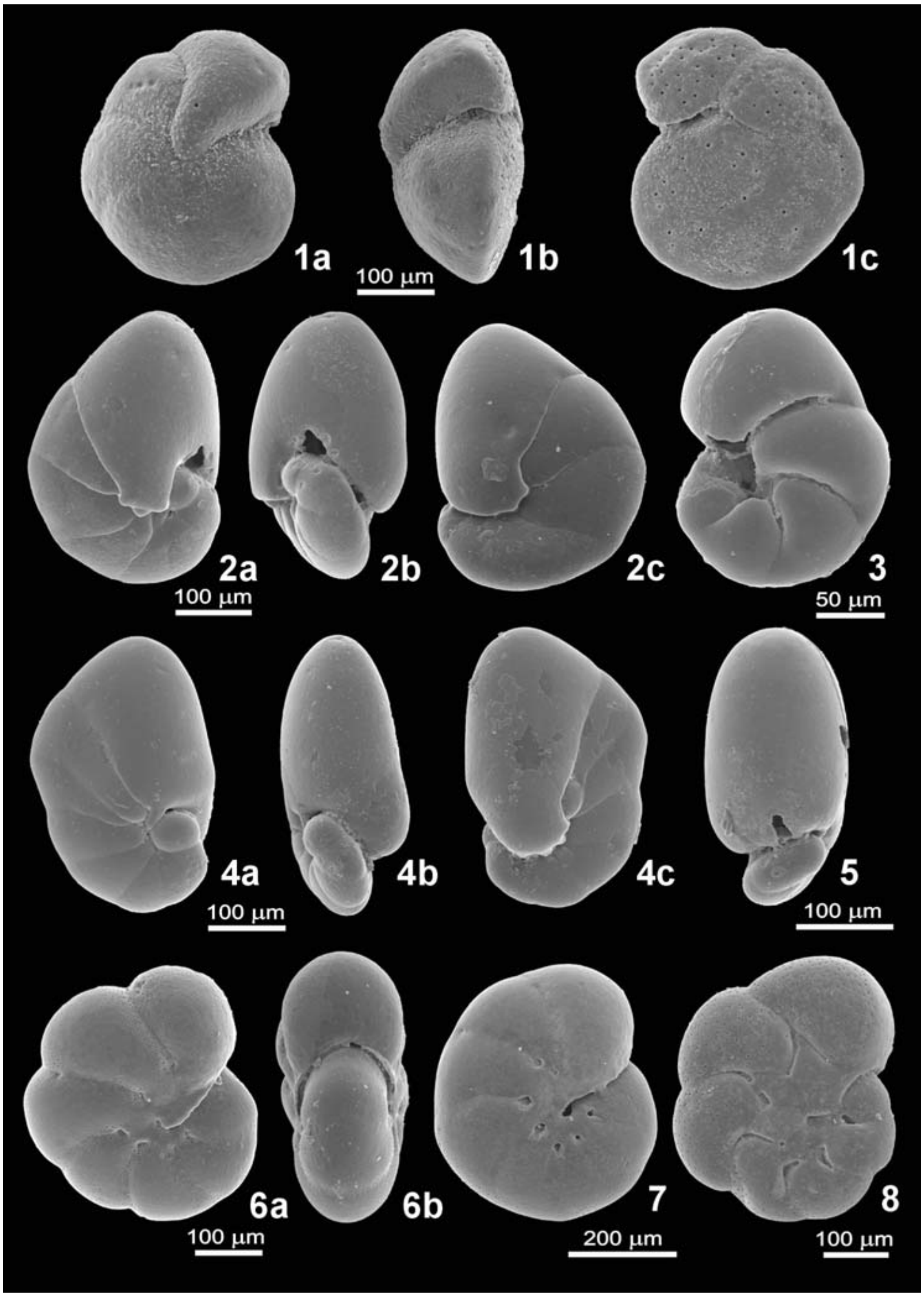


Fig. 25. **1**. *Cibicides refulgens* de Montfort, 1808; 3, 5–6 cm. **2–3**. *Nonionella iridea* Herron-Allen *et* Earland, 1932; 27, 0–1 cm, station*1. **4–5**. *Nonionella bradii* (Chapman, 1916); 8, 0–1, 8, 7–8 cm. **6–7**. *Astrononion echolsi* Kennet, 1967; station*1. **8**. *Astrononion antarcticum* Parr, 1950; 15, 10–15 cm.

