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BIOSTRATIGRAPHY AND INTER-
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BELGIUM BASED ON PLANKTONIC
FORAMINIFERA; THE OLIGOCENE -
MIOCENE BOUNDARY ON THE SOUTHERN
EDGE OF THE NORTH SEA BASIN

BY

H. J. F. HOOYBERGHS & F. J. C. DE MEUTER



1972

PALEIS DER ACADEMIËN — HERTOOGSSTRAAT, 1
BRUSSEL

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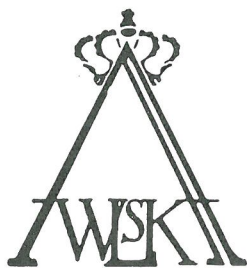
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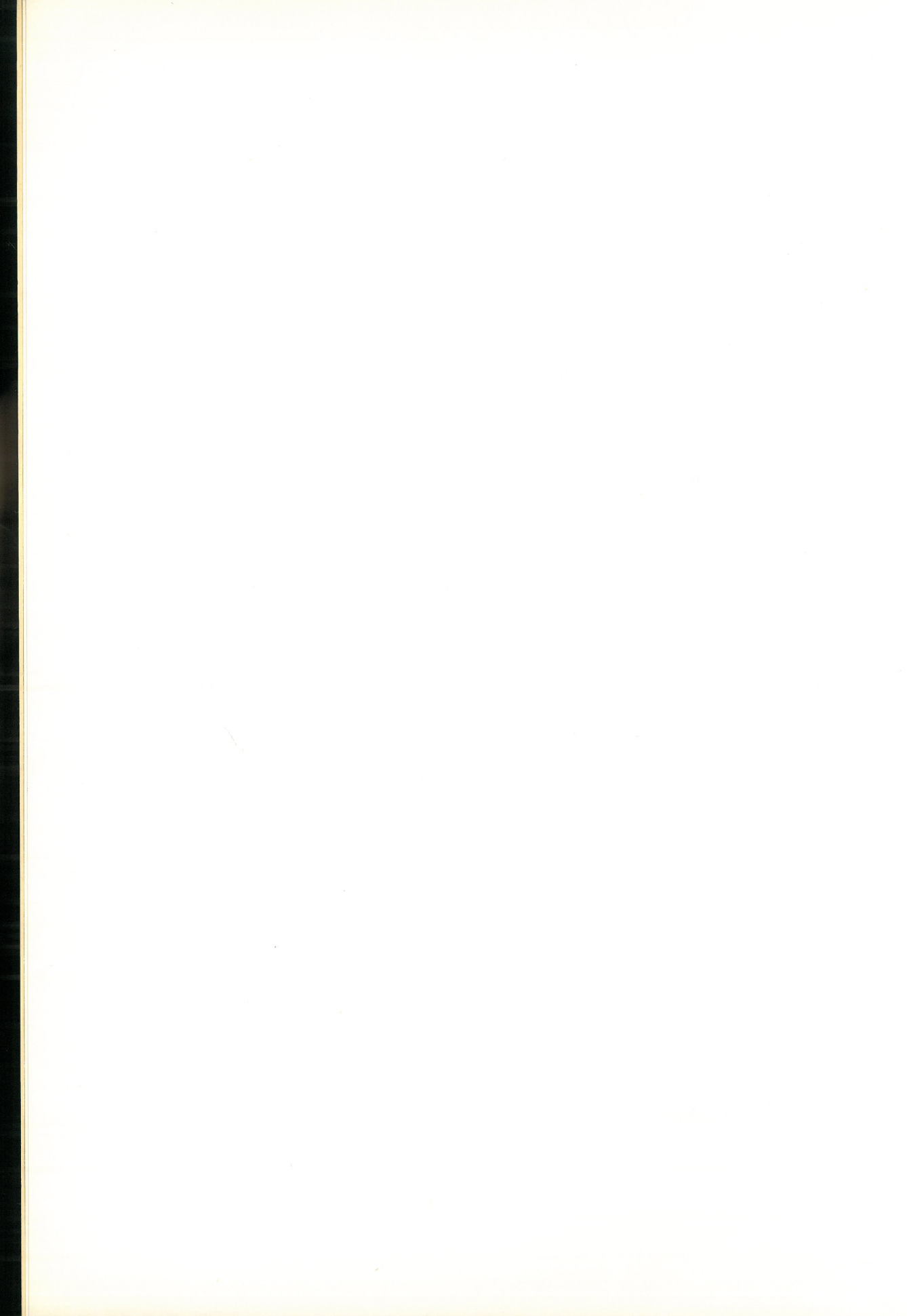
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PALEIS DER ACADEMIËN — HERTOOGSSTRAAT, 1
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SAMENVATTING

Glaucioniethoudende mariene zanden van Noord-België werden tot heden op basis van hun rijke fossielinhoud chronostratigrafisch tot de Mioceene Serie gerekend. Lithologisch kunnen ze ingedeeld worden in enerzijds de Zanden van Edegem, Antwerpen en Deurne in de omgeving van de stad Antwerpen en anderzijds de Zanden van Houthalen uit boringen in de Kempen.

De tot nogtoe bestudeerde fossielgroepen lieten echter niet toe te komen tot voldoende nauwkeurige bio- en chronostratigrafische besluiten. In deze studie wordt de determinatie van de, steeds goed bewaarde, planktonische foraminiferen uit genoemde Formaties doorgevoerd. Ze laten zowel een lokale biozonering toe, alsook correlaties met de interregionale biozones, zoals die vooral de laatste jaren uitgewerkt werden.

De fauna van de Zanden van Edegem kan geplaatst worden in de *Globigerina ampliapertura* Zone, overeenkomend met de gelijknamige Zone N.1 (=P.20) van BLOW (1969). Bijgevolg moeten deze sedimenten geplaatst worden in het midden van het Oligoceen en niet in het „Midden-Mioceen” van de auteurs. De Zanden van Houthalen bevatten twee opeenvolgende lokale Zones : de *Globigerinoides quadrilobatus primordius* Zone en de *Globigerinoides quadrilobatus altiapertura* Zone. Ze kunnen gecorreleerd worden met respectievelijk Zone N.4-Zone N.5 van BLOW. Zo moeten ze tot het onderste Mioceen, Aquitanian, gerekend worden. In de Zanden van Antwerpen kan biostratigrafisch de *Sphaeroidinellopsis subdehiscens subdehiscens* - *Globigerina druryi* Zone herkend worden, te vergelijken met de gelijknamige Zone N.13 van BLOW. Ze moeten dus geplaatst worden in het midden Mioceen, Serravallian. Vanaf de Zanden van Deurne is er geen correlatie meer mogelijk met de wereldwijde biozonering, daar de fauna behoort tot de boreale bioprovincie. Traditioneel worden deze zanden in het boven Mioceen behouden.

De correlaties op basis van de studie der planktonische foraminiferen hebben tot volgende belangrijke besluiten geleid. Enerzijds wordt de belangrijkheid van de hiaten tussen de bestudeerde Formaties nauwkeuriger bepaald. Anderzijds dient in het bestudeerd gebied de grens Oligoceen-Mioceen geplaatst te worden tussen de Zanden van Edegem en de Zanden van Houthalen.

SUMMARY

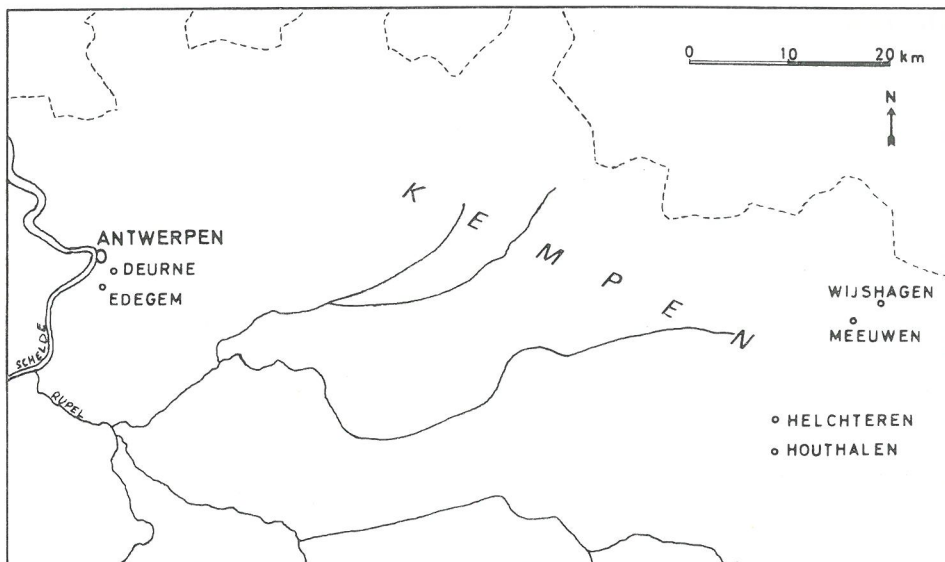
A rich and varied fauna of planktonic foraminifera from the glauconiferous "Miocene" sands of N Belgium has been determined. Five local biozones are erected and a correlation with the worldwide biozonation is here proposed. Chronostratigraphically the Edegem Sands have to be placed in the middle Oligocene and not in the middle Miocene as done by the previous authors. The Houthalen Sands contain two successive local Zones and the faunas correspond with those of the lowermost Miocene, Aquitanian. The Antwerpen Sands can be correlated with the middle Miocene or Serravallian. No comparison with the interregional biozonation can be made for the Deurne Sands, the very few species of planktonic foraminifera found therein being typical for the boreal bioprovince. Traditionally, they have been maintained in the upper Miocene.

I. LITHOSTRATIGRAPHIC FORMATIONS STUDIED IN THIS PAPER

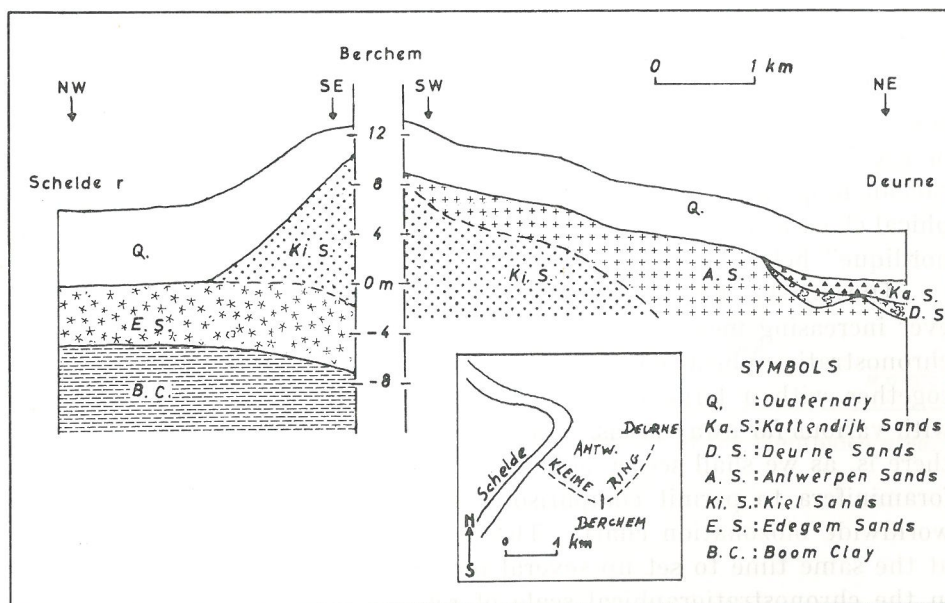
Abundant new material from temporary exposures around and in the city of Antwerpen and from boreholes in the Kempen enabled us to study the microfauna of the marine sediments of N Belgium. Our investigations are especially concerned with the planktonic foraminifera from those Formations which are traditionally placed in the Miocene Series. The most important localities are given on text-figure 1.

Most of these Formations have been studied and sampled during the digging-work for the "E3 - Kleine Ring" highway around Antwerpen. The whole of these excavations has clearly shown the relative positions of the lithostratigraphical units. A schematic longitudinal profile along the "Kleine Ring" is given on text-figure 2. The Boom Clay (Oligocene) is successively overlaid by the *Edegem Sands*, the *Antwerpen Sands* and the *Deurne Sands*. These glauconiferous sands contain a rich and well preserved foraminiferal fauna.

