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# Recent Planktonic Foraminifera from Sediments of the Drake Passage, Southern Ocean

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with 4 figures and 1 table in the text and 3 plates (I–III)

## ABSTRACT

Based on a qualitative and quantitative evaluation of Recent sediments samples (top 3 cm of cores as well as Petersen grab samples) from the Drake Passage, between South America and Antarctica, the distribution of planktonic foraminifera and their relation to oceanographic conditions was investigated. The Antarctic Convergence – the northern limit of the cold Antarctic Surface Water – is shown to be of major importance in controlling the distributional pattern of planktonic species as well as their total numbers. South of the convergence, *Globigerina pachyderma* is usually the only species found in the sediment. It occurs with abundances not greater than 6000 per gram dry sediment, and at most stations less than 100 specimens per gram of dry sediment were recovered. At a number of deep-sea stations below 3700 m depth approx. no planktonic foraminifera were found at all. It is most probable, that at least some of these stations are located below the limit of $CaCO_3$ dissolution. North of the Antarctic Convergence planktonic foraminiferal numbers are much higher and range from 1800 to 120000 per gram of dry sediment. Eight species are the major constituents of the population: *Globigerina pachyderma*, *Globigerina bulloides*, *Globigerina quinqueloba*, *Globigerina inflata*, *Globorotalia truncatulinoides*, *Globorotalia scitula*, *Globigerinita glutinata* and *Globigerinita uvula*. The widespread occurrence of *Globorotalia truncatulinoides*, which in the northern hemisphere is usually a subtropical form, is especially noteworthy. Another Globigerina, morphologically similar to *G. pachyderma*, has been recognized frequently north of the Antarctic Convergence. *Globigerina megastoma* which has its type area in the Drake Passage, has been found only rarely. *Orbulina universa* occurs in samples from the areas of higher water temperature around the South American Continent. *Globigerina pachyderma* is predominantly sinistrally coiled throughout the area investigated, but a slight increase in the percentage of dextrally coiled specimens may be noticed with increasing water temperature, i.e. from south to north.

## ZUSAMMENFASSUNG

Auf Grund einer qualitativen und quantitativen Untersuchung von rezenten Sedimentproben (oberste 3 cm von Kernen sowie Kastengreifer-Proben) aus der Drake-Strasse, zwischen Südamerika und der Antarktis, wurde die Verbreitung der planktonischen Foraminiferen in diesem Gebiet sowie deren Abhängigkeit von ozeanographischen Faktoren untersucht. Es zeigt sich, dass insbesondere die Antarktische Konvergenz – die nördliche Begrenzung des kalten antarktischen Oberflächenwassers – sowohl auf die Häufigkeit wie auch auf die Verbreitung der einzelnen Spezies einen grossen Einfluss ausübt. Südlich dieser Zone tritt fast ausschliesslich *Globigerina pachyderma* auf, und zwar in Häufigkeiten von maximal 6000, meist weniger als 100 Exemplaren pro Gramm getrocknetes Sediment. In zahlreichen Tiefseeproben unterhalb ca. 3700 m Wassertiefe fehlen planktonische Forami-

niferen vollständig, da diese Stationen vermutlich unterhalb des Grenzbereichs der Auflösung von $CaCO_3$ abgelagert wurden. Nördlich der Antarktischen Konvergenz sind die Foraminiferenzahlen bedeutend höher (1800–120000 pro Gramm getrocknetes Sediment), woran sich hauptsächlich acht Spezies in unterschiedlichen prozentualen Anteilen beteiligen: *Globigerina pachyderma*, *Globigerina bulloides*, *Globigerina quinqueloba*, *Globorotalia inflata*, *Globorotalia truncatulinoides*, *Globorotalia scitula*, *Globigerinita glutinata* und *Globigerina uvula*. Ferner tritt eine *G. pachyderma* nahestehende Globigerine auf. *Globigerina megastoma*, die ihr Typgebiet in der Drake-Strasse hat, wurde als seltene Form gelegentlich gefunden. Im Bereich wärmerer Gewässer anschliessend an den südamerikanischen Kontinent wurde ferner *Orbulina universa* gefunden. Das Auftreten von *Globorotalia truncatulinoides* und *G. inflata* im subantarktischen Bereich der Drake-Strasse ist bemerkenswert, da diese Spezies auf der nördlichen Hemisphäre vorwiegend subtropische bzw. gemässigte Zonen bevorzugen. *Globigerina pachyderma* als typisch antarktisch-subantarktische Spezies zeigt bei einem starken Überwiegen von linksgewundenen Formen eine leichte Zunahme von rechtsgewundenen Individuen mit Erhöhung der Wassertemperatur, d.h. von Süd nach Nord fortschreitend.

## Introduction

In connection with a study of Recent benthonic foraminifera from the Drake Passage (HERB, in press), the author had the opportunity to undertake a qualitative and quantitative investigation of the planktonic foraminifera found in sediment samples from the same area. The top 3 cm of 34 sediment cores (piston cores and trigger cores) as well as 6 Petersen grab samples, all collected on three subsequent cruises (4–6) of the USNS ELTANIN during the years 1962–1963, were utilized. The cores were split longitudinally, one half serving for sedimentological investigation, the other for foraminiferal work. The latter was washed trough a 250 mesh Tyler screen (0,61 $\mu$ openings). For faunal analysis the dried residue was divided repeatedly using an Otto microsplitter, in order to obtain a representative fraction suitable for quantitative work (500–1000 specimens of planktonic foraminifera). Percentages of each species with respect to the total population of planktonic foraminifera as well as numbers of individuals per gram dry sediment were calculated. The results are given in figure 1 and table 1.

The structure and composition of the Antarctic waters of the area studied has recently been summarized and discussed by GORDON (1967). Regarding the temperature of the surface-near waters, the Drake Passage is crossed in its middle part in a WSW-ENE direction by the Antarctic Convergence (Polar Front), along which the cold Antarctic Surface Water of relatively low salinity (usually somewhat less than 34,0‰) sinks below the warmer Subantarctic Surface Water (GORDON 1967).

## Distribution of Planktonic Foraminifera

The distribution of planktonic foraminiferal species in open ocean areas is generally assumed to be primarily related to water temperature. Therefore, it is reasonable to expect that the Antarctic Convergence — the northern limit of cold Antarctic Surface Water — will be the principal controlling factor on the distribution of planktonic organisms in the Drake Passage (fig. 1). It is also important to note that changes in other hydrographic conditions and bottom topography are important factors governing the distribution, relative frequency and abundance of calcareous tests found in deep-sea bottom sediments.