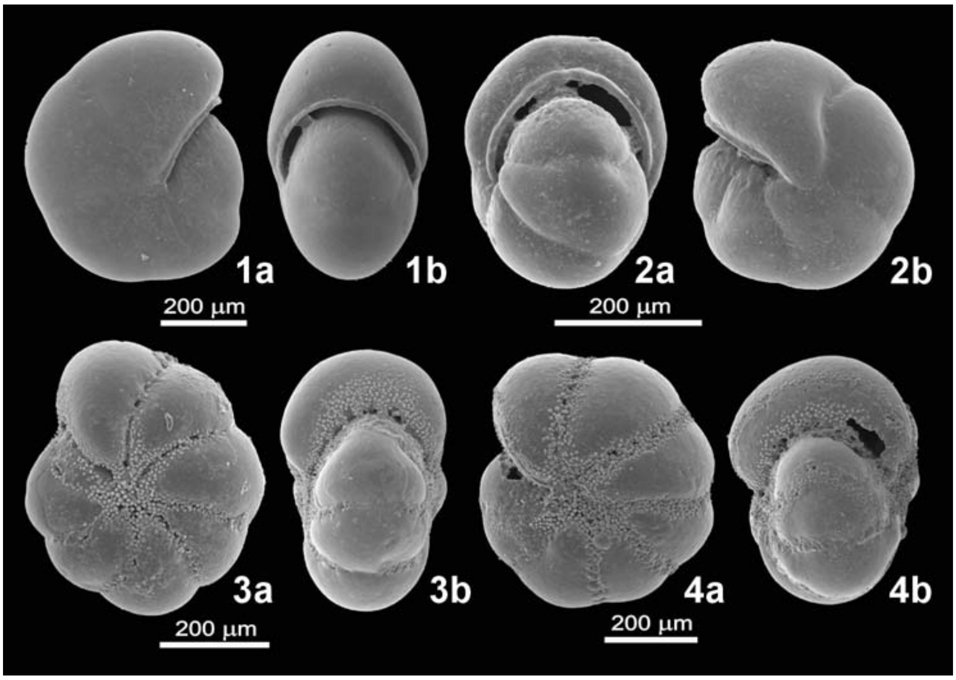


Fig. 26. **1**. *Pullenia subcarinata* (d'Orbigny, 1839); 15, 10–15 cm. **2**. *Pullenia* cf. *subcarinata* (d'Orbigny, 1839); 26, 9–10 cm. **3**–**4**. *Cribroelphidium* sp.; 7, 6–7 cm, 13, 9–10 cm.

*Rhumblerella* sp.
*Rhabdammina* sp.
*Rosalina globularis* d'Orbigny, 1826. Showers (1980, pls 1, 2).
*Saccorhiza* sp.
?*Sigmoilina* sp.
*Sorosphaera* sp.
*Spiroplectammina biformis* (Parker *et* Jones, 1865). Finger and Lipps (1981, pl. 1, fig. 17a–b).
*Tholosina centroforata* Rhumbler, 1935.
*Thurammina corrugata* Earland, 1934 (pl. 2, figs 15–18). In Admiralty Bay, both single and multi-chamber specimens occur.
*Thurammina* cf. *corrugata* Earland, 1934. Differs from *Thurammina corrugata* by not spherical but hexahedron outline. Nevertheless, it possesses irregular but distinguished appendages.
*Tolypammina vagans* (Brady, 1879). Violanti (1996, pl. 3, figs 7–8).
*Triloculinella antarctica* (Kennett 1967), figs 1–2.
*Vanhoefenella gaussi* Rhumbler, 1905. Violanti (1996, pl. 1, fig. 5).
*Webbinella limosai* Earland, 1933 (pl. 2, figs 1–2).
*Webbinella* cf. *limosai* Earland, 1933. Differs from *Webbinella limosai* by possessing aperture on short neck.
*Webbinella* cf. *limosai* Earland, 1933. Differs from *Webbinella limosai* by angular outline.

**Appendix B**

"Living" dataset; percentage values for the 31 most frequent "living" benthic foraminiferal species in Admiralty Bay, together with some faunal parameters.