The *Houthalen Sands* from the boreholes of the Kempen also yielded interesting paleontological data. The first results have been given on the occasion of the "Colloquium for the study of the Northern Neogene at Ipswich-Norwich" in 1970 (published in 1970). Therein M. GULINCK deals with the lithostratigraphy of the mentioned boreholes, whilst A. RINGELE identifies the molluscs and F. DE MEUTER the foraminifera from the borehole Helchteren. We can now add thereto two more fossiliferous



Text-fig. 1 : Location map.



Text-fig. 2 : Schematic longitudinal section along the E3-Kleine Ring, Antwerpen.

Houthalen Sands deposits from boreholes Wijshagen and Meeuwen, also in the Kempen. By the courtesy of M. GULINCK, Geological Survey of Belgium, we can compare the lithology of the three boreholes characterized by a diverse foraminiferal fauna (text-fig. 3).

II. LITHO-, BIO-, AND CHRONOSTRATIGRAPHY OF THE AREA

In this paper we restrict ourselves to the currently used nomenclature of the marine Formations as mentioned above. These Formations were defined by R. TAVERNIER & J. DE HEINZELIN and by M. GULINCK on the occasion of the Second Symposium on the Stratigraphy of the Northern Neogene in 1961 (published in 1963). Further definitions of the whole of the *lithostratigraphical* units of the Belgian "Neogene" will be refined in the near future.

Reliable *biostratigraphical* conclusions in the studied area have thus far hardly been reached. A good biozonation in the "Neogene" of the southern shore of the North Sea basin is very difficult to work out because of the numerous hiatus within the deposits of this area and owing to the geographical limitation of the Formations. Important studies on the "Miocene" molluscan faunas of Belgium were carried out by M. GLIBERT (1945 and 1952) and by M. GLIBERT & J. DE HEINZELIN (1955).

For the present, we can refer to the quantitative and qualitative study of the molluscan associations in the Belgian "Neogene" carried out by A. RINGELE. Some of his first, still unpublished, results appear to agree with the conclusions of this paper.

Chronostratigraphical interpretation, based on the *biostratigraphical* results, is a still more difficult task, the molluscan faunas of the "Neogene" of the North Sea basin being geographically isolated from the Mediterranean bioprovince. This could be read on the "provisional" stratigraphical chart drawn up at the "Symposium sur la stratigraphie du Néogène nordique" held at Gent in 1961 (published in 1963, p. 171).

During the last years planktonic foraminifera are being used in an ever increasing measure for the purpose of drawing bio- and, still more, *chronostratigraphical* conclusions. The synthetic study of BLOW (1969), together with a large number of other publications, allows correlation with various far away areas. In the major part of the Belgian "Miocene" there is, as we shall see, a sufficient variety of well preserved planktonic foraminifera to permit comparisons with the newly built up, practically worldwide biozonation chart. This has enabled us, in the studied area, at the same time to set up several biozones and to situate their position in the *chronostratigraphical* scale of reference.

III. SYSTEMATICS

The planktonic foraminifera group has been extremely split up, every distinguishable form being given a new species or subspecies name. At this taxonomic level, our nomenclature is based on the important, recently published studies of the group and mainly on the work of BLOW (1969). The "Treatise" of LOEBLICH & TAPPAN (1964) is used for the definition of the supraspecific units.

In this paper, only a selected synonymy and distribution is given. As a rule, we refer to the holotype, to the cited publication of BLOW, which gives a detailed range of the different forms, and occasionally to other important works. Wherever possible, a reference is made to the paper of DROOGER & BATJES (1959) dealing with the planktonic foraminifera from the Oligo-Miocene of the North Sea basin.

The figured specimens are stored in the collections of the "Laboratorium voor Paleontologie" at Leuven, Belgium (F 1500-1650).

Superfamily *Globigerinacea* CARPENTER, PARKER & JONES, 1862

Family *Heterohelicidae* CUSHMAN, 1927

Subfamily *Heterohelicinae* CUSHMAN, 1927

Genus *Chiloguembelina* LOEBLICH & TAPPAN, 1956

Chiloguembelina cubensis (PALMER, 1934)

(Pl. 1, fig. 1)

+ 1934 *Gümbelina cubensis* Palmer—PALMER, p. 74, text-figs. 1-6
(fide Ellis & Messina).

1957 *Chiloguembelina cubensis* (Palmer)—BECKMANN, p. 89, pl. 21,
fig. 21.

Description : cf. PALMER, 1934, p. 74.

Distribution : The stratigraphic range of *C. cubensis*, as indicated by
BECKMANN (1957), extends from the *Porticulasphaera mexicana*
Zone of the Eocene to the *Globorotalia opima opima*
Zone of the Oligocene.

Occurrence : Edegem Sands.

Family *Hantkeninidae* CUSHMAN, 1927

Subfamily *Hastigerininae* BOLLI, LOEBLICH & TAPPAN, 1957

Genus *Pseudohastigerina* BANNER & BLOW, 1959

Pseudohastigerina barbadoensis BLOW, 1969

(Pl. 1, fig. 2)

+ 1969 *Pseudohastigerina barbadoensis*, n.sp.—BLOW, p. 409, pl. 53,
figs. 7-9; pl. 54, figs. 1-3.

Description : cf. BLOW, 1969, p. 409.

Distribution : According to BLOW (1969), *P. barbadoensis* ranges from Zone
P.16 of the late Eocene to the top of Zone P.19 of the
Oligocene.

Occurrence : Base of Edegem Sands.

Subfamily *Cassigerinellinae* BOLLI, LOEBLICH & TAPPAN, 1957

Genus *Cassigerinella* POKORNY, 1955

Cassigerinella chipolensis (CUSHMAN & PONTON, 1932)

(Pl. 1, fig. 3)

+ 1932 *Cassidulina chipolensis* Cushman & Ponton—CUSHMAN &
PONTON, p. 98, pl. 15, figs. 2 a-c (fide Ellis & Messina).

1969 *Cassigerinella chipolensis* (CUSHMAN & PONTON)—BLOW, p. 377,
pl. 51, fig. 5.

Description : cf. CUSHMAN & PONTON, 1932, p. 98.

Distribution : According to BLOW (1969), *C. chipolensis* occurs from the Oligocene (Zone P.18) to the middle Miocene (Zone N.13-Zone N.14?).

Occurrence : Edegem Sands, Houthalen Sands.

Family *Globorotaliidae* CUSHMAN, 1927

Subfamily *Globorotaliinae* CUSHMAN, 1927

Genus *Globorotalia* CUSHMAN, 1927

Globorotalia aff. *mayeri* CUSHMAN & ELLISOR, 1939

(Pl. 1, figs. 4 a, b, c)

+ 1939 *Globorotalia mayeri* Cushman & Ellisor, n.sp.—CUSHMAN & ELLISOR, p. 11, pl. 2, figs. 4 a-c.

1969 *Globorotalia (Turborotalia) mayeri* CUSHMAN & ELLISOR—BLOW, p. 351, pl. 3, figs. 7, 8, 9.

1971 *Globorotalia* aff. *mayeri* CUSHMAN & ELLISOR—TJALSMA, p. 65, pl. 8, figs. 4 a-5, text-fig. 12.

Description : cf. CUSHMAN & ELLISOR, 1939, p. 11.

Remarks : *G. mayeri* was reexamined by BLOW (1969), who concluded that it was previously often confused with *Globorotalia siakensis* LE ROY, 1939. The latter species differs from *G. mayeri* in having radial sutures on both spiral and umbilical sides and in having less embracing chambers in the last whorl. Our specimens have five chambers in the last whorl, but resemble the type specimen in the curved sutures on the spiral side, in the radial sutures on the umbilical side, in the broadly rounded axial periphery and in the arched aperture, bordered by a distinct lip. BLOW (1969) noted that in subtropical-temperate regions, *G. (T.) mayeri* evolves from *G. (T.) peripheroronda* BLOW & BANNER, 1966. This evolution should be accompanied by an increase of wall thickness and increase in the mammillate and pustulate nature of the test wall, which is a common feature of planktonic foraminifera from cooler water environments. This characters are distinctly developed in our specimens. Further, *G. aff. mayeri* from the North Sea basin resembles well the individuals figured by TJALSMA (1971) in the number of chambers and the often more circular outline of the test. A number of specimens have a last chamber which is reduced in size.

Occurrence : Antwerpen Sands.

Globorotalia obesa BOLLI, 1957

(Pl. 1, figs. 5 a, b, c)

- + 1957 *Globorotalia obesa* Bolli, new species—BOLLI, p. 119, pl. 29, figs. 2 a-3.
1959 *Globorotalia obesa* Bolli—DROOGER & BATJES, p. 177, pl. 1, fig. 7.
1967 *Globorotalia obesa* Bolli—BIZON, p. 50, pl. III, figs. 2 a-c; pl. XIV, figs. 5 a-c.
1969 *Globorotalia (Turborotalia) obesa* BOLLI—BLOW, p. 352.

Description : cf. BOLLI, 1957, p. 119.

Remarks : Besides typical specimens of *G. obesa*, individuals occur with 3 1/2 chambers in the last whorl instead of 4 1/2 and with a generally larger aperture, belonging probably to *Globorotalia pseudobesa* (SALVATORINI, 1966). Those forms seem to evolve into *Globigerinopsis aquasayensis* BOLLI, 1962.

Distribution : According to BLOW (1969), *G. obesa* occurs from the Oligocene (Zone N.2) to the Pleistocene - Holocene (Zone N.23). DROOGER & BATJES (1959) recorded this species from the Oligo-Miocene deposits of the North Sea Basin.

Occurrence : Houthalen Sands, Antwerpen Sands.

Globorotalia opima nana BOLLI, 1957

(Pl. 2, figs. 1 a, b, c)

- + 1957 *Globorotalia opima nana* Bolli, new species, new subspecies—BOLLI, p. 118, pl. 28, figs. 3 a-c.
1969 *Globorotalia (Turborotalia) opima nana* BOLLI—BLOW, p. 352, pl. 39, fig. 1.

Description : cf. BOLLI, 1957, p. 118.

Remarks : *G. opima nana* differs from *Globorotalia opima opima* BOLLI, 1957, only in the size of the test. Both species have the same wall texture and structure. A number of small forms morphologically resemble *G. opima nana*, but have different umbilical and apertural characters. Those forms have also been observed by BLOW (1969). We included them here.

Distribution : The stratigraphical range of *G. opima nana*, given by BLOW (1969), extends from the late Eocene (Zone P.14?, P.15) to the Oligocene (Zone N.3 or P.22). Atypical specimens also occur in Zone N.4 and Zone N.5.

Occurrence : Edegem Sands, Houthalen Sands.

Globorotalia opima opima BOLLI, 1957
(Pl. 2, figs. 2 a, b, c)

- + 1957 *Globorotalia opima opima* Bolli, new species, new subspecies—
BOLLI, p. 117, pl. 28, figs. 1 a-2.
1969 *Globorotalia (Turborotalia) opima opima* BOLLI—BLOW, p. 353,
pl. 39, fig. 3.

Description : cf. BOLLI, 1957, p. 117.

Remarks : Our specimens show 4 to 5 chambers in the last whorl. An apertural lip has not always been observed. The last chamber often is laterally compressed and becomes rather large. Smaller individuals are more closely related to *Globorotalia opima nana* BOLLI, 1957.

Distribution : As noted by BLOW (1969), *G. opima opima* has a restricted stratigraphical range within the Oligocene. It evolves from *Globorotalia opima nana* BOLLI, 1957, within Zone P.19 and occurs up to Zone N.2 (=P.21). Typical specimens of *G. opima opima* however occur from the upper part of Zone N.1 (=P.20).

Occurrence : Edegem Sands.

Globorotalia aff. *peripheroronda* BLOW & BANNER, 1966
(Pl. 1, fig. 6)

- + 1966 *Globorotalia (Turborotalia) peripheroronda* Blow & Banner, new
species—BLOW & BANNER, p. 294, pl. 1, figs. 1 a-c; pl. 2, figs. 1-3.
1969 *Globorotalia (Turborotalia) peripheroronda* BLOW & BANNER—
BLOW, p. 354.

Description : cf. BLOW, 1969, p. 354.

Remarks : An individual with five chambers in the last whorl has been found at the base of the Antwerpen Sands. BLOW (1969) noted that this species gives rise to *Globorotalia (T.) mayeri* CUSHMAN & ELLISOR, 1939 in subtropical-temperate regions.

Distribution : BLOW (1969) noted that *G. (T.) peripheroronda* ranges from Zone N.6 to within Zone N.11 - Zone N.12(?).

Occurrence : This species was found only at the base of the Antwerpen Sands.