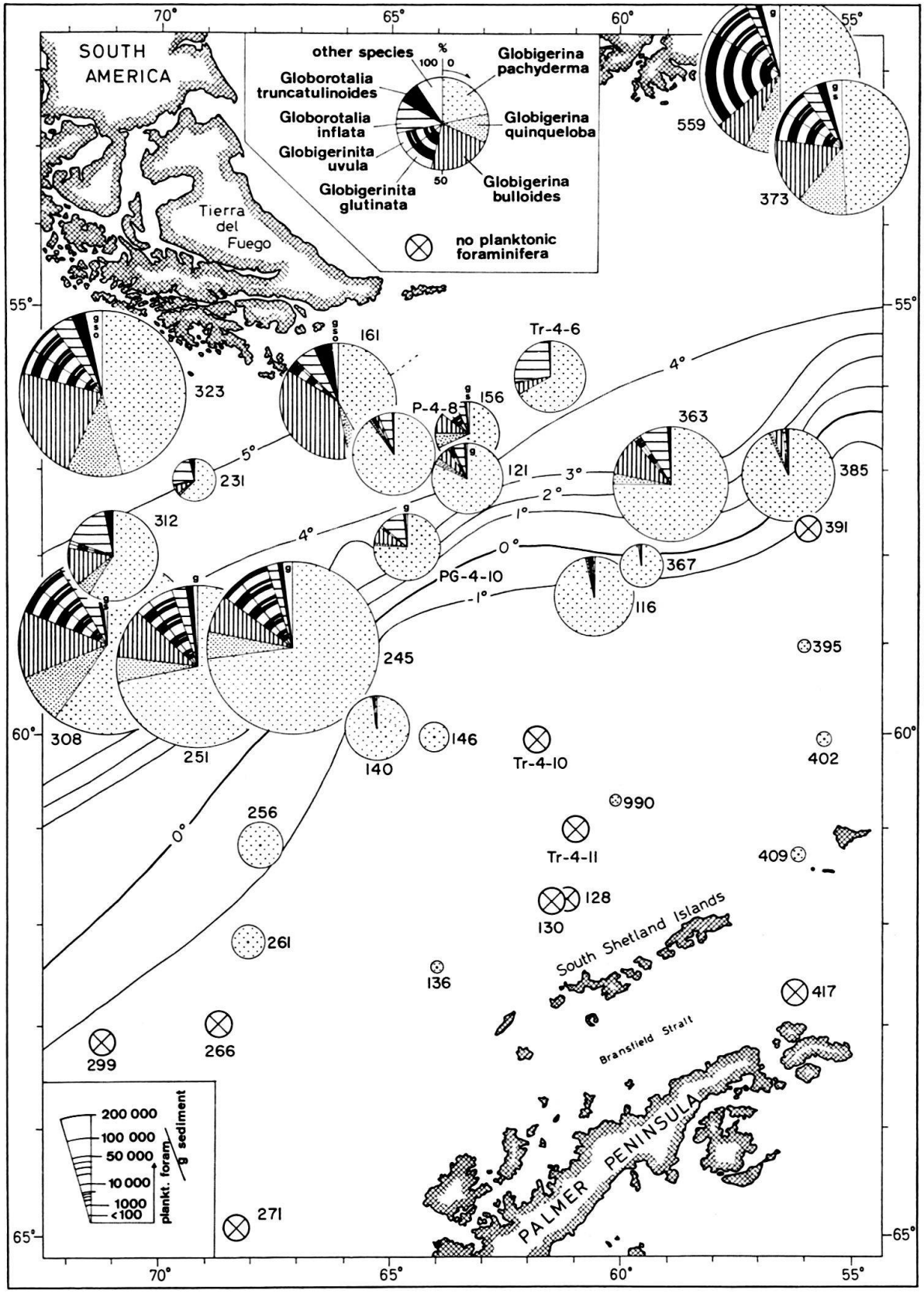


Fig. 1 Distribution of planktonic foraminifera in the Drake Passage. Foraminiferal numbers are indicated by the radius of the circles. Relative abundances of species are expressed by the angle of the respective sector of a circle. Isotherms show approximate surface/subsurface temperatures (June-October) of the Homogeneous Layer (after GORDON 1967). g = *Globigerina* sp. aff. *pachyderma;* s = *Globorotalia scitula;* o = *Orbulina universa.*

## South of the Antarctic Convergence

*Globigerina pachyderma* is the dominant species, often the only planktonic species present, in all bottom samples where planktonic foraminifera were recorded from south of the Antarctic Convergence. The range of ecophenotypic variation within populations of *G. pachyderma* is relatively small in this area. Rare occurrences of *Globorotalia inflata* which are sinistrally coiled, and *Globigerina bulloides* which are randomly coiled, were recorded at two stations (140 and 409), south of the convergence.

Planktonic foraminiferal numbers are low south of the convergence. Values usually do not exceed 20 specimens per gram of dry sediment in the areas northwest and northeast of the South Shetland Islands, but a slightly higher value of 79 did occur at station 409. Values in the southwestern area, between 60° and 62°S, are higher and range from 5900 at stations close to the convergence to 400 at stations farther south.

Planktonic foraminifera were absent in six samples from south of the convergence, at depths exceeding 3700 meters approximately. A high percentage of planktonic foraminifera compared with radiolarians and calcareous benthonic foraminifera was found in a shallow water sample (station 409; 225 m) northeast of the South Shetland Islands. This is an indication that calcite dissolution influences the distribution of planktonic foraminifera found in bottom samples from the southern Drake Passage. Due to the low bottom temperatures in the southeastern Drake Passage (GORDON, 1967), the boundary of $CaCO_3$ dissolution is probably situated at a relatively high level in this area.

Whether $CaCO_3$ dissolution or unfavorable living conditions are responsible for the lack of planktonic foraminifera at stations 271 and 417, in the deeper part of the Antarctic shelf, cannot be decided yet.

## Antarctic Convergence Area

Only a few samples were available from locations immediately beneath the Antarctic Convergence. They have been taken in the eastern Drake Passage and show a planktonic population of a somewhat transitional character between typical antarctic and typical subantarctic assemblages; foraminiferal numbers are usually higher than in the south and most of the species which, in addition to *Globigerina pachyderma*, are found north of the Antarctic Convergence, also occur here, although in considerably lower percentages. The contrast between stations 385 (with 93% *Globigerina pachyderma*, as well as *G. quinqueloba*, *G. bulloides*, *Globorotalia inflata*, *G. truncatulinoides*, *Globigerinita glutinata* and *G. uvula*) and station 391 (see fig. 1) where no planktonic foraminifera were found, may be due to the fact that the latter of the two stations (depth 3985 m) is probably situated below the $CaCO_3$ compensation level.

Crossing the Antarctic Convergence a distinct change in foraminiferal number as well as composition of the population can also be observed in the western Drake Passage as shown in figure 1.

## North of the Antarctic Convergence

*Globigerina pachyderma* is still the most frequent planktonic foraminiferal species but it has a greater range of ecophenotypic variation. Other planktonic species found north of the convergence are: *Globigerina pachyderma*, *Globigerina quinqueloba*, *Globigerina bulloides*, *Orbulina universa*, *Globigerinita glutinata*, *Globigerinita uvula*, *Globorotalia inflata*, *Globorotalia truncatulinoides*, *Globorotalia scitula*, *Globorotalia* aff. *G. crassaformis*.

Five general areas in the region north of the convergence can be distinguished on differences in planktonic foraminiferal numbers and relative frequency of species.