| station | *Nodulina dentaliniformis* | *Nodulina subdentaliniformis* | *Nodulina kerguelensis* | *Reophax scorpiurus* | *Reophax pilulifer* | *Labrospira jeffreysii* | *Adercotryma glomerata* | *Spiroplectammina biformis* | *Portatrochammina antarctica* | *Portatrochammina bipolaris* | *Atlantinella atlantica* | *Gordiospira fragilis* | *Quinqueloculina* sp. 1 | *Pyrgo elongata* | *Pyrgo bulloides* | *Oolina felsinea* | *Fissurina* sp. 2 | *Pseudofissurina mccullochae* | *Bolivina pseudopunctata* | *Angulogerina earlandi* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | 100 | | | | | | | |
| 2 | | | | | | | | | | | | | 77 | | | | | | | |
| 3 | 21.8 | 1.8 | 12.7 | | | 7.3 | | | | | | | | | | | 3.6 | | | |
| 4 | | | | | | | | 20.0 | 20.0 | | | | | | | | | | | |
| 6 | | | | | | | | | 71.4 | 7.1 | | | | | 14.3 | | | | | |
| 7 | 0.5 | | | | | | | | 1.2 | 0.5 | | | | | | | | | | |
| 8 | 40.0 | 4.7 | | | 1.2 | | | | 3.5 | | | | | | | | | 2.4 | 2.4 | 1.2 |
| 9 | 15.1 | 3.4 | | | | 2.7 | 1.4 | | 3.4 | 2.1 | | | | 1.4 | | | | | | |
| 11 | 24.4 | 4.9 | | | | 4.9 | | 4.9 | 22.0 | | | | | | | | | | | |
| 12 | 15.7 | 1.4 | | | | | | | 20.0 | | | | | | | | | | | |
| 13 | | | | | | | | | 4.7 | | | | | | | | | | | |
| 15 | 6.9 | | | | | 0.3 | | 0.6 | 6.9 | | | | | 0.3 | | | | | | |
| 16 | 19.2 | | | | | | | | 7.7 | 1.3 | | | | | | | | | | |
| 17 | 25.8 | 11.2 | 9.0 | | | | | | 1.1 | | | | | | | | | | | |
| 18 | 34.6 | | 1.2 | | | 1.2 | | | 1.2 | 2.5 | | | | 2.5 | | | | | | |
| 19 | 62.5 | | 10.4 | | | | | | 6.3 | 2.1 | 2.1 | | | | | 2.1 | | | 2.1 | |
| 20 | | | | | | 1.5 | | | 5.9 | | | 1.5 | 5.2 | | | | | | | |
| 21 | | | | | | 0.2 | | | 0.8 | | | 52.1 | 0.8 | | | | | | | |
| 22 | 1.9 | | 1.9 | | | | 1.9 | 1.9 | 26.7 | 1.0 | 1.0 | | | | | | | | | 1.0 |
| 23 | 15.7 | | 1.5 | | | 1.0 | | | 5.1 | 1.0 | 1.0 | | | 6.1 | | | | | | |
| 24 | 23.0 | | 1.4 | | | | | | 29.7 | | | | | | | 1.4 | | | | |
| 25 | | | | | | | | | 33.8 | | | | | 1.5 | | | | | | |
| 26 | 16.2 | 1.7 | 7.5 | | | | | | 6.9 | | 0.6 | | | | | | | | 0.6 | 3.5 |
| 27 | | | | | | | | | 88.9 | | | | | | | | | | | |
| 28 | 35.8 | | 3.3 | | | 6.7 | | 0.8 | 5.0 | 8.3 | | 0.8 | | | | | | | 0.8 | 0.8 |
| 29 | 2.4 | | 1.8 | | | 5.4 | | | 8.4 | 8.4 | 12.0 | | | | | | | | | 0.6 |
| 30 | 3.4 | 0.8 | 1.7 | | | 0.8 | 2.5 | 0.8 | 19.5 | 0.8 | | | | | | | | | | |
| 31 | 23.0 | 9.2 | | | | | 8.0 | 8.0 | 32.2 | 3.4 | | | | | | | | | 3.4 | |
| 32 | 45.1 | 6.3 | 8.0 | | | 0.6 | | | 2.9 | 1.1 | 0.6 | | | | | | | | 0.6 | |
| 33 | | 3.1 | | | | 3.7 | 3.1 | | 21.1 | 3.7 | | | | | | | | | 5.0 | 4.3 |
| 34 | 12.2 | | | | 2.8 | 6.2 | | | 2.5 | 9.4 | 3.4 | | | | | | | | 0.9 | 0.9 |
| 35 | 28.3 | 1.9 | 1.9 | 1.9 | | | | | 13.2 | 9.4 | | | | | | | 1.9 | | | 7.5 |
| 36 | 35.4 | 8.8 | 5.3 | 2.7 | | 2.7 | | | 2.7 | 3.5 | | | | | | | | | 6.2 | |
| 37 | 17.4 | 2.3 | 11.6 | 2.3 | | | 2.3 | | 3.5 | | | | | | | | | | 8.1 | |
| 38 | 26.5 | 4.9 | 1.2 | | | | | | 1.2 | 3.1 | | | | | | | | | 7.4 | |