Globorotalia pseudopachyderma CITA, PREMOLI SILVA & ROSSI, 1965
(Pl. 2, figs. 3 a, b, c)

- + 1965 *Globorotalia pseudopachyderma* n.sp.—CITA, PREMOLI SILVA & ROSSI, p. 233, pl. 20, figs. 3 a-c, 4 a-c; pl. 31, figs. T a-c; text-figs. 3 c-d.

Description : cf. CITA, PREMOLI SILVA & ROSSI, 1965, p. 233.

Remarks : The last chamber of our specimens is generally reduced in size. A distinct lip borders the umbilical-extraumbilical aperture.

Distribution : *G. pseudopachyderma* has been described from the type Tortonian in Italy.

Occurrence : Deurne Sands.

Globorotalia scitula (BRADY, 1884)
(Pl. 2, figs. 4 a, b, c)

- + 1884 *Pulvinulina scitula* Brady—BRADY, p. 716.
1957 *Globorotalia scitula* (Brady)—BOLLI, p. 120, pl. 29, figs. 11 a-12 c.
1959 *Globorotalia scitula scitula* (Brady)—BLOW, p. 219, pl. 19, figs. 126 a-c.
1969 *Globorotalia* (*Turborotalia*) *scitula* (BRADY)—BLOW, p. 356, pl. 39, fig. 7.

Description : cf. BLOW, 1959, p. 219.

Remarks : Some individuals resemble the type specimen in the small size of the test, in the hemispherical chambers in the last whorl, in the subacute to rounded peripheral margin and in the small, shallow umbilicus. The wall mostly appears glassy. Other specimens with a small conical-shaped test resemble *Globorotalia zealandica* HORNIBROOK, 1958.

Distribution : BLOW (1969) noted that *G. scitula* occurs from the middle Miocene (Zone N.11) to the Pleistocene-Holocene (Zone N.23).

Occurrence : Antwerpen Sands.

Globorotalia siakensis (LE ROY, 1939)
(Pl. 3, figs. 1 a, b, c)

- + 1939 *Globigerina siakensis* Le Roy—LE ROY, p. 262, pl. 4, figs. 20-22.
1969 *Globorotalia* (*Turborotalia*) *siakensis* (LE ROY)—BLOW, p. 356, pl. 10, figs. 7-9.

Description : cf. LE ROY, 1939, p. 262.

Remarks : As discussed by BLOW (1959), *G. siakensis* has frequently been misidentified as *Globorotalia mayeri* CUSHMAN & ELLISOR, 1939. The present species differs from the latter in the radial sutures on both spiral and umbilical sides, in the more rapid increase in size of the chambers in the last whorl, which results in a more elongate test and in a flatter spiral side. Our individuals resemble the type specimen in all the mentioned features.

Distribution : The stratigraphical range of *G. siakensis*, indicated by BLOW (1959), extends from Zone N.1 (=P.20) of the Oligocene up to Zone N.14 of the middle Miocene.

Occurrence : Edegem Sands, Houthalen Sands.

Globorotalia sp.
(Pl. 3, figs. 2 a, b, c)

1971 *Globorotalia* sp.—TJALSMA, p. 64, pl. 8, figs. 2 a-3 c.

Remarks : In the Antwerpen Sands, a lot of individuals occur with 4 to 5 chambers in the last whorl, resembling *Globorotalia* sp. of TJALSMA (1971). In the North Sea basin, transitional forms between *Globorotalia* sp. and *Globorotalia* aff. *mayeri* CUSHMAN & ELLISOR, 1939, also have been observed. Mostly, the wall has a distinct pustulate nature. The last chamber is often reduced in size.

Distribution : TJALSMA recorded those forms from the *Sphaeroidinellopsis subdehiscens* / *Globorotalia menardii* Form 1 association, which can be correlated with the lower part of Zone N.13 of BLOW.

Occurrence : Antwerpen Sands.

Family *Globigerinidae* CARPENTER, PARKER & JONES, 1862
Subfamily *Globigerininae* CARPENTER, PARKER & JONES, 1862
Genus *Globigerina* d'ORBIGNY, 1826
Globigerina ampliapertura BOLLI, 1957
(Pl. 3, figs. 3 a, b, c)

+ 1957 *Globigerina ampliapertura* Bolli, new species—BOLLI, p. 108, pl. 22, figs. 5-7.

1959 *Globigerina ampliapertura* Bolli—DROOGER & BATJES, p. 174, pl. 1, fig. 1.

1969 *Globigerina ampliapertura* BOLLI—BLOW, p. 108, pl. 22, figs. 5 a-7 b.

Description : cf. BOLLI, 1957, p. 108.

Remarks : The aperture of our specimens sometimes shows a tendency to become umbilical-extraumbilical in position, but remains predominantly umbilical. This agrees with the observations of BLOW (1969), who noted that *G. ampliapertura* evolves from *Globorotalia increbescens* BRADY, 1949 and that immature individuals of *G. ampliapertura* still show a tendency towards a globorotaloid apertural condition.

Distribution : The stratigraphical range of *G. ampliapertura*, given by BLOW (1969), is rather restricted. The present species occurs from the upper Eocene (Zone P.17) to the Oligocene (lower part of Zone N.2 or P.21).

Occurrence : Edegem Sands.

Globigerina anguliofficialis BLOW, 1969
(Pl. 4, figs. 1 a, b, c)

+ 1969 *Globigerina anguliofficialis* n.sp.—BLOW, p. 379, pl. 11, figs. 1-5.

Remarks : *G. anguliofficialis* was described as being a transitional form between *Globigerina officinalis* SUBBOTINA, 1953 and *Globigerina angulisuturalis* BOLLI, 1957.

Gradually a fifth chamber in the last whorl develops and the sutures become deeply incised and U-shaped as in *G. angulisuturalis*. In our material however, no specimens were found with well developed U-shaped, wide sutures as in typical individuals of *G. angulisuturalis*. *G. anguliofficialis*, with an abortive last chamber, also occurs.

Distribution : BLOW (1969) indicated that *G. anguliofficialis* ranges from Zone P.17 of the upper Eocene to Zone N.2 (=P.21) of the Oligocene.

Occurrence : Edegem Sands.

Globigerina angustiumbilocata BOLLI, 1957
(Pl. 3, figs. 4 a, b, c)

+ 1957 *Globigerina ciproensis angustiumbilocata* Bolli, new subspecies—BOLLI, p. 109, pl. 22, figs. 12 a-13 c.

1962 *Globigerina angustiumbilocata* Bolli—BANNER & BLOW, p. 85, pl. IWxz, figs. 9 (iv) 16 (vi, vii).

1969 *Globigerina angustiumbilocata* BOLLI—BLOW, p. 316.

Description : cf. BOLLI, 1957, p. 109.

- Remarks* : As already indicated by BOLLI (1957), the aperture of our specimens also shows a tendency to an umbilical-extra-umbilical position, becoming asymmetric. Individuals with only 4 1/2 chambers in the last whorl and a somewhat reduced last chamber have morphological affinities with *Globigerina officinalis* SUBBOTINA, 1953. BANNER & BLOW (1962) indeed have observed transitional forms between *G. angustiumbilitata* and *G. officinalis* in the Eocene and Oligocene.
- Distribution* : The stratigraphical range of *G. angustiumbilitata*, given by BLOW (1969), extends from Zone N.16. (late Miocene) to Zone N.22 (Pleistocene). The species however was described from the *Globigerina ciperoensis* Zone of BOLLI (1957), Cipero Formation, Oligocene of Trinidad.
- Occurrence* : Edegem Sands, Houthalen Sands, Antwerpen Sands.

Globigerina bulloides d'ORBIGNY, 1826
(Pl. 4, figs. 2 a, b, c)

- + 1826 *Globigerina bulloides* d'Orbigny—d'ORBIGNY, p. 277.
1960 *Globigerina bulloides* d'Orbigny—BANNER & BLOW, p. 3, pl. 1, figs. 1 a-e.
1969 *Globigerina bulloides bulloides* d'ORBIGNY—BLOW, p. 316, pl. 14, figs. 1, 2.

Description : cf. BANNER & BLOW, 1960, p. 3.

Remarks : Specimens from the Deurne Sands with an aberrant final chamber appear similar to *Globigerina diplostomum* REUSS, 1850, with a large umbilicus, or to *Globigerina quadrilatera* GALLOWAY & WISSLER, 1927, with a small umbilicus and a smaller test. BLOW (1969) noted that it is possible that these two species should be considered synonymous with *G. bulloides*. Our rare individuals of these species have been included here. Rarely, specimens with a very large aperture occur in the Deurne Sands, resembling *Globigerina apertura* CUSHMAN, 1918. These forms also have been included here, since they were found only exceptionally.

Distribution : BLOW (1969) indicated that *G. bulloides bulloides* develops from *Globigerina praebulloides* BLOW, 1959 in the middle part of Zone N.16 (late Miocene) and occurs up to Zone N.23 (Pleistocene-Holocene).

Occurrence : Deurne Sands.

Globigerina druryi AKERS, 1955

(Pl. 4, figs. 3 a, b, c)

+ 1955 *Globigerina druryi* AKERS—AKERS, p. 654, pl. 65, figs. 1 a-c.

1969 *Globigerina druryi* AKERS—BLOW, p. 318, pl. 14, fig. 4.

Description : cf. AKERS, 1955, p. 654.

Remarks : The size of the aperture of our specimens varies considerably and, as noted by BLOW (1969), it is often larger than in the type specimen figured by AKERS (1955). Rarely the test becomes slightly elongated, being a transitional form between *G. druryi* and *Globigerina nepenthes* TODD, 1957. Exceptionally, the present species has a higher trochospiral test, resembling *Globigerina decoraperta* TAKAYANAGI & SAITO, 1962, but these forms have been included here.

Distribution : The stratigraphical range of *G. druryi*, indicated by BLOW (1969), is very restricted. The species only occurs from Zone N.11 tot Zone N.14 of the middle Miocene.

Occurrence : Antwerpen Sands.

Globigerina eamesi BLOW, 1959

(Pl. 4, figs. 4 a, b, c)

+ 1959 *Globigerina eamesi* Blow, sp. nov.—BLOW, p. 176, pl. 8, figs. 39 a-c.

1965 *Globigerina eamesi* Blow—CITA, PREMOLI SILVA & ROSSI, p. 247, pl. 27, figs. 3 a-b, 4 a-c.

1966 *Globigerina eamesi* Blow—JENKINS, p. 4, pl. 1, figs. 10 a-c.

1969 *Globigerina eamesi* BLOW—BLOW, p. 318.

Description : cf. BLOW, 1959, p. 176.

Remarks : *G. eamesi* has a moderately highly coiled trochospiral test. The surface of our specimens has no spines, unlike the type specimen figured by BLOW (1959), but, as observed by JENKINS (1966), those spines can also be absent.

Distribution : BLOW (1969) indicated that *G. eamesi* ranges from the middle Miocene (Zone N.14) to the Pliocene (Zone N.18). CITA, PREMOLI SILVA and ROSSI (1965) have found the present species in the type Tortonian in Italy and JENKINS (1966) in the type Burdigalian of SW France.

Occurrence : Antwerpen Sands.

Globigerina globorotaloidea COLOM, 1954
(Pl. 5, figs. 1 a, b, c)

- + 1954 *Globigerina globorotaloidea* Colom—COLOM, p. 212, pl. 17, figs. 1-25 (fide Ellis & Messina).
1965 *Globigerina globorotaloidea* Colom—CITA, PREMOLI SILVA & ROSSI, p. 249, pl. 18, figs. 1 a-c, 2 a-c, 3.

Description : cf. COLOM, 1954, p. 212.

Remarks : In our specimens, the form and position of the last chamber varies and the last chamber is often of smaller size than the penultimate one. As noted by CITA, PREMOLI SILVA & ROSSI (1965), the position of the aperture also varies. Mostly, there are five chambers in the last whorl.

Distribution : CITA, PREMOLI SILVA & ROSSI noted that *G. globorotaloidea* has been recorded from Burdigalian to Recent deposits.

Occurrence : Antwerpen Sands.

Globigerina gortanii (BORSETTI, 1959)
(Pl. 5, figs. 2 a, b, c)

- + 1959 *Catapsydrax gortanii* n. sp.—BORSETTI, p. 205, pl. 13, figs. 1 a-d.
1962 *Globigerina turrilina turrilina* Blow & Banner, subsp. nov.—BANNER & BLOW, p. 98, pl. XIII D-G.
1969 *Globigerina gortanii gortanii* BORSETTI—BLOW, p. 320, pl. 17, fig. 1.

Description : cf. BANNER & BLOW, 1962, p. 98.