1) The western area is characterized by high foraminiferal numbers, and values of over 100000 specimens per gram of dry sediment are not uncommon. Samples from this area frequently contain many small individuals of *Globigerina pachyderma*, *Globigerina quinqueloba*, *Globigerinita uvula* and *Globigerinita glutinata*.
2) Stations located near the Antarctic Convergence in the northeastern sector have foraminiferal numbers ranging from 18000 to 34000 specimens per gram of dry sediment and most of the species are typical of the area north of the convergence.
3) Samples from southeast of the Falkland Islands contain an abundance of glauconite and have foraminiferal numbers of about 50000 specimens per gram. A significant percentage of the population is made up of small specimens as is the case for area one.
4) An abundance (up to 37%) of *Globigerina bulloides* characterizes the warmer water south and southwest of Tierra del Fuego. Foraminiferal numbers of around 100000 specimens per gram, rare occurrences of *Orbulina universa* and the presence of 5–9% dextrally coiled *Globigerina pachyderma* are characteristic features attributed to higher water temperatures in this area.
5) The lowest foraminiferal numbers north of the convergence are found in an east-west trending zone between areas 1 and 4, and also in the north-central part of the Drake Passage. *Globigerina pachyderma* is the most frequent species, but the percentage of five chambered individuals is lower than in areas 1 and 2, and it has greater affinities to the cold water forms south of the convergence. *Globorotalia inflata* is a major constituent, attaining a relative frequency of up to 26% of the population, but small forms such as *Globigerina quinqueloba*, *Globigerinita uvula* and *Globigerinita glutinata* are of minor importance.

Compared with subarctic ocean areas of the northern hemisphere, especially the northern Pacific (BRADSHAW, 1959), the greater diversity of the planktonic foraminiferal population in the Drake Passage is noteworthy. Species like *Globorotalia truncatulinoides* and *Globorotalia inflata* are usually considered to be mainly subtropical resp. temperate forms (BRADSHAW, 1959; BÉ, 1962; BÉ and HAMLIN, 1967; SCHOTT, 1966). In the case of *Globorotalia truncatulinoides* there are some morphological differences between subtropical and subantarctic occurrences (see p. 477). With respect to *Globorotalia inflata*, further investigations are needed, but it seems that the subantarctic forms have thicker walls—a feature common to all planktonic species, but especially striking in the case of *G. inflata*. The sutures are less pronounced in the subantarctic form of this species.

Table 1 Planktonic foraminiferal data.

| USNS ELTANIN Stations | Type of Sample C = Core, P = Petersen Grab | Medium Position | | Water Depth in Meters | Total Number of Planktonic Foraminifera per Gram dry Sediment | Relative Abundance of Planktonic Species in % of total Planktonic Foraminifera | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Latitudes S | Longitude W | | | *Globigerina pachyderma* | *Globigerina* sp. aff. *pachyderma* | *Globigerina quinqueloba* | *Globigerina bulloides* | *Globigerina megastoma* | *Globorotalia inflata* | *Globorotalia truncatulinoides* | *Globorotalia scitula* | *Globigerinita glutinata* | *Globigerinita uvula* | *Orbulina universa* |
| 116 | C | 58° 28' | 60° 38' | 3084 | 12000 | 97 | | × | 1 | | × | | | 1 | × | |
| 121 | C | 57° 06' | 63° 21' | 3900 | 8200 | 82 | 1 | 3 | 6 | × | 6 | × | | 2 | × | |
| 128 | C | 61° 45' | 61° 14' | 4758 | 0 | | | | | | | | | | | |
| 130 | C | 61° 47' | 61° 30' | 3750 | 0 | | | | | | | | | | | |
| 136 | C | 62° 39' | 64° 02' | 3734 | 1 | 100 | | | | | | | | | | |
| 140 | P | 59° 56' | 65° 18' | 3687 | 6000 | 99 | | | × | | × | | | | | |
| 146 | C | 60° 01' | 64° 50' | 3421 | 400 | 100 | | | | | | | | | | |
| 156 | C | 56° 31' | 63° 16' | 3927 | ca.7000 | 67 | × | 8 | 13 | | 4 | × | × | 5 | 3 | |
| 161 | P | 56° 12' | 66° 12' | 878 | 35000 | 42 | 2 | 5 | 37 | | 6 | 5 | × | 3 | 1 | × |
| 231 | C | 57° 09' | 69° 09' | 4188 | 1800 | 62 | | 2 | 7 | | 25 | 4 | | × | | |
| 245 | C | 59° 05' | 67° 04' | 3485 | 105000 | | | | | | | | | | | |
| 251 | C | 59° 14' | 69° 05' | 3742 | 84000 | | | | | | | | | | | |
| 256 | C | 61° 11' | 67° 49' | 3977 | 1900 | 100 | | | × | | | | | | | |
| 261 | C | 62° 13' | 67° 59' | 3771 | 570 | 100 | | | | | | | | | | |
| 266 | C | 63° 00' | 67° 42' | 3692 | 0 | | | | | | | | | | | |
| 271 | C | 64° 54' | 68° 20' | 412 | 0 | | | | | | | | | | | |
| 299 | C | 63° 10' | 71° 15' | 3777 | 0 | | | | | | | | | | | |
| 308 | C | 59° 00' | 71° 00' | 3789 | 122000 | 58 | 2 | 9 | 14 | | 6 | 1 | | 5 | 5 | |
| 312 | C | 58° 00' | 70° 57' | 4005 | 15000 | 59 | | 5 | 14 | | 17 | 3 | | 1 | 1 | |
| 323 | C | 56° 05' | 71° 11' | 1900 | 100000 | 46 | 2 | 11 | 22 | | 4 | 3 | × | 5 | 6 | × |
| 363 | C | 57° 35' | 58° 54' | 3500 | 34000 | 75 | | 3 | 11 | | 8 | 1 | | 1 | 1 | |
| 367 | C | 58° 07' | 59° 37' | 3870 | 1600 | 98 | | × | 1 | | 1 | × | | | | |
| 373 | C | 53° 01' | 55° 49' | 1962 | 50000 | 49 | 4 | 12 | 16 | | 4 | 2 | × | 7 | 6 | |
| 385 | C | 57° 02' | 56° 58' | 3282 | 18000 | 93 | | 1 | 4 | × | 1 | × | | × | × | |
| 391 | C | 57° 39' | 55° 56' | 3958 | 0 | | | | | | | | | | | |
| 395 | C | 58° 58' | 56° 03' | 3775 | 16 | 100 | | | | | | | | | | |
| 402 | C | 60° 22' | 55° 34' | 3537 | 7 | 100 | | | | | | | | | | |
| 409 | C | 61° 16' | 56° 11' | 224 | 98 | 96 | | | 3 | | 1 | | | | | |
| 417 | C | 62° 40' | 56° 13' | 500 | 0 | | | | | | | | | | | |
| 559 | C | 52° 01' | 56° 38' | 641 | 92000 | 50 | 5 | 7 | 7 | | 2 | 1 | | 20 | 9 | |
| 990 | C | 60° 42' | 60° 07' | 3770 | 10 | 100 | | | | | | | | | | |
| Tr-4-6 | C | 55° 54' | 61° 36' | 4108 | 7900 | 67 | | | 5 | | 26 | 1 | | | × | |
| P-4-8 | C | 56° 50' | 65° 00' | 3715 | 12000 | 91 | × | 1 | 1 | | 5 | × | | 1 | × | |
| Tr-4-10 | C | 60° 03' | 61° 50' | 4062 | 0 | | | | | | | | | | | |
| Tr-4-11 | C | 61° 02' | 61° 01' | 3468 | 0 | | | | | | | | | | | |
| PG-4-10 | P | 57° 56' | 64° 42' | 4108 | 6000 | 76 | 1 | 1 | 8 | | 12 | 2 | | 1 | × | |

## Systematic Part

The taxonomy of the planktonic forms mentioned in this report has been discussed in detail by PARKER (1962). Since PARKER's species descriptions agree well with our observations on the Drake Passage material, especially for the ranges of variation within a given species, the reader is referred to PARKER's report which also includes complete synonymy lists. Only additional observations or comments are given here. A detailed description of the planktonic foraminifera of parts of the Scotia Sea and the Drake Passage is given in an unpublished thesis by D.G. BLAIR (1965).