Appendix B continued

| station | *Cassidulinoides parkerianus* | *Cassidulinoides porrectus* | *Globocassidulina biora* | *Fursenkoina fusiformis* | *Rosalina globularis* | *Cibicides refulgens* | *Nonionella iridea* | *Astrononion echolsi* | *Astrononion antarcticum* | *Pullenia subcarinata* | *Cribroelphidium* sp. | standing stock (N/10 cm sq.) | life-to-dead ratio x10 | percent agglutinating forms | number of species (S) | species richness (d) | total foraminifera counted (N) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | 1.81 | 14 | 0 | 2 | 0.72 | 4 |
| 2 | | | 23.1 | | | | | | | | | 6.71 | 1.268 | 0 | 3 | 0.61 | 27 |
| 3 | | 3.6 | 5.5 | | | 9.1 | 1.8 | 30.9 | | 1.8 | | 14.2 | 0.441 | 44 | 12 | 2.66 | 63 |
| 4 | | | 60.0 | | | | | | | | | 1.29 | 0.106 | 40 | 3 | 1.24 | 5 |
| 6 | 7.1 | | | | | | | | | | | 3.61 | 0.057 | 79 | 6 | 1.7 | 19 |
| 7 | | | 96.7 | 1.2 | | | | | | | | 219 | 1.089 | 2.1 | 6 | 0.96 | 181 |
| 8 | 1.2 | 2.4 | 8.2 | 1.2 | 4.7 | 9.4 | 1.2 | 15.3 | | 1.2 | | 21.9 | 0.674 | 49 | 21 | 4.6 | 78 |
| 9 | 1.4 | | 66.4 | | | | | 2.7 | | | | 37.7 | 1.012 | 28 | 14 | 2.76 | 112 |
| 11 | 9.8 | | 29.3 | | | | | | | | | 10.6 | 0.168 | 61 | 9 | 2.27 | 34 |
| 12 | 45.7 | | 17.1 | | | | | | | | | 18.1 | 0.505 | 37 | 9 | 1.59 | 154 |
| 13 | 7.8 | | 84.4 | | | | | | | | 3.1 | 16.5 | 0.222 | 4.7 | 5 | 1.15 | 33 |
| 15 | 0.9 | | 81.4 | | | | | 2.5 | | | | 82.1 | 1.222 | 15 | 11 | 1.85 | 226 |
| 16 | 5.1 | | 66.7 | | | | | | | | | 20.1 | 0.505 | 28 | 8 | 1.77 | 53 |
| 17 | | | 37.1 | | | | | 15.7 | | | | 23 | 0.114 | 47 | 9 | 2.01 | 54 |
| 18 | | 2.5 | 34.6 | | | | | 19.8 | | | | 20.9 | 0.252 | 41 | 13 | 2.95 | 59 |
| 19 | | | 10.4 | | | | | 2.1 | | | | 12.4 | 0.311 | 83 | 12 | 2.76 | 54 |
| 20 | | | 85.6 | | 0.4 | | | | | | | 69.7 | 1.13 | 8.9 | 7 | 1.11 | 223 |
| 21 | 0.4 | | 45.5 | 0.2 | | | | | | | 0.2 | 343 | 4.626 | 53 | 10 | 1.45 | 495 |
| 22 | | | 61.0 | | | | | 1.9 | | | | 27.1 | 0.814 | 36 | 11 | 2.15 | 106 |
| 23 | 4.0 | | 55.1 | | | | | 6.6 | | 3.0 | | 51.1 | 0.929 | 25 | 14 | 2.7 | 125 |
| 24 | 6.8 | | 35.1 | | | | | 1.4 | | 1.4 | | 19.1 | 0.251 | 54 | 12 | 2.47 | 87 |
| 25 | 4.6 | | 58.5 | 1.5 | | | | | | | | 33.5 | 0.13 | 34 | 6 | 1.19 | 68 |
| 26 | 0.6 | | 37.6 | 1.2 | 0.6 | 2.9 | | 19.1 | | 0.6 | | 44.6 | 0.841 | 33 | 18 | 3.29 | 176 |
| 27 | | | 11.1 | | | | | | | | | 2.32 | 0.039 | 89 | 4 | 0.84 | 35 |
| 28 | | 0.8 | 9.2 | | | 7.5 | 2.5 | 15.8 | | 1.7 | | 31 | 0.708 | 61 | 16 | 3.1 | 127 |
| 29 | 0.6 | | 27.1 | | 0.6 | 22.9 | | 5.4 | | 3.0 | | 171 | 1.903 | 39 | 17 | 3.13 | 168 |
| 30 | 19.5 | 0.8 | 47.5 | | 1.7 | | | | | | | 30.5 | 0.948 | 31 | 15 | 2.9 | 125 |
| 31 | 3.4 | | 9.2 | | | | | | | | | 22.5 | 0.83 | 84 | 11 | 2.45 | 60 |
| 32 | 1.7 | | 1.7 | | | | | 30.3 | | | | 45.2 | 2.585 | 65 | 18 | 3.19 | 207 |
| 33 | 3.7 | 1.9 | 33.5 | 1.2 | 6.8 | 1.2 | | 2.5 | | 4.3 | | 41.5 | 0.405 | 35 | 18 | 3.57 | 117 |
| 34 | 0.7 | 6.7 | 0.9 | 0.9 | 0.7 | 8.0 | | 25.7 | 7.1 | 10.1 | | 113 | 1.588 | 36 | 25 | 4.81 | 147 |
| 35 | 3.8 | 5.7 | 15.1 | | | 1.9 | | 3.8 | | 3.8 | | 13.7 | 0.246 | 57 | 18 | 4.16 | 60 |
| 36 | | 0.9 | 5.3 | | | | | 21.2 | | 2.7 | | 29.2 | 0.781 | 61 | 23 | 4.87 | 92 |
| 37 | 2.3 | 5.8 | 2.3 | 3.5 | | | | 38.4 | | | | 22.2 | 0.849 | 40 | 15 | 3.5 | 55 |
| 38 | | 1.9 | 1.9 | | | | | 49.4 | | | | 41.8 | 1.038 | 37 | 17 | 3.43 | 106 |