Remarks : Our rare specimens resemble well the type specimen in the highly coiled trochospiral test and rather restricted apertural opening. Specimens with a broader umbilicus and a higher aperture rather resemble *Globigerina gortanii praeturrilina* BLOW & BANNER, 1962. A number of individuals have a well developed apertural flap, covering the umbilical area,

Distribution : The restricted stratigraphical range of *G. gortanii gortanii*, as given by BLOW (1969), extends from Zone P.18 to Zone N.3 (=P.23) of the Oligocene.

Occurrence : Edegem Sands.

Globigerina juvenilis BOLLI, 1957
(Pl. 5, figs. 3 a, b, c)

+ 1957 *Globigerina juvenilis* Bolli, new species—BOLLI, p. 110, pl. 24, figs. 5 a-c, 6.

1969 *Globigerina juvenilis* BOLLI—BLOW, p. 320, pl. 17, figs. 5, 6.

Description : cf. BOLLI, 1957, p. 110.

Distribution : *G. juvenilis* occurs from Zone N.4 of the early Miocene to Zone N.23 of the Pleistocene-Holocene, as has been indicated by BLOW (1969).

Occurrence : Antwerpen Sands.

Globigerina officinalis SUBBOTINA, 1953
(Pl. 5, figs. 4 a, b, c)

+ 1953 *Globigerina officinalis* Subbotina—SUBBOTINA, p. 78, pl. 11, figs. 1 a-c, 2 a-c, 6 a-7 c, 5 a-c.

1959 *Globigerina parva* Bolli—DROOGER & BATJES, p. 175, pl. 1, fig. 4.

1959 *Globigerina bulloides* d'Orbigny—DROOGER & BATJES, p. 175, pl. 1, fig. 3.

1962 *Globigerina officinalis* Subbotina—BANNER & BLOW, p. 88, pl. IX a-c; fig. 16.

1969 *Globigerina officinalis* SUBBOTINA—BLOW, p. 320, pl. 1, figs. 1-3.

Description : cf. BANNER & BLOW, 1962, p. 88.

Remarks : *Globigerina bulloides*, as figured by DROOGER & BATJES (1959), apparently belongs to *G. officinalis*, the species being of small size and occurring most frequently in the Oligocene of the North Sea basin. Transitional forms between *G. officinalis* and *Globigerina anguliofficialis* BLOW 1969, and between *G. officinalis* and *Globigerina angustiumbilitata* BOLLI, 1957 have been observed.

Distribution : *G. officinalis* occurs from the Eocene (Zone P.13?-Zone P.14 of BLOW, 1969) to the Oligocene (Zone N.2 or P.21). DROOGER & BATJES (1959) recorded it from the Oligo-Miocene deposits of the North Sea basin.

Occurrence : Edegem Sands.

Globigerina ouachitaensis ciproensis BOLLI, 1954
(Pl. 6, figs. 1 a, b, c)

- + 1954 *Globigerina ciproensis* Bolli, new species—BOLLI, p. 1, text-figures 3-6.
1959 *Globigerina ciproensis* Bolli—DROOGER & BATJES, p. 179, pl. 1, fig. 10.
1969 *Globigerina ouachitaensis ciproensis* BOLLI—BLOW, p. 320, pl. 2, figs. 4, 5, 6.

Description : cf. BOLLI, 1954, p. 1.

Remarks : *G. ouachitaensis ciproensis* shows morphological affinities with *Globigerina concinna* REUSS, 1850, from which it differs however by the larger size of the test and the smaller increase in size of the chambers in the last whorl. Both species also have a different stratigraphical range. Individuals of *G. ouachitaensis ciproensis* with only 4 chambers in the last whorl and a slightly reduced last chamber show morphological affinities with *Globigerina ouachitaensis ouachitaensis* HOWE & WALLACE, 1932.

Distribution : BLOW (1969) noted that typical specimens of *G. ouachitaensis ciproensis* range from Zone P.19 of the Oligocene to Zone N.4 of the early Miocene. In the North Sea basin, DROOGER & BATJES (1959) recorded *G. ciproensis* from the Oligo-Miocene deposits.

Occurrence : Edegem Sands, Houthalen Sands.

Globigerina ouachitaensis gnaucki BANNER & BLOW, 1962
(Pl. 6, figs. 2 a, b, c)

- + 1962 *Globigerina ouachitaensis gnaucki* Blow & Banner, subsp. nov.—BANNER & BLOW, p. 91, pl. IXL-N.
1969 *Globigerina ouachitaensis gnaucki* BLOW & BANNER—BLOW, p. 320, pl. 2, figs. 1-3.

Description : cf. BANNER & BLOW, 1962, p. 91.

Remarks : Our individuals show 4 1/2 to 5 chambers in the last whorl, increasing rapidly in size. The last chamber is often reduced and the size of the umbilicus varies.

Distribution : *G. ouachitaensis gnaucki* has a rather restricted stratigraphical range, as indicated by BLOW (1969). This subspecies occurs from Zone P.17 of the late Eocene to Zone N.1 (=P.20) of the Oligocene.

Occurrence : Edegem Sands.

Globigerina ouachitaensis ouachitaensis HOWE & WALLACE, 1932

(Pl. 6, figs. 3 a, b, c)

- + 1932 *Globigerina ouachitaensis ouachitaensis* Howe & Wallace—
HOWE & WALLACE, p. 74, pl. 10, figs. 7 a-b (fide Ellis & Messina).
1962 *Globigerina ouachitaensis ouachitaensis* Howe & Wallace—
BANNER & BLOW, p. 90, pl. IX D, M-K, figs. 9 (vi).
1969 *Globigerina ouachitaensis ouachitaensis* HOWE & WALLACE—
BLOW, p. 320, pl. 17, figs. 3, 4.

Description : cf. BANNER & BLOW, 1962, p. 90.

Remarks : *G. ouachitaensis ouachitaensis* originally has been described as having four chambers of nearly the same size in the last whorl, a fairly high aperture and a large umbilicus in which the apertures of the previous chambers remain visible. Our specimens show a last chamber which is more or less reduced, as observed also by BANNER & BLOW (1962) in topotype material and in their own individuals. Smaller specimens with a relatively strongly reduced last chamber and a smaller umbilicus seem to be closely related to *Globigerina officinalis* SUBBOTINA, 1953. Our individuals are typically rather highly trochospirally coiled.

Distribution : According to BLOW (1969), *G. ouachitaensis ouachitaensis* ranges from the late Eocene (Zone P.17) to the Oligocene (Zone N.2 or P.21).

Occurrence : Edegem Sands.

Globigerina pachyderma (EHRENBERG, 1861)

(Pl. 6, figs. 4 a, b, c)

- + 1861 *Aristerospira pachyderma*—EHRENBERG, p. 303, (1873), pl. 1, fig. 4.
1968 *Globigerina pachyderma* (Ehrenberg)—KENNETT, p. 316, pl. 1, figs. 1-32.
1970 *Globigerina pachyderma* (EHRENBERG, 1861)—DE MEUTER & LAGA, p. 179, pl. 1, figs. 1-6.

Description : cf. KENNETT, 1968, p. 309-316.

Remarks : The species from the Deurne Sands has been studied in detail by DE MEUTER & LAGA (1970). The test is dominantly dextral coiled with 4 or 4 1/2 chambers in the last whorl.

Distribution : KENNETT (1968) noted that *G. pachyderma* has been recorded from upper Miocene to Recent deposits.

Occurrence : Deurne Sands.

Globigerina parabulloides BLOW, 1959
(Pl. 7, figs. 1 a, b, c)

+ 1959 *Globigerina parabulloides* Blow, sp. nov.—BLOW, p. 179, pl. 10, figs. 46 a-c.

1969 *Globigerina parabulloides* BLOW—BLOW, p. 320, pl. 18, figs. 1, 2.

Description : cf. BLOW, 1959, p. 179.

Remarks : Most specimens from the Antwerpen Sands have a rather low arched aperture. Transitional forms between *G. parabulloides* and *Globigerina praebulloides* occur.

Distribution : BLOW (1969) indicated that *G. parabulloides* ranges from the middle Miocene (Zone N.13) to the Pleistocene - Holocene (Zone N.23).

Occurrence : Antwerpen Sands.

Globigerina praebulloides leroyi BLOW & BANNER, 1962
(Pl. 7, figs. 2 a, b, c)

+ 1962 *Globigerina praebulloides leroyi* Blow & Banner, subsp. nov. — BANNER & BLOW, p. 93, pl. IX R-T, fig. 9 (v).

1969 *Globigerina praebulloides leroyi* BLOW & BANNER—BLOW, p. 321, pl. 1, figs. 7-9.

Description : cf. BANNER & BLOW, 1962, p. 93.

Remarks : The characteristic features of this subspecies have been observed in our specimens : a small umbilicus, a low symmetrical aperture, bordered by a distinct lip and a rather slow rate of chamber enlargement. A number of individuals however seem to be intermediate between the present subspecies and *Globigerina praebulloides praebulloides* BLOW, 1959.

Distribution : As indicated by BLOW (1969), *G. praebulloides leroyi* occurs from Zone P.16 of the late Eocene to Zone N.8 of the early Miocene. In the *G. praebulloides* group, it is the subspecies with the most restricted stratigraphical range.

Occurrence : Edegem Sands, Houthalen Sands.

Globigerina praebulloides occlusa BLOW & BANNER, 1962
(Pl. 7, figs. 3 a, b, c)

- + 1962 *Globigerina praebulloides occlusa* Blow & Banner, subsp. nov.—
BANNER & BLOW, p. 93, pl. IX u-w, figs. 14 (i-ii).
1969 *Globigerina praebulloides occlusa* BLOW & BANNER—BLOW, p.
321, pl. 2, figs. 7-9.

Description : cf. BANNER & BLOW, 1962, p. 93.

Remarks : Our individuals have a rather small umbilicus and a small asymmetric aperture, without a lip. Some specimens of the present subspecies are rather difficult to be distinguished from *Globigerina praebulloides praebulloides* BLOW, 1959.

Distribution : The stratigraphical range of *G. praebulloides occlusa* is rather important. This subspecies occurs from Zone P.13 of BLOW (1969), middle Eocene, to Zone N.19, Pliocene.

Occurrence : Edegem Sands, Houthalen Sands, Antwerpen Sands.

Globigerina praebulloides praebulloides BLOW, 1959
(Pl. 7, figs. 4 a, b, c)

- + 1959 *Globigerina praebulloides* Blow, sp. nov.—BLOW, p. 180, pl. 8, figs. 47 a-c; pl. 9, fig. 48.
1962 *Globigerina praebulloides praebulloides* Blow—BANNER & BLOW, p. 92, pl. IX 0-9.
1969 *Globigerina praebulloides praebulloides* BLOW—BLOW, p. 321, pl. 2, figs. 7-9.

Description : cf. BLOW, 1962, p. 92.

Remarks : *G. praebulloides praebulloides* from the North Sea basin shows a typical rapid increase in size of the chambers in the last whorl and an asymmetrical arched aperture. In equatorial view, the test is slightly elongated.

Distribution : BLOW (1969) indicated that typical specimens of *G. praebulloides praebulloides* occur from Zone P.16 of the late Eocene to within Zone N.17 of the late Miocene.

Occurrence : Edegem Sands, Houthalen Sands, Antwerpen Sands.

Globigerina praebulloides pseudociperoensis BLOW, 1969
(Pl. 8, figs. 1 a, b, c)

- + 1969 *Globigerina praebulloides pseudociperoensis*, n. subsp.—BLOW, p. 381, pl. 17, figs. 8-9.

Description : cf. BLOW, 1969, p. 381.

Remarks : *G. praebulloides pseudociperoensis* is morphologically very close to *Globigerina ouachitaensis ciperoensis*. The differences between both subspecies are given by BLOW (1969). They have also different stratigraphical ranges.

Distribution : BLOW (1969) indicated that *G. praebulloides pseudociperoensis* has been observed over the interval of Zone N.7 of the Burdigalian to Zone N.12 of the "Langhian".

Occurrence : Antwerpen Sands.

Globigerina prasaepis BLOW, 1969
(Pl. 8, figs. 2 a, b, c)

- + 1969 *Globigerina prasaepis* n. sp.—BLOW, p. 382, pl. 10, figs. 13; pl. 18, figs. 3-7.

Description : cf. BLOW, 1969, p. 382.