### *Globigerina bulloides* d'Orbigny

Plate II, figures 3a–c, 4a–c

*Globigerina bulloides* d'Orbigny, 1826, Ann. Sc. Nat., sér. 1, vol. 7, p. 277.

The species shows a great amount of variation with respect to the form of the last chamber. The specimen figured on plate II, fig. 3a–c might be called the "typical" form; the last chamber is about equal in size to the preceeding one. In many specimens, however, the size of the last chamber is considerably smaller and we might count $4^1/_2$ or even five chambers in the last whorl. Specimens with a larger last chamber are more triangular in outline and show only $3^1/_2$ chambers in the final whorl. Despite this variation the species is well defined by its large umbilical aperture. Only very small specimens might be somewhat difficult to separate from juvenile forms of *Globigerina pachyderma* (see also BÉ, 1960). Coiling ratios range between 65 and 73% of sinistrally coiled specimens. With frequencies of mostly 10–20% of the total planktonic foraminifera, *Globigerina bulloides* is a major constituent of the assemblages north of the Antarctic Convergence. South of this boundary, the species is found only occasionally.

### *Globigerina pachyderma* (Ehrenberg)

Plate III, Figures 1a–c, 2a–c; textfigure 3

*Aristerospira pachyderma* Ehrenberg, 1861, K. Preuss. Akad. Wiss. Berlin, Monatsber., p. 276, 277, 303.

With few exceptions, *Globigerina pachyderma* is the only planktonic foraminifer found in areas south of the Antarctic Convergence. In these cold Antarctic waters most individuals are of medium size (2,5 mm) and have four chambers in the last whorl. They are identical with the typical *G. pachyderma* described from the Arctic seas by BÉ (1960).

Specimens from deep-sea samples are usually heavily incrusted, and consequently, the sutures are often rather indistinct. In contrast, individuals collected at a shallower depth (station 409; 225 m) have thinner walls and more clearly visible sutures. However, the tests are still not as thin walled as those from similar depths north of the convergence. 99–100% of the individuals are sinistrally coiled (fig. 2).

For the area north of the Antarctic Convergence, a greater amount of ecophenotypic variation can be observed. In addition to the typical four chambered form mentioned previously, a large number of the specimens have depressed sutures and $4^1/_2$ or 5 distinct chambers in the last whorl. There is considerable variation in the

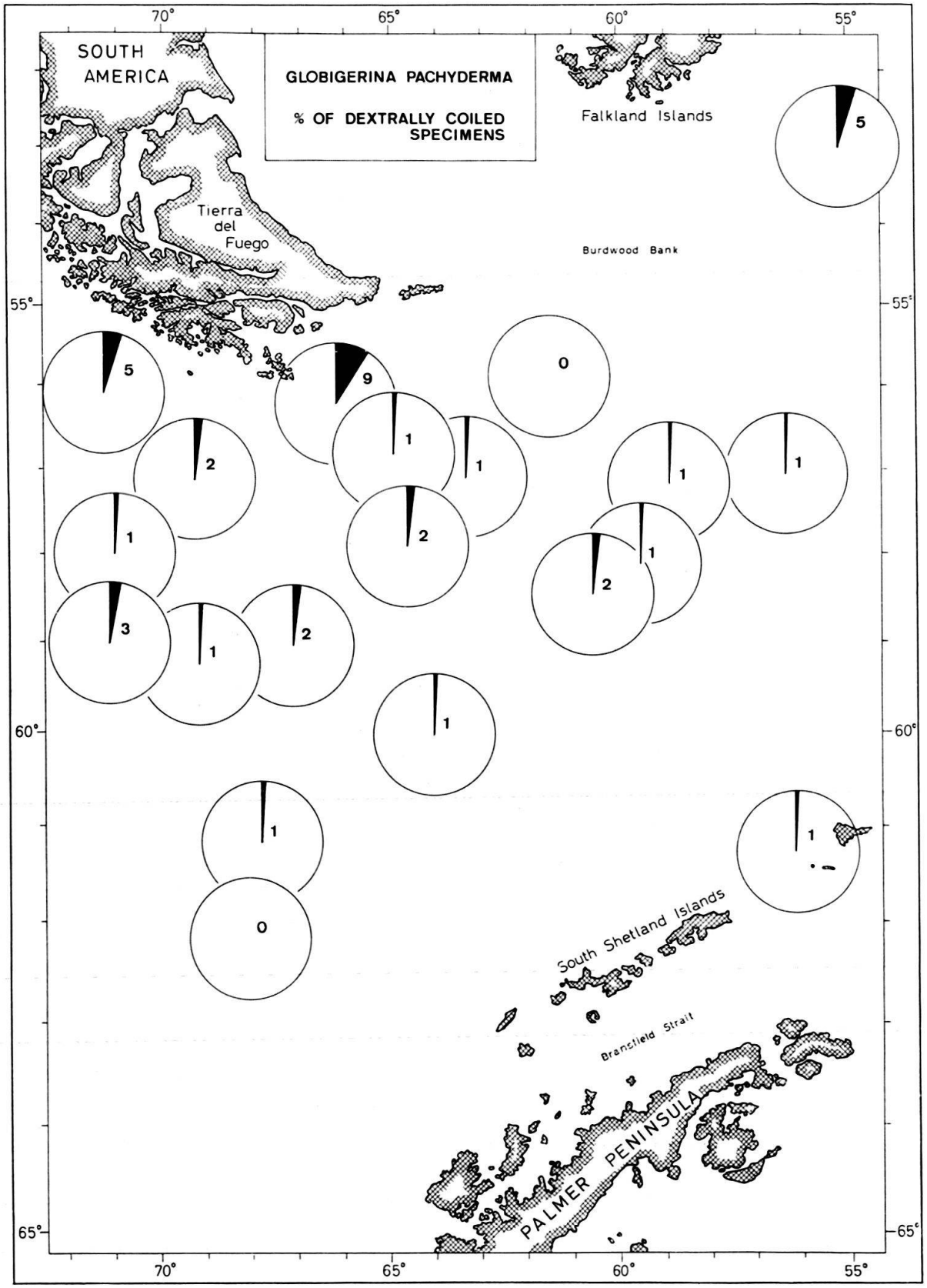


Fig. 2 Distribution of dextrally coiled *Globigerina pachyderma* (Ehrenberg) in percentages of the total population of this species at each station.