## Appendix C

"Dead" dataset; percentage values for the 36 most frequent "dead" benthic foraminiferal species in Admiralty Bay, together with some faunal parameters.

| station | *Rhabdammina* sp. | *Lagenammina arenulata* | *Armorella spherica* | *Psammosphaera fusca* | *Hemisphaerammina bradyi* | *Miliammina arenacea* | *Hormosinella* sp. | *Nodulina dentaliniformis* | *Nodulina subdentaliniformis* | *Nodulina kerguelensis* | *Reophax pilulifer* | *Labrospira jeffreysii* | *Adercotryma glomerata* | *Spiroplectammina biformis* | *Paratrochammina bartmani* | *Paratrochammina lepida* | *Portatrochammina antarctica* | *Portatrochammina bipolaris* | *Atlantinella atlantica* | *Gordiospira fragilis* | *Quinqueloculina* sp. 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | | | | 0.5 | | 3.4 | | | | | | | | | | | | | | | 22.4 |
| 3 | 0.2 | 22.0 | | 0.7 | 0.2 | 11.1 | 0.3 | 6.7 | 0.2 | 0.9 | 0.1 | 3.0 | 0.4 | 0.4 | 0.4 | 1.1 | 13.3 | 0.8 | 0.4 | | |
| 4 | | | | 15.9 | | 0.4 | | | | | | | | 1.3 | | | 2.5 | 0.2 | | | |
| 5 | | | | 15.5 | 22.1 | 1.2 | | | | | | | | 5.3 | | | 2.8 | | | | 0.2 |
| 6 | | | 0.7 | 10.8 | | 4.2 | 0.4 | 0.7 | | | | 0.2 | | 0.6 | 0.0 | 0.4 | 4.6 | 0.4 | 0.2 | | |
| 7 | | | | 44.6 | 0.2 | 1.4 | 0.1 | 0.0 | | | | 0.1 | 0.1 | 2.5 | | 0.1 | 1.4 | 0.2 | 0.1 | | 0.0 |
| 8 | 0.4 | 14.4 | 1.0 | 5.0 | | 21.3 | 1.8 | 22.1 | 3.5 | | 0.5 | 2.5 | | 0.4 | 0.8 | | 3.6 | 0.8 | | | 0.1 |
| 9 | 0.8 | 22.5 | 1.0 | 21.2 | 0.7 | 11.4 | 1.8 | 11.6 | 0.4 | | 0.2 | 0.6 | 0.9 | 0.4 | 0.8 | 0.1 | 8.6 | 1.7 | | | |
| 10 | | 1.6 | | 1.6 | 82.3 | | | 1.6 | | | | | | | | | 6.5 | | | | |
| 11 | | 8.7 | 0.1 | 19.7 | 0.7 | 8.3 | 3.5 | 3.5 | 0.3 | | | 0.2 | 0.4 | 1.7 | 0.1 | | 20.5 | 0.1 | | | |
| 12 | | 2.0 | | 6.3 | 0.1 | 6.2 | 4.8 | 1.6 | 0.1 | | | 0.2 | 0.1 | | 0.1 | | 22.1 | | | | |
| 13 | | | | 12.3 | 0.1 | 3.8 | 0.4 | | | | | | | 0.3 | | | 1.6 | | | | 0.1 |
| 14 | | | | 6.7 | 13.3 | | | | | | | | | | | | 3.3 | | | | 3.3 |
| 15 | 0.4 | 13.1 | 0.2 | 10.0 | 0.2 | 8.8 | 1.7 | 4.2 | 0.2 | | | 0.4 | | 0.8 | 0.2 | 0.1 | 10.2 | 0.1 | 0.0 | | 0.1 |
| 16 | | 17.2 | | 23.8 | 0.1 | 7.6 | 3.1 | 3.8 | | 0.2 | | 5.6 | 0.1 | 0.4 | 1.6 | 0.1 | 10.8 | 0.5 | | | |
| 17 | 0.4 | 8.7 | 0.0 | 2.7 | 0.1 | 4.0 | 0.8 | 1.7 | 0.3 | 0.2 | | 0.5 | 0.1 | 0.5 | 0.2 | | 4.3 | 0.2 | 0.0 | | |