Remarks : *G. prasaepis* has the same wall characters as *Globigerina ampliapertura* BOLLI, 1957. According to BLOW (1969), *Globigerina euapertura* JENKINS, 1960 has a more restricted aperture and a well developed apertural lip. Our specimens show closely appressed chambers in the last whorl. The aperture of the penultimate chamber remains visible in the deep umbilicus. Most of the tests are rather highly coiled.

Distribution : BLOW (1969) noted that *G. prasaepis* first occurs in the middle part of Zone P.17 (upper Eocene) and ranges to within Zone N.2 (=P.21) of the Oligocene.

Occurrence : Edegem Sands.

Globigerina quinqueloba Natland, 1938
(Pl. 8, figs. 3 a, b, c)

- + 1938 *Globigerina quinqueloba* Natland—NATLAND, p. 149, pl. 6, fig. 7 (fide Ellis & Messina).
1965 *Globigerina quinqueloba* Natland—CITA, PREMOLI SILVA & ROSSI, p. 253, pl. 25, figs. 6 a-c, 8 a-b.

Description : cf. CITA, PREMOLI SILVA & ROSSI, 1965, p. 253.

Remarks : Specimens with a well developed apertural flap covering the umbilicus are rare in our material. Most individuals have a relatively larger last chamber and an aperture bordered by a distinct lip, but *G. quinqueloba* without lip occurs as well. Specimens with an aberrant last chamber, not covering the umbilical area, also occur. The umbilicus always remains small.

Distribution : CITA, PREMOLI SILVA & ROSSI (1965) noted that *G. quinqueloba* has been recorded from Miocene to Recent deposits.

Occurrence : Antwerpen Sands.

Globigerina woodi JENKINS, 1960
(Pl. 8, figs. 4 a, b, c)

+ 1960 *Globigerina woodi* Jenkins, new species—JENKINS, p. 352, pl. 2, figs. 2 a-c.

1966 *Globigerina woodi* Jenkins—JENKINS, p. 6, pl. 1, figs. 18 a-c.

Description : cf. JENKINS, 1960, p. 352.

Remarks : The intraspecific variation described by JENKINS (1960), has also been observed in our specimens : the relative size of the last chamber varies distinctly and the position of the aperture depends on the size and position of the last chamber. The size of the aperture also varies considerably, but never a slit-like aperture as in *G. woodi connecta* JENKINS, 1964 has been observed. The last whorl consist of 3 to 4 chambers.

Distribution : JENKINS (1966) noted that *G. woodi* ranges from the lower Aquitanian to the Helvetian.

Occurrence : Houthalen Sands : Wijshagen.

Genus *Globigerinoides* CUSHMAN, 1927
Globigerinoides bollii BLOW, 1959
(Pl. 9, figs. 1 a, b, c)

+ 1959 *Globigerinoides bollii* Blow, sp. nov.—BLOW, p. 189, pl. 10, figs. 65 a-c.

1969 *Globigerinoides bollii* BLOW—BLOW, p. 324, pl. 20, figs. 2-3.

Description : cf. BLOW, 1959, p. 189.

Remarks : Our specimens resemble well the type specimen of BLOW in having a small test and small semicircular primary and secondary apertures.

Distribution : According to BLOW (1969), *G. bollii* ranges from the middle Miocene (Zone N.11) to the Pliocene (Zone N.19).

Occurrence : Antwerpen Sands.

Globigerinoides quadrilobatus altiapertura BOLLI, 1957
(Pl. 9, figs. 2 a, b, c)

+ 1957 *Globigerinoides triloba altiapertura* Bolli, new subspecies—BOLLI, p. 113, pl. 25, figs. 7 a-8; text-fig. 21, nr. 3.

1969 *Globigerinoides quadrilobatus altiapertura* BOLLI—BLOW, p. 325.

Description : cf. BOLLI, 1957, p. 113.

Remarks : *G. triloba altiapertura* of BOLLI (1957) rather belongs to the *Globigerinoides quadrilobatus* group, since the chambers of the last whorl are not much embracing. Our specimens from the North Sea basin distinctly show the high arched apertures, bordered by a thickened rim. The last whorl consists of 3 1/2 chambers.

Distribution : The stratigraphical range of *G. quadrilobatus altiapertura*, indicated by BLOW (1969), is very restricted. The present species only occurs in the early Miocene (Zone N.5 to Zone N.7).

Occurrence : Houthalen Sands : Wijsshagen.

Globigerinoides quadrilobatus primordius BANNER & BLOW, 1962
(Pl. 9, figs. 3 a, b, c)

+ 1962 *Globigerinoides quadrilobatus primordius* Blow & Banner, subsp. nov.—BANNER & BLOW, p. 115, pl. IX Dd-Ff; fig. 14 (iii-viii).

1966 *Globigerinoides* cf. *G. primordius* Blow & Banner—JENKINS, p. 8, pl. 2, figs. 7 a-c.

1969 *Globigerinoides quadrilobatus primordius* BLOW & BANNER—BLOW, p. 325, pl. 20, figs. 1, 5-6.

Description : cf. BANNER & BLOW, 1962, p. 115.

Remarks : In the *Globigerinoides quadrilobatus* group, *G. quadrilobatus primordius* differs from *G. quadrilobatus quadrilobatus* in having a single secondary aperture. Our specimens show some variability in the rugosity of the wall and in the height of the primary and secondary apertures. Rarely, the apertures are bordered by a thickened rim. These differences have also been observed by JENKINS (1966). They seem to be of no taxonomical value.

Distribution : As indicated by BLOW (1969), *G. quadrilobatus primordius* has a restricted stratigraphical range. This species only occurs in the early Miocene (Zone N.4 and Zone N.5).

Occurrence : Houthalen Sands.

Globigerinoides quadrilobatus quadrilobatus BANNER & BLOW, 1960
(Pl. 9, figs. 4 a, b, c)

+ 1960 *Globigerinoides quadrilobatus* (d'Orbigny)—BANNER & BLOW,
p. 17, pl. 4, figs. 3 a-b.

1969 *Globigerinoides quadrilobatus quadrilobatus* (d'ORBIGNY)—BLOW,
p. 325.

Description : cf. BANNER & BLOW, 1960, p. 17.

Remarks : Our specimens show some variability in the embracing character of the chambers and in the height of the primary and multiple secondary apertures, but remain always easily distinguishable.

Distribution : BLOW (1969) indicated that *G. quadrilobatus quadrilobatus* ranges from Zone N.4 of the early Miocene to Zone N.23 of the Pleistocene-Holocene.

Occurrence : Houthalen Sands, Antwerpen Sands.

Globigerinoides sacculifer subsacculifer CITA, PREMOLI SILVA & ROSSI, 1965
(Pl. 10, figs. 1 a, b, c)

+ 1965 *Globigerinoides sacculifer subsacculifer* n. subsp.—CITA, PREMOLI
SILVA & ROSSI, p. 268, pl. 28, figs. 5 a-c, 6 a-b; pl. 31, figs. 3
a-c, text-figs. 9 e-e'.

Description : cf. CITA, PREMOLI SILVA & ROSSI, 1965, p. 268.

Remarks : According to CITA, PREMOLI SILVA & ROSSI, *G. sacculifer subsacculifer* differs from *Globigerinoides sacculifer sacculifer* (BRADY, 1877) in the last chamber, which is radially elongated, but not in a pointed way. Our specimens also have a typically smaller aperture, situated above the second chamber of the last whorl. The last chamber is often of smaller size than the penultimate one.

Distribution : CITA, PREMOLI SILVA & ROSSI (1965) recorded *G. sacculifer subsacculifer* from the type Tortonian in Italy.

Occurrence : Houthalen Sands, Antwerpen Sands.

Globigerinoides subquadratus BRONNIMANN, 1954
(Pl. 1, figs. 7 a, b)

+ 1954 *Globigerinoides subquadratus* Bronnimann—BRONNIMANN, p. 680, pl. 1, fig. 5, 8 a-c.

1969 *Globigerinoides subquadratus* BRONNIMANN—BLOW, p. 327, pl. 21, figs. 5, 6.

Description : cf. BRONNIMANN, 1954, p. 680.

Remarks : *G. subquadratus* is morphologically very near to *Globigerinoides ruber* (d'ORBIGNY, 1839). BLOW (1969) indicated that both species however are taxonomically differentiated. It is assumed that the two species do not have overlapping stratigraphical ranges.

Distribution : BLOW (1969) noted that *G. subquadratus* develops from *Globigerinoides quadrilobatus altiapertura* BOLLI, 1957, in Zone N.5 (early Miocene) and ranges up to Zone N.13 (middle Miocene).

Occurrence : Antwerpen Sands.

Globigerinoides trilobus (REUSS, 1850)
(Pl. 10, figs. 2 a, b, c)

+ 1850 *Globigerina triloba* Reuss—REUSS, p. 374, pl. 47, figs. 11 a-d (fide Ellis & Messina).

1956 *Globigerinoides triloba triloba* (Reuss)—BLOW, p. 62, fig. 1, nr. 1-3.

1959 *Globigerinoides triloba* (Reuss)—DROOGER & BATJES, p. 180, pl. 1, fig. 9.

1969 *Globigerinoides quadrilobatus trilobus* (REUSS)—BLOW, p. 326.

Description : cf. BLOW, 1956, p. 62.

Remarks : Some variation was observed in the embracing character of the chambers, but the specimens always remain quite distinct. Most of the specimens from the North Sea basin are of considerable size, but smaller individuals occur as well.

Distribution : The stratigraphical range of *G. quadrilobatus trilobus* given, by BLOW (1969), extends from Zone N.6 of the early Miocene to Zone N.23 of the Pleistocene-Holocene. DROOGER & BATJES (1959) have found this species in the Miocene deposits of the North Sea basin.

Occurrence : Houthalen Sands, Antwerpen Sands.

Genus *Globigerinopsis* BOLLI, 1962
Globigerinopsis aguasayensis BOLLI, 1962
(Pl. 10, figs. 3 a, b, c)

+ 1962 *Globigerinopsis aguasayensis* Bolli—BOLLI, p. 282, pl. 1, figs. 1-7 (fide Ellis & Messina).

1969 *Globigerinopsis aguasayensis* BOLLI—BLOW, p. 375.

Description : cf. BOLLI, 1962, p. 282.

Remarks : *G. aguasayensis* from the Miocene of the North Sea basin resembles well the type specimen figured by BOLLI (1962). Our individuals have four or five chambers in the last whorl. Rarely, the last chamber is slightly reduced. Mostly, it is often laterally compressed. The aperture is interior-marginal, spiroumbilical in position. The surface is finely pitted.

Distribution : BLOW (1969) noted that the total range of *G. aguasayensis* is not yet known, but he observed the species from Zone N.10 to within Zone N.13 in the middle Miocene.

Occurrence : Houthalen Sands : Helchteren.

Genus *Globorotaloides* BOLLI, 1957
Globorotaloides suteri BOLLI, 1957
(Pl. 10, figs. 4 a, b, c)

+ 1957 *Globorotaloides suteri* Bolli, new species—BOLLI, 117, pl. 27, figs. 9 a-13 b.

1969 *Globorotaloides suteri* BOLLI—BLOW, p. 274.

Description : cf. BOLLI, 1957, p. 117.

Remarks : *G. suteri* from the North Sea basin typically has 4 to 5 chambers in the last whorl. The umbilicus is more or less covered by the last bulla-like chamber.

Distribution : According to BLOW (1969), *G. suteri* ranges from the middle Eocene (Zone P.13) to the early Miocene (Zone N.8).

Occurrence : Edegem Sands, Houthalen Sands.

Subfamily *Sphaeroidinellinae* BANNER & BLOW, 1959
Genus *Sphaeroidinellopsis* BANNER & BLOW, 1959
Sphaeroidinellopsis subdehiscens subdehiscens (BLOW, 1959)
(Pl. 11, figs. 1 a, b, c)

- + 1959 *Sphaeroidinella dehiscens subdehiscens* Blow, subsp. nov.—BLOW, p. 195, pl. 12, figs. 71 a-c, 72.
1969 *Sphaeroidinellopsis subdehiscens subdehiscens* (BLOW)—BLOW, p. 338, pl. 10, figs. 1-3, 6; pl. 31; pl. 32.

Description : cf. BLOW, 1959, p. 115.

Remarks : Our specimens have 3 to 3 1/2 chambers in the last whorl. The outer cortex of the wall, appearing glassy in reflected light, is rather indistinct. The inner part of the wall is thick and coarsely perforate. The aperture often extends to the periphery, but an arched opening occurs as well. Some specimens of *S. subdehiscens subdehiscens* in our material look like transitional forms with *Globigerinoides trilobus* (REUSS, 1850).