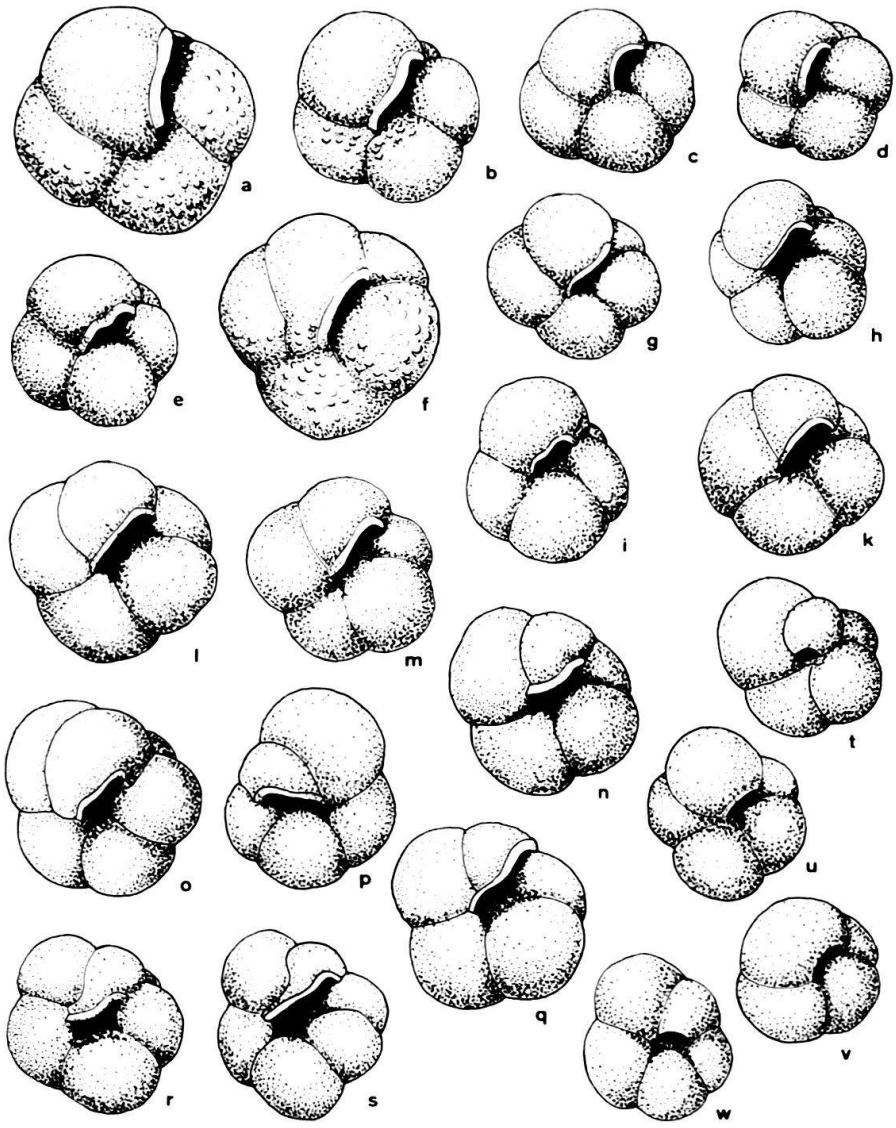


Fig. 3 Umbilical views of *Globigerina pachyderma* (Ehrenberg) showing the amount of variation in Subantarctic Waters north of the Antarctic Convergence. All specimens from station 323. 75 ×

size of the last chamber which may cover portions of the umbilical area (fig. 3)[1]). The five chambered form has been called "*Globigerina dutertrei*" by several authors, e.g. EARLAND (1934, p. 177), but already this author noted, that his "*Globigerina dutertrei*" and *G. pachyderma* intergrade (see also discussion in PARKER, 1962, p. 224). The true *Globoquadrina dutertrei* does not occur in the area of the Drake Passage.

BÉ (1960) and BLAIR (1965) considered the five chambered forms to be an earlier ontogenetic stage of the adult four chambered *G. pachyderma*. This might be true for the arctic forms described by BÉ (l.c.), but most of the specimens dealt with here and illustrated in figure 3 should be regarded as adults. The number of chambers in the last whorl generally depends on the size of the final chamber.

[1]) The latitudinal variation of *Globigerina pachyderma* in the southwest Pacific Ocean is discussed in detail in a recent article by KENNETT (1968b).

### *Globigerina* sp. aff. *G. pachyderma* (Ehrenberg)

North of the Antarctic Convergence, especially in the area southeast of the Falkland Islands (stations 559 and 373) a small Globigerina has been found which differs from *Globigerina pachyderma* in showing a more flat dorsal side and more rapidly increasing chambers. The aperture is extraumbilical and mostly shows a narrow lip. Regarding the number and arrangement of chambers the form is very similar to *Globoquadrina hexagona* (Natland), but it definitly lacks the pitted surface typical for that species. It seems to be related to *Globigerina pachyderma*, since intergradations with this species were observed.

### *Globigerina quinqueloba* Natland

Plate III, figures 3a–c

*Globigerina quinqueloba* Natland, 1938, Calif. Univ., Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 4, No. 5, p. 149, pl. 4, fig. 23.

A typical feature of this species is the hispid surface of the last chamber. Compared with *Globigerina pachyderma*, there is relatively little variation in the arrangement and the form of the five chambers. On the umbilical side, however, the platformlike extension of the apertural lip shows a great amount of variation and sometimes covers large parts of the umbilicus (see PARKER, 1962). An important percentage of the specimens are dextrally coiled, but exact ratios have not yet been calculated. The species is restricted to the areas north of the Antarctic Convergence, where it reaches a frequency maximum of 12% at station 373. South of the convergence it did not occur in the sediments.

### *Globigerina megastoma* Earland

*Globigerina megastoma* Earland, 1934, Discovery Reports, vol. 10, p. 177, pl. VIII, figs. 9–12.

The species has its type area in the central part of the Drake Passage, just north of the Antarctic Convergence. It was found in our material as a very rare form at few locations, including station 121, close to the type locality. The specimens correspond well with EARLAND's figures and description as well as with the lectotype chosen by BANNER and BLOW (1960, p. 14).

### *Orbulina universa* d'Orbigny

*Orbulina universa* d'Orbigny, 1939, in DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, «Foraminifères», p. 3; vol. 8, pl. 1, fig. 1.

Rare occurrences of *Orbulina universa* were noted at stations 323 and 161, in the warmer waters close to the South American Continent.

### *Globorotalia inflata* (d'Orbigny)

Plate I, figures 1a–c, 2a–c

*Globigerina inflata* d'Orbigny, in BARKER-WEBB et BERTHELOT, Hist. Nat., Iles Canaries, «Foraminifères», vol. 2, pt. 2, Zool., p. 134, pl. 2, figs. 7–9.