| 18 | 1.2 | 25.2 | 0.3 | 2.2 | | 2.6 | 1.3 | 4.2 | 0.7 | 0.3 | 0.0 | 1.0 | 0.1 | 0.1 | 0.2 | 0.0 | 5.1 | 0.3 | | | |
| 19 | | 2.8 | 0.3 | 15.5 | 0.9 | 6.7 | 9.1 | 4.4 | 0.5 | 0.1 | | 0.8 | 0.5 | 1.4 | 0.1 | | 22.8 | 0.1 | 0.1 | | |
| 20 | | | 0.1 | 50.4 | 0.1 | 1.2 | | | | | | 0.2 | | 0.6 | 0.3 | | 9.9 | | | 0.0 | 1.4 |
| 21 | | | 0.1 | 42.0 | | 3.3 | 0.5 | | | | | 0.1 | | 1.2 | 0.0 | | 6.2 | | 0.1 | 8.1 | 1.1 |
| 22 | | 0.3 | | 5.0 | | 1.6 | 2.2 | 2.0 | 0.1 | 0.2 | | 0.2 | 0.1 | 1.3 | 2.2 | 0.1 | 29.1 | 1.6 | 0.3 | | |
| 23 | 0.1 | 7.4 | 1.3 | 0.8 | 0.1 | 2.4 | 2.8 | 5.1 | 0.0 | 0.1 | | 0.3 | 0.3 | | 0.1 | | 8.3 | 1.2 | 0.6 | 0.0 | |
| 24 | | 15.0 | 0.0 | 10.4 | 0.3 | 9.8 | 1.4 | 1.7 | 0.2 | 0.1 | | 0.2 | 0.1 | 0.6 | 0.1 | | 13.7 | 0.1 | 0.2 | | 0.0 |
| 25 | | 0.4 | 0.0 | 5.3 | 0.0 | 2.4 | | | | | | | | 0.4 | | | 5.1 | | | | |
| 26 | 0.1 | 19.3 | 0.5 | 0.2 | | 3.1 | 0.8 | 7.2 | 1.3 | 0.9 | 0.0 | 1.0 | 0.1 | 0.0 | 0.5 | 0.3 | 6.5 | 0.9 | 0.5 | | 0.1 |
| 27 | | | 0.2 | 1.1 | 2.5 | 7.9 | 0.0 | 0.0 | | | | 1.0 | 0.0 | 1.4 | 1.0 | 0.3 | 39.8 | | 0.1 | 0.1 | 0.2 |
| 28 | 0.8 | 10.1 | 0.2 | 0.6 | | 12.9 | 2.3 | 12.3 | 0.6 | 0.4 | 0.1 | 3.7 | 0.2 | | 0.6 | 0.5 | 17.6 | 3.5 | 0.6 | | |
| 29 | 0.1 | 13.3 | 0.1 | 0.7 | | 3.2 | 0.6 | 3.7 | | 0.6 | 0.2 | 1.0 | 0.5 | | 1.0 | 0.2 | 23.6 | 2.6 | 1.8 | | |
| 30 | | 0.3 | 0.9 | 9.2 | 0.6 | 1.4 | 1.0 | 0.3 | 0.2 | | | 1.0 | 0.7 | 1.8 | 1.0 | 0.2 | 17.4 | 0.3 | 0.3 | | 0.2 |
| 31 | 0.5 | 0.7 | 2.1 | 6.2 | | 2.1 | 3.1 | 3.1 | 0.7 | | | | 5.2 | 9.5 | 1.4 | | 35.5 | 0.7 | 1.0 | | |
| 32 | 0.1 | 18.5 | 0.3 | 1.8 | | 8.7 | 3.7 | 5.2 | 5.8 | 0.3 | | 0.6 | 0.4 | 0.3 | 1.5 | 1.3 | 5.0 | 0.9 | 0.7 | | |
| 33 | | 0.3 | | 0.3 | 0.4 | 2.4 | 0.6 | 0.6 | 0.1 | | | 0.4 | 1.0 | 0.9 | 6.9 | 1.3 | 10.1 | 0.5 | 0.2 | | |
| 34 | 2.9 | 5.5 | 0.8 | 1.6 | 0.7 | 6.5 | 0.5 | 6.1 | 0.1 | | 2.7 | 2.4 | | | 3.4 | 1.6 | 8.8 | 3.0 | 1.3 | | 0.2 |
| 35 | 0.4 | 7.9 | 0.1 | 0.8 | 0.0 | 9.5 | 0.6 | 3.9 | 0.2 | 0.1 | 0.2 | 0.6 | 0.1 | 0.0 | 6.1 | 2.0 | 16.2 | 3.5 | 0.2 | | |
| 36 | 1.7 | 13.8 | 0.3 | 2.0 | 0.3 | 30.0 | 1.4 | 5.9 | 3.0 | 0.7 | 0.5 | 0.7 | 0.1 | | 2.1 | 1.1 | 5.5 | 2.7 | 1.1 | | |
| 37 | 0.2 | 39.3 | | 1.2 | | 19.7 | 1.3 | 4.4 | 1.5 | 0.8 | 0.2 | 1.7 | 0.3 | | 3.5 | 0.5 | 5.1 | 1.5 | 0.3 | | |
| 38 | 0.8 | 54.8 | 0.1 | 1.0 | 0.2 | 12.7 | 0.3 | 4.9 | 1.7 | 0.1 | 0.1 | 0.4 | 0.1 | | 1.6 | 0.1 | 1.2 | 1.3 | 0.5 | | |