Distribution : BLOW (1969) has indicated that *S. subdehiscens subdehiscens* ranges from the middle Miocene (Zone N.13) to the Pliocene (Zone N.19).

Occurrence : Antwerpen Sands.

Subfamily *Catapsydracinae* BOLLI, LOEBLICH & TAPPAN, 1957
Genus *Globigerinita* BRONNIMANN, 1951
Globigerinita martini scandretti BLOW & BANNER, 1962
(Pl. 11, figs. 2 a, b, c)

- + 1962 *Globigerinita martini scandretti* Blow & Banner subsp. nov.—BANNER & BLOW, p. 111, pl. XIV v-x.
1969 *Globigerinita martini scandretti* BLOW & BANNER—BLOW, p. 328, pl. 24, figs. 6, 7.

Description : cf. BLOW & BANNER, 1962, p. 111.

Remarks : Our specimens show the typical tight coiling and small umbilicus.

Distribution : According to BLOW (1969), this subspecies is a useful marker for the early to middle Oligocene. It ranges from within Zone P.17 to the early part of Zone N.1 (=P.20).

Occurrence : Edegem Sands.

Globigerinita unicava primitiva BLOW & BANNER, 1962
(Pl. 11, figs. 3 a, b, c)

- + 1962 *Globigerinita unicava primitiva* Blow & Banner subsp. nov.—
BLOW & BANNER, p. 114, pl. XIV, y-2.
1969 *Globigerinita unicava primitiva* BLOW & BANNER—BLOW, p. 330,
pl. 25, figs. 1, 2.

Description : cf. BLOW & BANNER, 1962, p. 114.

Remarks : The test of our specimens has a typical strongly vaulted ventral surface and a distinctly inflated bulla.

Distribution : The stratigraphical range of *G. unicava primitiva*, given by BLOW (1969), extends from Zone P.14 of the late Eocene to Zone N.1 (=P.20) of the Oligocene.

Occurrence : Edegem Sands.

Globigerinita unicava unicava (BOLLI, LOEBLICH & TAPPAN, 1957)
(Pl. 11, figs. 4 a, b, c)

- 1957 *Catapsydrax unicava*, Bolli, Loeblich & Tappan, new species—
BOLLI, LOEBLICH & TAPPAN, p. 37, pl. 7, figs. 9 a-c.
1962 *Globigerinita unicava* (Bolli, Loeblich & Tappan)—BLOW &
BANNER, p. 113, pl. XIV, MN.
1969 *Globigerinita unicava unicava* (BOLLI, LOEBLICH & TAPPAN)—
BLOW, p. 330, pl. 24, figs. 8, 9.

Description : cf. BLOW & BANNER, 1962, p. 113.

Remarks : *G. unicava unicava* from the North Sea basin has a small subquadrate bulla. The infralaminar accessory opening is bordered by a distinct rim.

Distribution : BLOW (1969) indicated that *G. unicava unicava* ranges from within Zone N.1 (=P.20) (Oligocene) to Zone N.6, early Miocene.

Occurrence : Edegem Sands, Houthalen Sands.

IV. BIOZONATION (text-fig. 4)

The planktonic foraminifera, recorded from the "Miocene" deposits of N Belgium, allowed us to recognize five local biostratigraphical range zones, although some of the species of typical tropical thanatocoenoses are absent for local reasons. Due to the discontinuity of the sections

and to the often barren character of the sands, the recognition of the zonal boundaries within the different sections of the studied area, however, is hampered.

In the Deurne Sands, the planktonic foraminiferal fauna is strongly impoverished, on account of its belonging to the boreal bioprovince. Here, only the dextrally coiling *Globigerina pachyderma* seems to be useful for local zonation and correlation.

The geographical extension of the different Zones has not been studied here. Some observations from other localities within the studied area suggest that the Zones, proposed here, could be recognized there too. However, no other biostratigraphical Zones, based on planktonic foraminifera, appear to be recognizable in the "Miocene" deposits of N Belgium.

Globigerina ampliapertura Zone

Author : BOLLI, 1957, emended by BLOW, 1969.

Reference section : Edegem Sands at Antwerpen, Zuidstation. Cores between —5 and 0 m (see text-fig. 2).

The base of this Zone was defined at the horizon of extinction of *Pseudohastigerina barbadoensis* (see table 1). Our Zone is characterized by the the part of the range of *G. ampliapertura* situated above the extinction of *P. barbadoensis* and below the first evolutionary appearance of *Globigerina angulisuturalis*. In this Zone, no typical specimens of *G. angulisuturalis* have thus been found. The observed faunal assemblage includes : *Chiloguembelina cubensis*, *Cassigerinella chipolensis*, *Globorotalia opima nana*, *G. opima opima*, *Globorotalia siakensis*, *Globigerina ampliapertura*, *G. anguliofficialis*, *G. angustiumbilitata*, *G. gortanii*, *G. officinalis*, *G. ouachitaensis ciproensis*, *G. ouachitaensis gnaucki*, *G. ouachitaensis ouachitaensis*, *G. prasaepis*, *Globorotaloides suteri*, *Globigerinita martini scandretti*, *G. unicava primitiva*, *G. unicava unicava*. At the base of this Zone, *Pseudohastigerina barbadoensis* has been found. Within the Zone, transitional forms between *G. opima nana* and *G. opima opima* occur. More typical specimens of the latter subspecies have only been found in the upper part of the Zone.

Globigerinoides quadrilobatus primordius Zone

Authors : CATI & al., 1968.

Reference section : Boring at Wijshagen, cores between —172,5 and —162,5 m (see text-fig. 3).

This Zone is defined by the presence of *G. quadrilobatus primordius* before the first evolutionary appearance of *G. quadrilobatus ampliapertura*. The

BLOW 1969			
PERIODS	STAGES	ZONATION	LOCAL BIOTRATIGRAPHICAL ZONES
LATE MIOCENE	TORTONIAN MESSINIAN	ZONE N.18	GLOBIGERINA PACHYDERMA <i>forma</i> DEXTRALIS ZONE
		ZONE N.17	
		ZONE N.16	
		ZONE N.15	
MIDDLE MIOCENE	LANGHIAN	ZONE N.14	SPHAERODINELLOPSIS SUBDENISCENS SUBDENISCENS-GLOBIGERINA DRURYI ZONE
		ZONE N.13	
		ZONE N.12	
		ZONE N.11	
		ZONE N.10	
		ZONE N.9	
		ZONE N.8	
		ZONE N.7	
EARLY MIOCENE	GIRONDIAN AQUITANIAN-BURDIGALIAN	ZONE N.6	GLOBIGERINOIDES ALTIAPERTURUS QUADRILOBATUS PRIMORDIUS ZONES
		ZONE N.5	
		ZONE N.4	
		ZONE N.3 P.22	
		ZONE N.2 P.21	
EARLY OLIGOCENE	RUPELLIAN CHATTIAN	ZONE N.1 P.20	GLOBIGERINA AMPLIAPERTURA ZONE
		ZONE P.19	
		ZONE P.18	

Text-fig. 4 : Local biozonation and correlation with BLOW (1969).

Species & subspecies		FOR- MATIONS	LOCAL BIOSTRAT- GRAPHICAL ZONES
Deurne Sands	<i>Globigerina pachyderma</i> forma <i>dextralis</i> Zone		
Antwerpen Sands	<i>Sphaeroidinellopsis subdehiscens</i> <i>Globigerina druryi</i> Zone		
Houthalen Sands	<i>Globigerinoides quadrilobatus</i> <i>altiaperturus</i> Zone		
Edegem Sands	<i>Globigerinoides quadrilobatus</i> <i>primordius</i> Zone		
	<i>Globigerina ampliapertura</i> Zone		
Voort Sands			
		<i>Pseudohastigerina barbadoensis</i> <i>Globigerinita martini scandretti</i> <i>Globigerinita unicava primitiva</i> <i>Chiloguembelina cubensis</i> <i>Globorotalia opima opima</i> <i>Globigerina ampliapertura</i> <i>Globigerina anguliofficialis</i> <i>Globigerina gortanii</i> <i>Globigerina officialis</i> <i>Globigerina ouachitaensis gnaucki</i> <i>Globigerina ouachitaensis ouachitaensis</i> <i>Globigerina prasaepis</i> <i>Globorotalia opima nana</i> <i>Cassigerinella chipolensis</i> <i>Globorotalia siakensis</i> <i>Globigerina ouachitaensis ciperoensis</i> <i>Globigerina praebulloides leroyi</i> <i>Globorotaloides suteri</i> <i>Globigerinita unicava</i> <i>Globigerina angustumbilicata</i> <i>Globigerina praebulloides occlusa</i> <i>Globigerina praebulloides praebulloides</i> <i>Globigerinoides quadrilobatus primordius</i> <i>Globigerinopsis aguasayensis</i> <i>Globorotalia obesa</i> <i>Globigerinoides quadrilobatus quadrilobatus</i> <i>Globigerina woodi</i> <i>Globigerinoides quadrilobatus altiaperturus</i> <i>Globigerinoides sacculifer subsacculifer</i> <i>Globigerinoides trilobus</i> <i>Globorotalia aff. peripheroronda</i> <i>Globorotalia aff. mayeri</i> <i>Globorotalia scitula</i> <i>Globorotalia sp.</i> <i>Globigerina druryi</i> <i>Globigerina eamesi</i> <i>Globigerina globorotaloidea</i> <i>Globigerina juvenilis</i> <i>Globigerina parabulloides</i> <i>Globigerina praebulloides pseudociperoensis</i> <i>Globigerina quinqueloba</i> <i>Globigerinoides bollii</i> <i>Globigerinoides subquadratus</i> <i>Sphaeroidinellopsis subdehiscens subdehiscens</i> <i>Globorotalia pseudopachyderma</i> <i>Globigerina bulloides</i> <i>Globigerina pachyderma</i>	

Table 1 : Occurrence of the planktonic foraminifera in the Edegem, Houthalen, Antwerpen and Deurne Sands.

faunal assemblage of this Zone includes *Cassigerinella chipolensis*, *Globorotalia obesa*, *G. opima nana*, *G. siakensis*, *Globigerina angustiumbilitata*, *G. ouachitaensis ciproensis*, *G. praebulloides leroyi*, *G. praebulloides occlusa*, *G. praebulloides praebulloides*, *Globigerinoides quadrilobatus primordius*, *G. quadrilobatus quadrilobatus*, *Globigerinopsis agasayensis*, *Globorotaloides suteri*, *Globigerinita unicava unicava*. The Zone has been recognized also in the boring at Meeuwen (cores between —139 and —132 m) and in the boring at Helchteren (cores between —105 and —99 m). The boundary between the Voort Sands and the Houthalen Sands is thus to be corrected in text-fig. 3, for borehole Wijshagen.

Globigerinoides quadrilobatus altiapturus Zone

Authors : CATI & al., 1968.

Reference section : Boring at Wijshagen, cores between —162,5 and —150 m (see text-fig. 3).

The lower limit of this Zone is defined by the first evolutionary appearance of *G. quadrilobatus altiapturus*. The upper limit could not be recognized because of the absence of planktonic foraminifera higher up in the Houthalen Sands. The following species have been recorded from this Zone : *Cassigerinella chipolensis*, *Globorotalia obesa*, *G. siakensis*, *Globigerina angustiumbilitata*, *G. ouachitaensis ciproensis*, *G. ouachitaensis ouachitaensis*, *G. praebulloides leroyi*, *G. praebulloides occlusa*, *G. praebulloides praebulloides*, *G. woodi*, *Globigerinoides sacculifer subsacculifer*, *G. quadrilobatus altiapturus*, *G. quadrilobatus quadrilobatus*, *Globigerinoides trilobus*, *Globorotaloides suteri*, *Globigerinita unicava unicava*. In this Zone, *Globigerinoides sacculifer subsacculifer* and *G. trilobus* have been found also for the first time. *Globigerina woodi* seems to occur only in this Zone.

Sphaeroidinellopsis subdehiscens subdehiscens — *Globigerina druryi* Zone
Author : BLOW, 1969.

Reference section : Antwerpen Sands at Borgerhout, E3-Kleine Ring, —2,5 m to —7,5 m below the land surface (see text-fig. 2).