*Globorotalia inflata* is a good example of a planktonic species showing a thick secondary calcite incrustation of the type described by BÉ and ERICSON (1963) and

BÉ (1965). Most planktonic species in the Drake Passage have a heavily incrusted wall, but in none of them is the cortex as heavy as in *G. inflata*. The majority of specimens found in sediments from stations deeper than 900 m show a very thick, smooth wall which is often glassy in appearance (plate I, fig. 1). However, at almost every station from the deep-sea, a few specimens have a thinner test and a somewhat spinose instead of a smooth surface (plate I, fig. 2). At shallower depths and in warmer water (stations 323 and 373), southwest of Tierra del Fuego and southeast of the Falkland Islands, the spinose form makes up approximately half of the *G. inflata* population.

### *Globorotalia truncatulinoides* (d'Orbigny)

Plate II, figures 1a–c, 2a–c

*Rotalina truncatulinoides* d'Orbigny, 1839, in BARKER-WEBB and BERTHELOT, Hist. Nat. Iles Canaries, «Foraminifères», vol. 2, pt. 2, p. 132, pl. 2, figs. 25–27.

The widespread occurence of this species at all stations north of the Antarctic Convergence merits special attention, since in the North Atlantic and in the North Pacific it is usually considered to be a subtropical species (BRADSHAW 1959, BÉ 1962, SCHOTT 1966, BÉ and HAMLIN, 1967). Recently, KENNETT (1968a) has demonstrated that this species, when occurring in the cold waters of the southern oceans, differs morphologically from the subtropical form. Our specimens are typical representatives of this cold water variant (subspecies ?) characterized by a somewhat convex dorsal side and very inconspicuous sutures of the adult specimens (see plate II, fig. 1). Juvenile forms with a thinner wall may show the sutures more distinctly (plate II, fig. 2). A close relation to *Globorotalia tosaensis* Takanagai and Saito can be observed.

### *Globorotalia scitula* (Brady)

Plate II, figures 4a–c

*Pulvinulina scitula* Brady, 1882, Roy. Soc. Edinburgh, Proc., vol. 11 (1880–82), no. 111, p. 716.

*Globorotalia scitula* is a rather rare, but characteristic species, occurring occasionally in the warmer waters of the northern Drake Passage as well as at stations 308. There is little morphological variation among the specimens found and all of them are dextrally coiled.

### *Globorotalia* aff. *G. crassaformis* (Galloway and Wissler)

Plate I, figure 3; textfigure 4

This form was found only in a Petersen grab sample (station 249) from the western Drake Passage (59° 31′ S, 69° 15′ W at a depth of 4000 m)[2]). Compared with the original description by GALLOWAY and WISSLER our specimens usually have a larger aperture and a lip can only barely be detected. In the side view the periphery is more rounded, especially in specimens like the one figured on plate I, figure 3, which seem to be similar to *Globorotalia inflata*. However, the surface of the test does not show the polished and glassy appearance of the test, as may be seen in typical *Globorotalia*

[2]) This station was not included in the quantitative investigation because no dry weight value of the sediment was available.

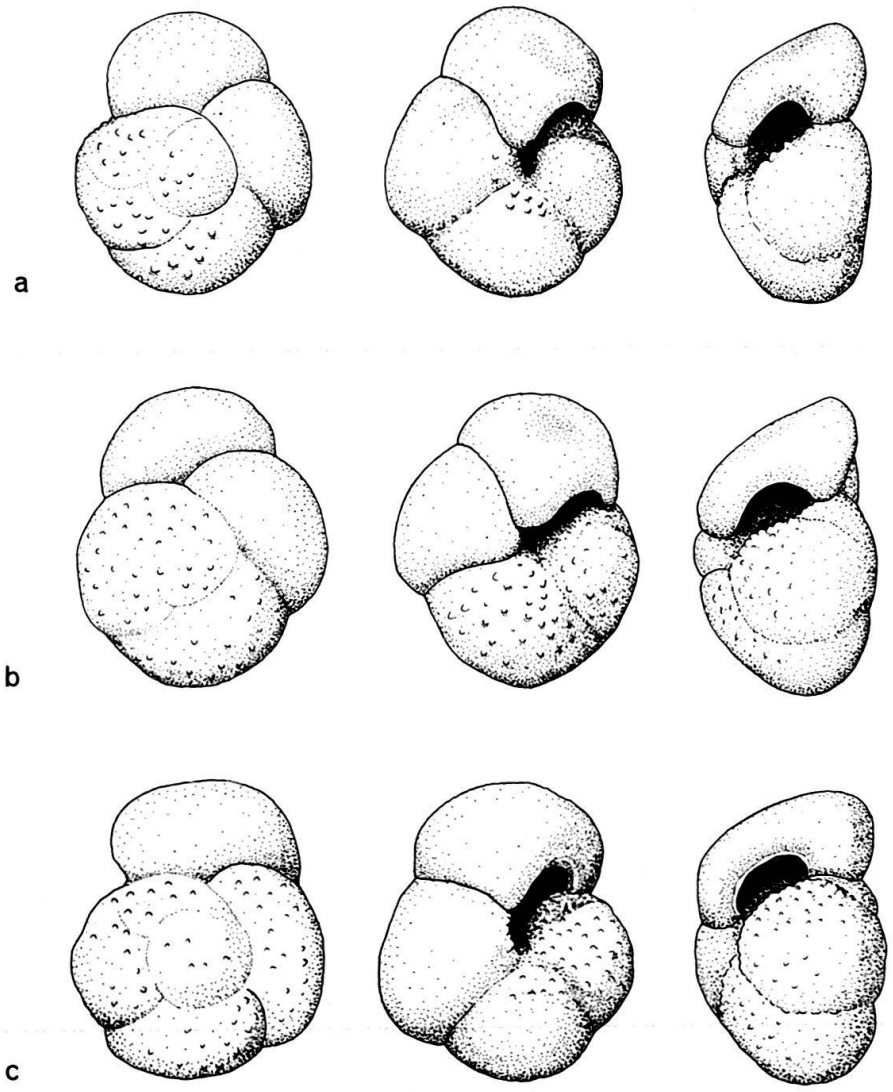


Fig. 4 *Globorotalia* aff. *G. crassaformis* (Galloway and Wissler). ELTANIN station 249. 50 ×

*inflata* from the same sample. In addition, there are four chambers in the last whorl, instead of $3^1/_2$ in *G. inflata*, and the sutures are deeper and more curved. The form might represent a cold water variant of *Globorotalia crassaformis*. BLAIR (1965) noted, that this species was relatively abundant in subsurface core samples but occurred only rarely in the surface samples he studied.

*Globorotalia puncticulata* (Fornasini) is possibly conspecific with the present form.

### *Globigerinita glutinata* (Egger)

Plate III, figures 4a–c, 5a–c, 6a–c

*Globigerina glutinata* Egger, 1893, Abhandl. K. Bayer, Akad. Wiss. München, Kl. II, vol. 18, p. 371, pl. 13, figs. 19–21.