Appendix C continued

| station | *Pyrgo elongata* | *Bolivina pseudopunctata* | *Angulogerina earlandi* | *Cassidulinoides parkerianus* | *Cassidulinoides porrectus* | *Globocassidulina biora* | *Fursenkoina fusiformis* | *Rosalina globularis* | *Cibicides lobatulus* | *Cibicides refulgens* | *Nonionella iridea* | *Astrononion echolsi* | *Astrononion antarcticum* | *Pullenia subcarinata* | *Cribroelphidium* sp. | abundance (N/10 cm sq.) | life-to-dead ratio x10 | percent agglutinating forms | number of species (S) | species richness (d) | total foraminifera counted (N) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | | | | | | 73.7 | | | | | | | | | | 52.9 | 1.27 | 3.9 | 4 | 0.56 | 205 |
| 3 | | 0.3 | 0.6 | 1.1 | 1.1 | 22.5 | 0.1 | 1.1 | 0.9 | 2.5 | 0.1 | 6.3 | 0.1 | 0.1 | | 322 | 0.44 | 62.2 | 36 | 4.92 | 1247 |
| 4 | | | | | | 74.8 | | 0.6 | | | | 0.4 | | | 3.0 | 122 | 0.11 | 20.3 | 10 | 1.52 | 378 |
| 5 | | | | | | 52.0 | 0.2 | 0.2 | | | | | | | 0.2 | 145 | 0.02 | 47 | 11 | 1.58 | 562 |
| 6 | | | | 0.9 | | 74.4 | | | | 1.1 | | | | | 0.0 | 629 | 0.06 | 23.5 | 18 | 2.27 | 1814 |
| 7 | | | | 0.3 | | 48.2 | | | | | | | 0.1 | | 0.7 | 2015 | 1.09 | 50.8 | 18 | 2.22 | 2099 |
| 8 | 0.3 | 0.2 | 1.7 | 0.6 | 2.1 | 4.4 | 0.3 | 0.8 | | 0.9 | 0.7 | 7.1 | 0.1 | 0.8 | | 325 | 0.67 | 78.9 | 36 | 5.02 | 1071 |
| 9 | 0.1 | | 0.6 | 0.6 | 0.3 | 10.3 | 0.1 | 0.1 | | | 0.3 | 1.9 | | 0.3 | | 372 | 1.01 | 84.9 | 31 | 4.22 | 1238 |
| 10 | | | | | | 3.2 | | | | | | 1.6 | | | | 16 | 0.32 | 93.5 | 8 | 1.7 | 61 |
| 11 | 0.2 | | 0.0 | 2.7 | | 26.0 | | 0.0 | | 0.1 | 0.1 | 1.7 | 0.0 | 0.3 | | 629 | 0.17 | 67.8 | 27 | 3.48 | 1762 |
| 12 | | | | 6.1 | | 48.4 | 0.2 | 0.2 | | | | 0.4 | | | | 358 | 0.5 | 43.5 | 17 | 2.21 | 1387 |
| 13 | | | | 2.8 | | 75.4 | | 0.1 | | | | | | | 3.2 | 744 | 0.22 | 18.5 | 11 | 1.35 | 1679 |
| 14 | | | | | | 73.3 | | | | | | | | | | 15.5 | 0 | 23.3 | 5 | 1.2 | 28 |
| 15 | 0.4 | | 0.1 | 1.7 | 0.1 | 42.3 | 0.0 | 0.6 | | 0.2 | 0.2 | 1.7 | 0.2 | 0.5 | 0.2 | 672 | 1.22 | 50.4 | 33 | 4.16 | 2206 |
| 16 | 0.4 | | | 0.8 | 0.1 | 13.0 | | 0.3 | | 0.2 | 0.1 | 7.2 | 1.0 | 0.2 | | 399 | 0.5 | 75.3 | 27 | 3.63 | 1300 |
| 17 | | 0.1 | 0.0 | 0.2 | 0.1 | 73.6 | 0.2 | 0.1 | | 0.1 | 0.1 | 0.7 | 0.0 | 0.1 | | 2021 | 0.11 | 24.7 | 32 | 3.73 | 4079 |
| 18 | | | 0.2 | 0.8 | 0.6 | 44.9 | 0.1 | 0.2 | | 0.3 | 0.2 | 7.4 | 0.1 | 0.2 | | 831 | 0.25 | 45 | 33 | 4.21 | 2007 |