The Zone is defined by the concurrent range of *G. druryi* and *S. subdehiscens subdehiscens*, below the lowest stratigraphical occurrence of *Globigerina nepenthes*. Typical specimens of the latter species have indeed not been observed. The faunal assemblage recorded from this Zone includes : *Globorotalia* aff. *mayeri*, *G. aff. peripheroronda*, *G. obesa*, *G. scitula*, *G. sp.*, *Globigerina angustiumbilitata*, *G. druryi*, *G. eamesi*, *G. globorotaloidea*, *G. juvenilis*, *G. parabolloides*, *G. praebulloides occlusa*, *G. praebulloides praebulloides*, *G. praebulloides pseudociproensis*, *G. quin-*

queloba, *Globigerinoides bollii*, *G. quadrilobatus quadrilobatus*, *G. sacculifer subsacculifer*, *G. subquadratus*, *G. trilobus*, *Sphaeroidinellopsis subdehiscens subdehiscens*. *Globorotalia* aff. *mayeri*, *Globigerina praebulloides pseudociperoensis* and *Globigerinoides subquadratus* thus still occur. *Globorotalia* aff. *peripheroronda* has been found at the base of this Zone.

Globigerina pachyderma forma *dextralis* Zone

Authors : proposed here.

Reference section : Sands of Deurne, Rivierenhof near Deurne, —4,50 m to —5,50 m below the land surface (See text-fig. 2).

In this Zone, the planktonic foraminiferal fauna is strongly impoverished, since it belongs to the boreal bioprovince. *G. pachyderma* is the most frequently occurring species. This species has dominantly a dextral coiled test (more than 90 %). Further, only two forms have been recorded from this Zone : *Globorotalia pseudopachyderma* and *Globigerina bulloides*.

V. INTERREGIONAL CORRELATION

The distribution of the upper Eocene to Holocene planktonic foraminifera from several tropical regions has been worked out in detail by BLOW (1969). A synthetic biozonation, based on planktonic foraminifera of the Mediterranean Neogene, was proposed by CATI & al. (1968).

Although some of the species of the typical thanatocoenoses from the tropical areas are absent for local reasons, it still is possible to correlate the local biozonation within the North Sea basin with the detailed zonation of BLOW.

The correlation of our biozonation with the results of BLOW is shown on text-figure 4. The assumption is made that the horizons of extinction and initial appearance of planktonic foraminiferal species are synchronous. The Langhian of BLOW includes in fact the Langhian : Zone N.8 (pars) to Zone N.10 (pars) and the Serravallian : Zone N.10 (pars) to Zone N.14.

The *Globigerina ampliapertura* Zone from the Edegem Sands conforms with Zone N.1 (=P.20) of BLOW. *Pseudohastigerina barbadoensis* disappears at the base of this Zone. No typical specimens of *Globigerina angulisurealis*, appearing at the base of Zone (N.2= P.21), just before the extinction of *Globigerina ampliapertura*, have been found.

The *Globigerinoides quadrilobatus primordius* Zone from the base of the Houthalen Sands can be correlated with the upper part of Zone N.4, where *Globigerinoides quadrilobatus quadrilobatus* occurs and the lower part of Zone N.5, since *Globigerinoides quadrilobatus altiapertura* appears just above the base of Zone N.5.

The *Globigerinoides quadrilobatus altiapertura* Zone, beginning at the first occurrence of this subspecies, conforms to the higher part of Zone N.5 of BLOW. The upper limit of this Zone could not be defined because of the absence of planktonic foraminifera in the higher part of the Houthalen Sands.

The *Sphaeroidinellopsis subdehiscens subdehiscens* — *Globigerina druryi* Zone from the Antwerpen Sands can be correlated with Zone N.13 of BLOW. At the base of this Zone, *Sphaeroidinellopsis subdehiscens subdehiscens* occurs for the first time. No typical specimens of *Globigerina nepenthes*, appearing at the base of Zone N.14, have been found. *Globorotalia* aff. *mayeri*, *Globigerina praebulloides pseudociperoensis* and *Globigerinoides subquadratus* still occur in this Zone. *Globorotalia* aff. *peripheroronda*, occurs in the base of the Antwerpen Sands. *Globigerina parabolloides*, appearing at the base of Zone N.13, has been found. Because of the hiatus between the different Zones, it is rather difficult to define the exact limits of this Zone here.

In the Deurne Sands, the planktonic foraminiferal fauna is strongly impoverished. No good criteria could be found for interregional correlation. Only the dominantly dextral coiled test of *Globigerina pachyderma* seems to suggest that the Deurne Sands belong to the uppermost part of the Miocene : Messinian (see DE MEUTER & LAGA, 1970).

VI. GEOCHRONOLOGICAL DATA

Absolute age-determinations of the classical stages of the relative chronological scale and their boundaries have frequently been recorded in recent stratigraphical studies, with a view to establishing worldwide isochronous surfaces. "The Phanerozoic Timescale", published by HARLAND, SMITH and WILCOX (1964), is a good survey of age-determinations of different stages. SELLI (1968) attempted to correlate the radiometric time-scale, the chronostratigraphy and the planktonic foraminiferal zonation of the Neogene. BLOW (1969) gave the absolute age of important extinctions and appearances of planktonic foraminifera within the middle Eocene to Pleistocene interval. No new data are added here, but results of previous investigations are considered. Recently, the absolute ages of glauconiferous sediments of the Tertiary of Belgium have been measured (ODIN, GULINCK, BODELLE & LAY, 1969). Eleven age-determinations are given, ranging from the Edegem Sands of the "middle Miocene" down to the Gelinden Marls of the lower Landenian. Ten of them seemed to be correct. Only the absolute age of the Edegem Sands could not be explained : $30.1 \pm 2 \times 10^6$ years. These sands previously were considered as being of middle Miocene age : $\pm 15 \times 10^6$ years. Now, the

Edegem Sands are considered as belonging to the Oligocene : *G. ampliapertura* Zone. BLOW (1969) indicated that *Pseudohastigerina barbadoensis* disappears at the base of this Zone and the absolute age he gave for this extinction is 30×10^6 years. This agrees perfectly with our results and the absolute age of the Edegem Sands.

Presently, absolute age-determinations of the Neogene deposits of N Belgium are being carried out.

VII. DISCUSSION ON THE OLIGOCENE-MIOCENE BOUNDARY

The relationship of the Oligocene/Miocene boundary to the planktonic foraminiferal zonation has been discussed in several stratigraphical studies during the last years. Recently, especially the works of BERGGREN (1969) and BLOW (1969) have cleared up some questions on this problem.

Since the studies of BEYRICH (1854 & 1857), the Chattian has been considered as Oligocene. In the Doberg section, HUBACH (1922) distinguished an "Eochattian" and a "Neochattian", based on *Pectinacea*. In 1963, ANDERSON observed three pectinid units : Chatt A and Chatt B (= $\pm$ Eochattian) and Chatt C (= $\pm$ Neochattian). BERGGREN (1969) and BLOW (1969) indicated that in the Eochattian, Zone P.19 and Zone N1 (=P.20) could be recognized. No planktonic foraminifera have been recorded from the Neochattian. In the Bormidian stage, the upper part of Zone N.1 (=P.20), Zone N.2 (=P.21) and N.3 (=P.22) could be defined. BLOW suggested that the Neochattian could be the time-equivalent of Zone N.2 (=P.21) and N.3 (=P.22).

In the area studied here, the Edegem Sands consequently belong to the Eochattian. The position of the Voort Sands will be defined in the near future. On planktonic foraminiferal evidence we can assume that there is a small hiatus between the Voort Sands from the boreholes in the Kempen and the Edegem Sands from the Antwerpen area.

As indicated by BLOW, the base of the Aquitanian is defined at the lower limit of Zone N.4, which coincides with the first appearance of *Globigerinoides quadrilobatus primordius*. Following the recommendations of the "Committee on Mediterranean Neogene Stratigraphy", the Oligo-Miocene boundary is placed at this "*Globigerinoides*-datum". The lower limit of the Miocene, consequently, is well defined in the stratotype of the Aquitanian.

In the base of the Houthalen Sands, *Globigerinoides quadrilobatus quadrilobatus* occurs. It seems thus that the lower part of Zone N.4 is not developed in the area studied here. The hiatus between the Edegem Sands of the Oligocene and the Houthalen Sands of the Miocene includes thus Zone N.2 (=P.21), Zone N.3 (=P.22) and the lower part of Zone N.4 (text-fig. 4).

VIII. CONCLUSIONS

Our findings lead to very unexpected results. The time gap between the end of deposition of the Edegem Sands and the beginning of deposition of the Antwerpen Sands was thought to be nil or very short. East of Antwerpen city these glauconiferous, and rather similar sands, lie immediately one above the other, without a clear sign of unconformity or erosion. However, in the Antwerpen area, unfossiliferous sands, named the Kiel Sands, and attaining a thickness of 10 m, come to lie in between them. It now appears that the considered time interval is relatively large, embracing the final Oligocene, the early Miocene and more than half of the middle Miocene. The Kiel Sands fit in this time interval (text-fig. 5).

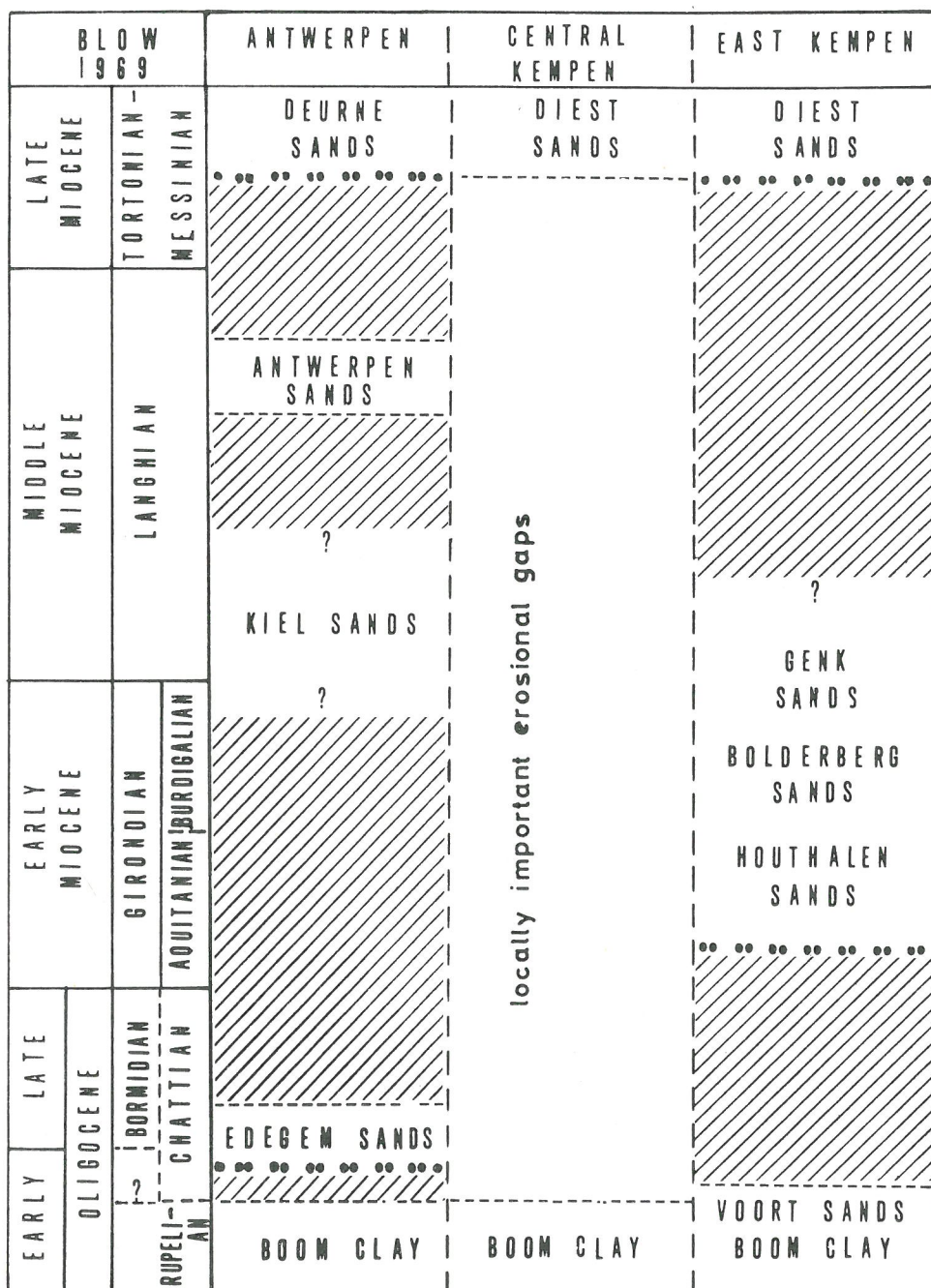
The Houthalen Sands have not yet been found in contact with either the Edegem Sands or the Antwerpen Sands. They were thought to be older than both (see chart, p. 171, Symposium on Stratigraphy of Northern Neogene). They occupy, in fact, an intermediate position. There is a short hiatus between the Edegem and the Houthalen Sands, high up in the Oligocene and in the earliest Miocene. There is a relatively large gap between the fossiliferous marine Houthalen Sands and the Antwerpen Sands, covering the late early Miocene and the early middle Miocene. The Houthalen Sands laterally pass into the unfossiliferous Sands of Bolderberg or the continental Sands of Genk (text-fig. 5).