PARKER (1962) gave a detailed description of this species which corresponds in all details with the forms found in our samples from areas north of the convergence. The specimens of the Drake Passage, in particular, show the same amount of variation

with respect to the presence or absence as well as to the morphology of the bulla. The majority of the individuals do not show a bulla (see plate III, fig. 4). The specimens shown in figures 5 and 6 of plate III are two examples out of the broad spectrum of different forms and sizes of the bulla.

### *Globigerinita uvula* (Ehrenberg)

Plate III, figures 7a–b, 8

*Pylodexia uvula* Ehrenberg, 1861, K. Preuss. Akad. Wiss. Berlin, Monatsber., pp. 276–277, 308.

The majority of the specimens do not show an umbilical bulla, but at all stations where this species has been recovered, at least a few specimens have been found which show this feature. At a number of stations, about half of the individuals exhibit a somewhat lower spire with a more rapid increase in the size of the chambers, as described by NATLAND (1933) for his *Globigerinoides minuta*. However, as PARKER (1962) noted, transitional bioseries between the two forms can be observed.

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## Plate I

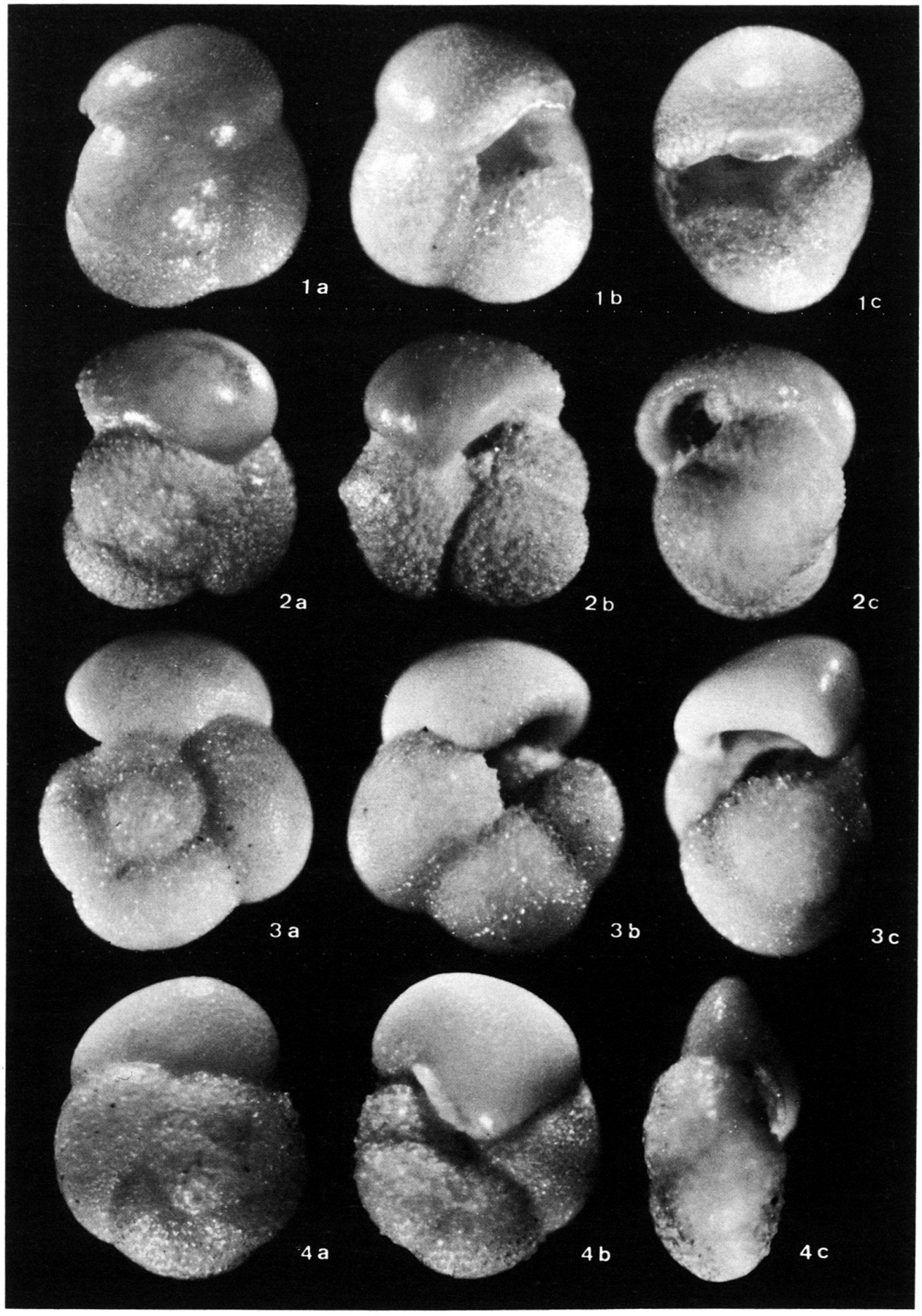
Fig. 1a–c *Globorotalia inflata* (d'Orbigny). Typical subantarctic form showing thick smoothly polished wall with heavy cortex. Station 323.

Fig. 2a–c *Globorotalia inflata* (d'Orbigny). Spinose form showing considerably thinner cortex than specimen of fig. 1. Station 323.

Fig. 3a–c *Globorotalia* sp. aff. *G. crassaformis* (Galloway and Wissler). Station 249 (see p. 477).

Fig. 4a–c *Globorotalia scitula* (Brady). Station 232.