| 19 | | | | 6.4 | | 22.7 | 0.3 | 0.1 | | | | 0.1 | | | 2.4 | 399 | 0.31 | 66.6 | 28 | 3.77 | 1297 |
| 20 | | | | 2.3 | | 33.1 | | 0.1 | | | | | | | 0.1 | 617 | 1.13 | 62.9 | 14 | 1.72 | 1927 |
| 21 | | | | 3.5 | | 32.9 | | | | | | | | | 0.4 | 742 | 4.63 | 61.5 | 18 | 2.31 | 1593 |
| 22 | | | 0.5 | 2.9 | 0.3 | 45.0 | 0.3 | 0.5 | | 0.5 | | 1.6 | | 0.5 | 0.1 | 333 | 0.81 | 46.4 | 34 | 4.68 | 1158 |
| 23 | 1.3 | | 0.2 | 4.5 | 0.1 | 54.7 | 0.1 | 0.5 | | 0.1 | 0.1 | 3.6 | 0.1 | 0.5 | 0.8 | 550 | 0.93 | 30.9 | 39 | 5.02 | 1949 |
| 24 | 0.1 | | 0.1 | 6.0 | 0.2 | 38.6 | 0.1 | 0.2 | | 0.0 | | 0.1 | | | 0.0 | 761 | 0.25 | 54 | 36 | 4.5 | 2395 |
| 25 | 0.2 | | | 1.0 | | 83.7 | | 0.0 | | | 0.0 | | | | 1.2 | 2576 | 0.13 | 13.6 | 18 | 2.03 | 4452 |
| 26 | | | 1.8 | 1.1 | 0.0 | 40.0 | 0.2 | 0.8 | 0.3 | 2.7 | 0.1 | 7.8 | 0.3 | 0.3 | | 531 | 0.84 | 43.4 | 38 | 4.89 | 1939 |
| 27 | | | 0.0 | 7.9 | | 34.9 | 0.1 | 0.3 | | 0.1 | 0.1 | 0.1 | | | | 601 | 0.04 | 55.6 | 26 | 3.3 | 1949 |
| 28 | | 0.3 | 0.6 | 2.3 | 0.6 | 15.3 | 0.2 | 0.9 | 0.2 | 4.4 | 0.8 | 4.8 | | 0.6 | | 437 | 0.71 | 66.7 | 37 | 4.84 | 1703 |
| 29 | | 0.2 | 0.5 | 1.5 | 0.7 | 17.2 | 0.2 | 5.3 | | 15.2 | | 4.2 | | 0.1 | | 901 | 1.9 | 53.3 | 32 | 4.58 | 874 |
| 30 | | | | 3.4 | 0.1 | 53.2 | 0.2 | 4.2 | 0.3 | 0.1 | 0.1 | 0.2 | | | | 321 | 0.95 | 36.8 | 35 | 4.77 | 1247 |
| 31 | | 0.2 | | 9.3 | 0.7 | 16.0 | 0.2 | 0.2 | | | | 0.3 | | | | 270 | 0.83 | 71.8 | 24 | 3.57 | 627 |
| 32 | | 3.4 | | 3.5 | 1.8 | 16.4 | 0.9 | 1.3 | 0.1 | 0.9 | 2.2 | 10.5 | | 0.3 | | 175 | 2.58 | 55.1 | 33 | 4.92 | 677 |
| 33 | | 0.5 | 4.7 | 5.1 | 4.0 | 44.8 | 1.7 | 1.2 | 0.3 | 1.0 | 0.1 | 3.4 | 0.5 | 4.9 | | 1027 | 0.4 | 25.9 | 43 | 5.31 | 2734 |
| 34 | 0.2 | | 2.3 | 0.3 | 4.1 | 3.5 | 0.1 | 1.6 | 0.1 | 7.7 | 0.4 | 12.9 | 1.3 | 8.4 | | 709 | 1.59 | 48.3 | 47 | 7.25 | 572 |
| 35 | 0.0 | 0.2 | 12.1 | 2.0 | 8.9 | 6.2 | 0.2 | 0.4 | 0.1 | 2.1 | 0.1 | 7.8 | 0.5 | 3.4 | | 555 | 0.25 | 52.6 | 54 | 6.91 | 2152 |
| 36 | | 0.8 | 2.7 | 1.3 | 2.5 | 2.0 | | 0.6 | 0.4 | 1.0 | | 6.2 | 0.7 | 1.4 | | 373 | 0.78 | 72.8 | 56 | 7.65 | 1341 |
| 37 | | 0.3 | | 1.2 | 0.7 | 4.6 | 0.2 | 0.3 | 0.8 | 1.5 | 0.3 | 4.9 | 0.2 | 0.3 | | 261 | 0.85 | 81.4 | 33 | 5 | 607 |
| 38 | | 0.5 | 0.4 | 0.4 | 2.1 | 1.0 | 0.1 | 0.2 | | 0.2 | | 7.5 | 0.5 | 0.3 | | 403 | 1.04 | 82.1 | 42 | 6 | 938 |

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