all 75 ×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## Plate II

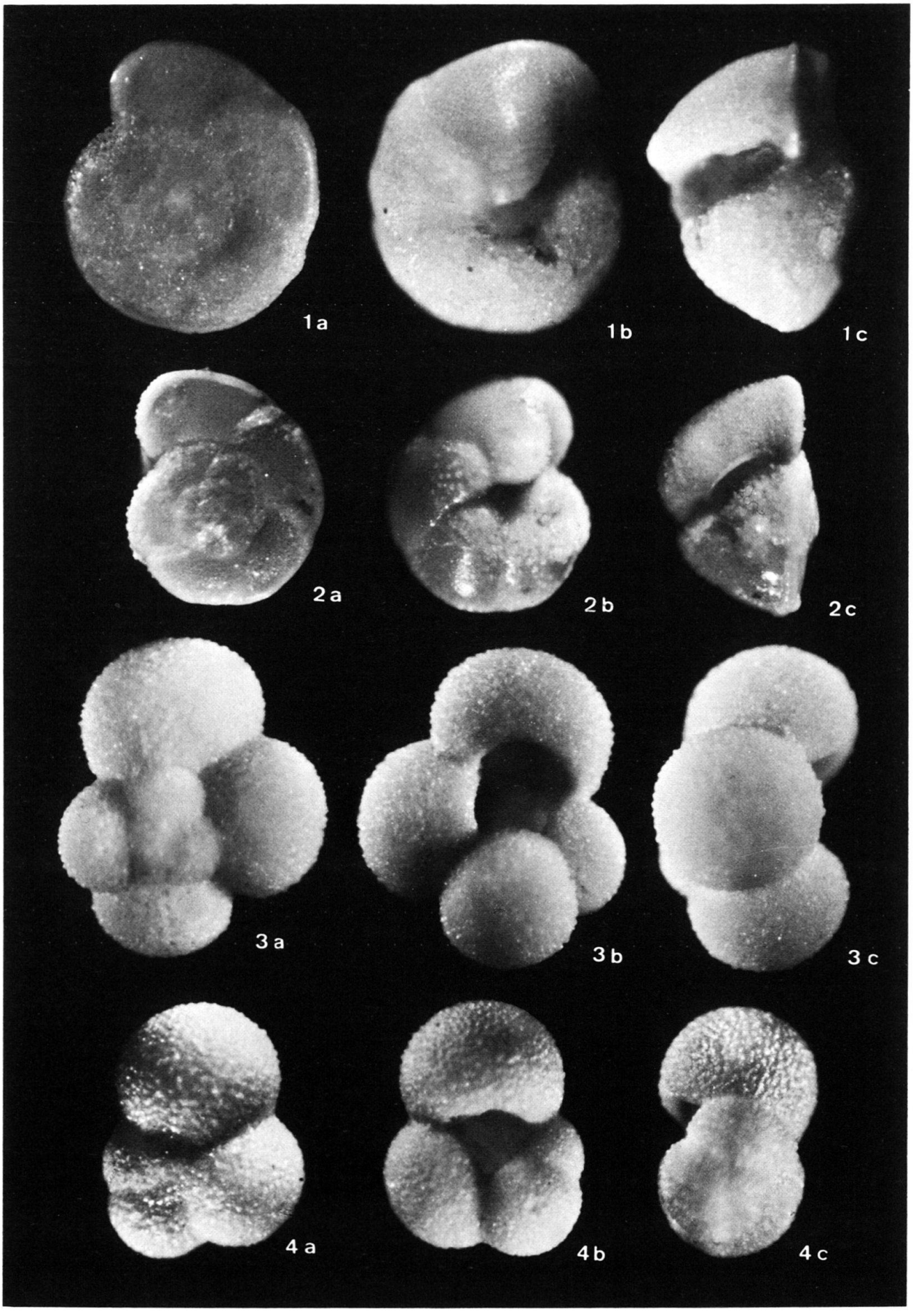
Fig. 1a–c *Globorotalia truncatulinoides* (d'Orbigny). Adult specimen. Station 323.

Fig. 2a–c *Globorotalia truncatulinoides* (d'Orbigny). Juvenile form. Station 559

Fig. 3a–c *Globigerina bulloides* d'Orbigny. Station 363

Fig. 4a–c *Globigerina bulloides* d'Orbigny. Station 363

all 75 ×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## Plate III

Fig. 1a–c *Globigerina pachyderma* (Ehrenberg). Large specimen. Station 363

Fig. 2a–c *Globigerina pachyderma* (Ehrenberg). Typical subantarctic form. Station 363

Fig. 3a–c *Globigerina quinqueloba* Natland. Station 373

Fig. 4a–c *Globigerinita glutinata* (Egger). Specimen without bulla. Station 308

Fig. 5a–c *Globigerinita glutinata* (Egger). Specimen with large bulla. Station 312

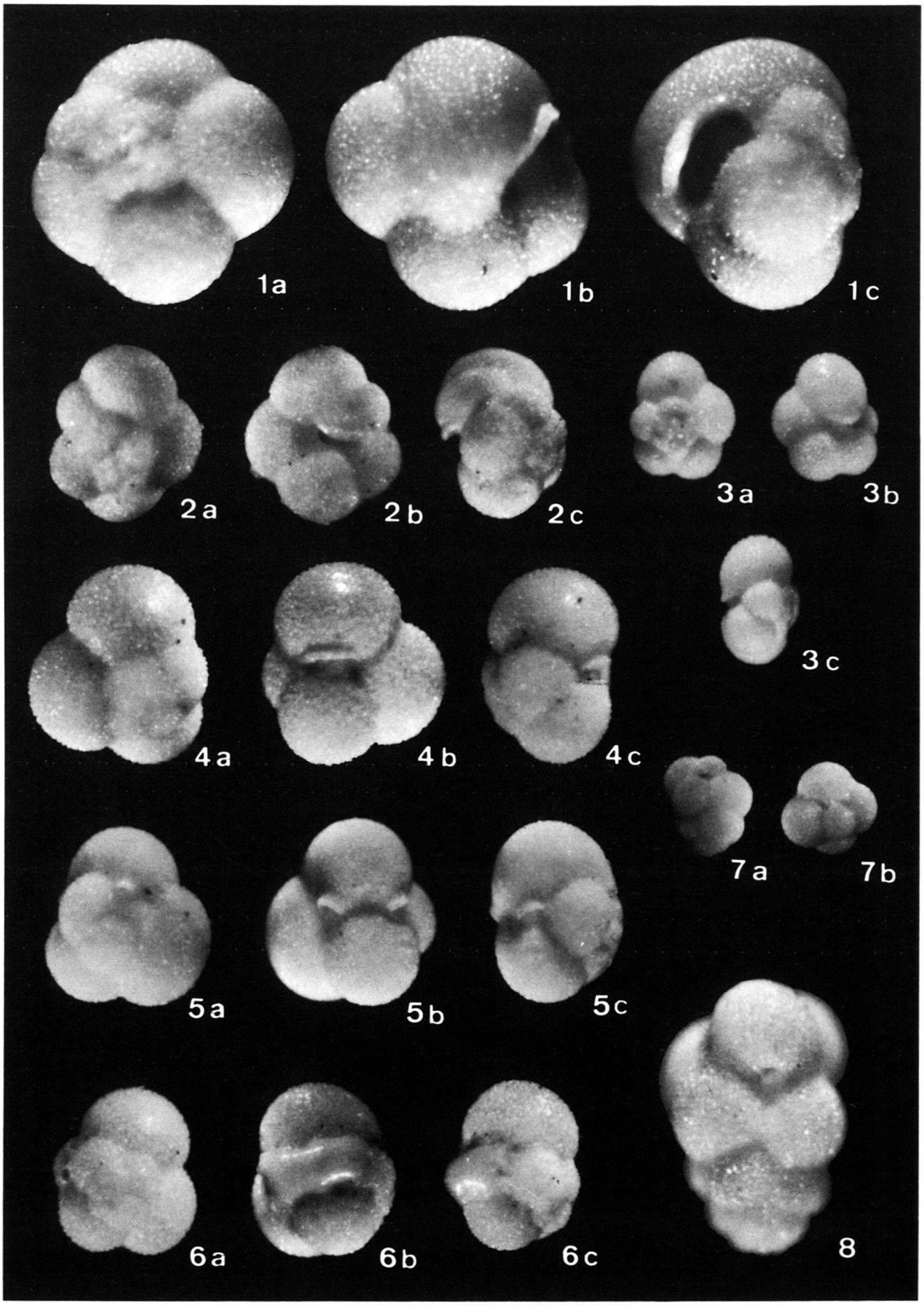
Fig. 6a–c *Globigerinita glutinatą* (Egger). Specimen with bulla. Station 245

Fig. 7a–b *Globigerinita uvula* (Ehrenberg). Station 308

Fig. 8 *Globigerinita uvula* (Ehrenberg). Station 245

Figures 1–7: 100 ×

Figure 8: 250 ×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