A very poor fauna of planktonic foraminifera is found in the Deurne Sands. We cannot offer additional proof of the concept that these Sands would be of uppermost Miocene age, which was the stratigraphical level assigned to them some years ago. The existence of a gap has been clearly demonstrated between the Antwerpen and Deurne Sands in a few exposures that were visible lately east of the city of Antwerpen.

So we may admit that there are gaps, more or less important as the case may be, between all the sandy Formations under consideration. Moreover, the fauna of the Voort Sands, not studied in our paper, seems to show that there is also a hiatus between them and the younger Edegem Sands. All these gaps can be explained by the situation of the area on the southern shoreline of the North Sea in Oligo-Miocene times.

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Text-fig. 5 : Chronostratigraphical position of the middle Oligocene to uppermost Miocene sediments from N Belgium.

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Instituut voor Aardwetenschappen
Laboratorium voor Paleontologie
Redingenstraat 16*bis*
B-3000 — Leuven (Belgium)

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PLATES

PLATE 1

- FIG. 1 : *Chiloguembelina cubensis* (PALMER, 1934)
Edegem Sands, Antwerpen-Zuidstation section.
× 170.
- FIG. 2 : *Pseudohastigerina barbadoensis* BLOW, 1969
Edegem Sands, Antwerpen-Zuidstation section.
× 185.
- FIG. 3 : *Cassigerinella chipolensis* (CUSHMAN & PONTON, 1932)
Houthalen Sands, Meeuwen deepboring.
× 125.
- FIG. 4 : *Globorotalia* aff. *mayeri* CUSHMAN & ELLISOR, 1939
- a. Umbilical view — Antwerpen Sands, Borgerhout-Kleine Ring section.
× 125.
 - b. Spiral view — idem
× 110.
 - c. Axial view — idem
× 110.
- FIG. 5 : *Globorotalia obesa* BOLLI, 1957
- a. Umbilical view — Houthalen Sands, Helchteren deepboring.
× 90.
 - b. Spiral view — idem
× 110.
 - c. Axial view — idem
× 105.
- FIG. 6 : *Globorotalia* aff. *peripheroronda* BLOW & BANNER, 1966
Antwerpen Sands, Borgerhout-Kleine Ring section.
× 100.
- FIG. 7 : *Globigerinoides subquadratus* BRONNIMANN, 1954
- a. Umbilical view — Antwerpen Sands, Borgerhout-Kleine Ring section.
× 85.
 - b. Spiral side of the same specimen.
× 85.

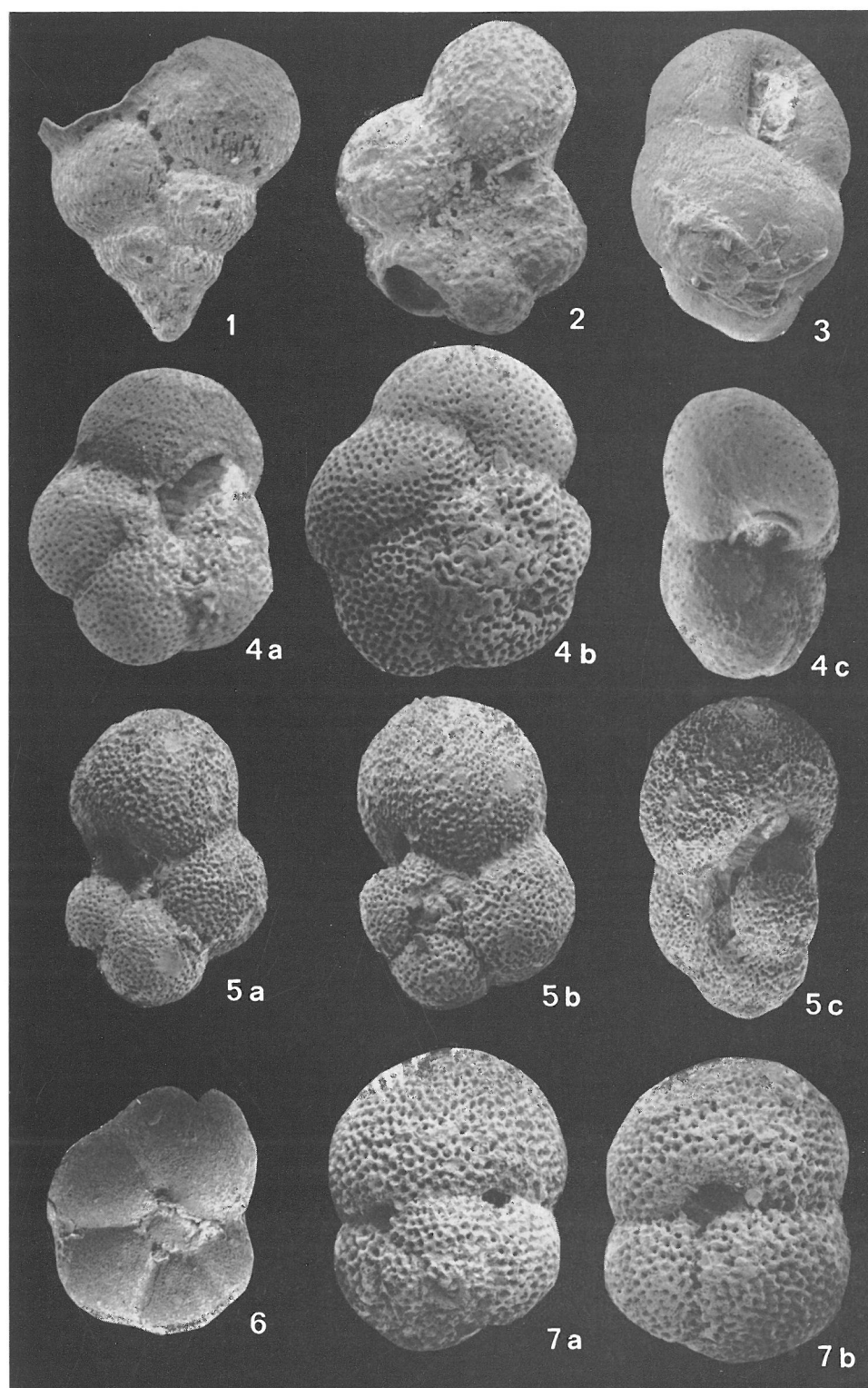


PLATE 2

FIG. 1 : *Globorotalia opima nana* BOLLI, 1957

- a. Umbilical view — Edegem Sands, Antwerpen-Zuidstation section.
× 180.
- b. Spiral view — idem
× 180.
- c. Axial view — idem
× 200.

FIG. 2 : *Globorotalia opima opima* BOLLI, 1957

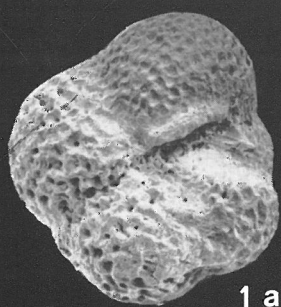
- a. Umbilical view — Edegem Sands, Antwerpen-Zuidstation section.
× 140.
- b. Spiral view — idem
× 130.
- c. Axial view — idem
× 130.

FIG. 3 : *Globorotalia pseudopachyderma* CITA, PREMOLI SILVA & ROSSI, 1965

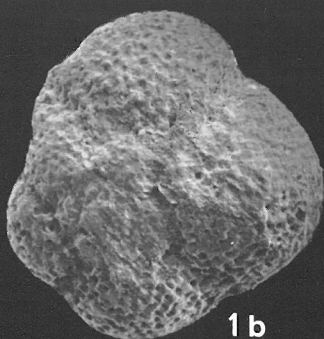
- a. Umbilical view — Deurne Sands, Deurne-Rivierenhof section.
× 200.
- b. Spiral view — idem
× 200.
- c. Axial view — idem
× 175.

FIG. 4 : *Globorotalia scitula* (BRADY, 1884)

- a. Umbilical view — Antwerpen Sands, Borgerhout-Kleine Ring section.
× 155.
- b. Spiral view — Antwerpen Sands, Borgerhout-Kleine Ring section.
× 165.
- c. Axial view — idem
× 160.



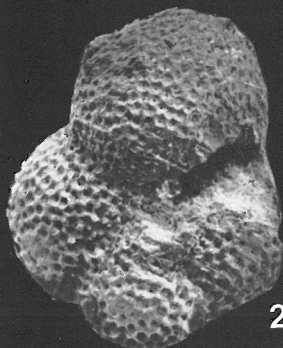
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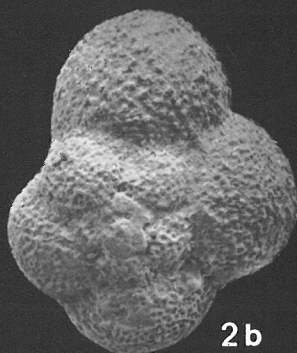
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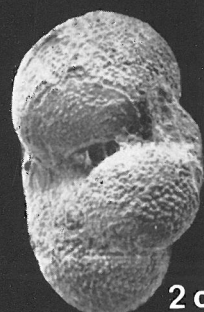
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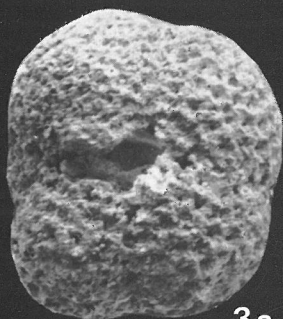
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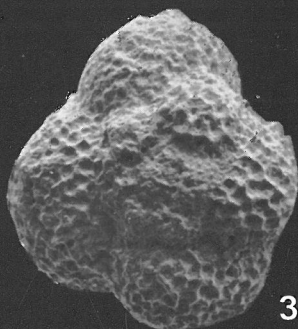
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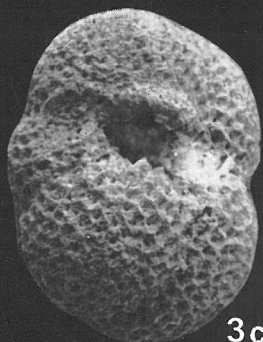
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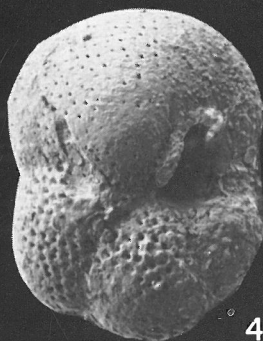
3 a



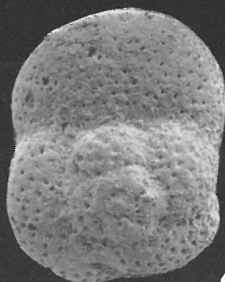
3 b



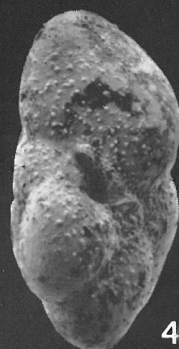
3 c



4 a



4 b



4 c

PLATE 3

FIG. 1 : *Globorotalia siakensis* (LE ROY, 1939)

- a. Umbilical view — Edegem Sands, Antwerpen-Zuidstation section.
× 140.
- b. Spiral view — idem
× 140.
- c. Axial view — idem
× 150.

FIG. 2 : *Globorotalia* sp.

- a. Umbilical view — Antwerpen Sands, Borgerhout-Kleine Ring section.
× 150.
- b. Spiral view — idem
× 125.
- c. Axial view — idem
× 120.

FIG. 3 : *Globigerina ampliapertura* BOLLI, 1957

- a. Umbilical view — Edegem Sands, Antwerpen-Zuidstation section.
× 150.
- b. Spiral view — idem
× 150.
- c. Axial view — idem
× 150.

FIG. 4 : *Globigerina angustiumbilicala* BOLLI, 1957

- a. Umbilical view — Houthalen Sands, Helchteren deepboring.
× 170.
- b. Spiral view — idem
× 170.
- c. Axial view — idem
× 170.

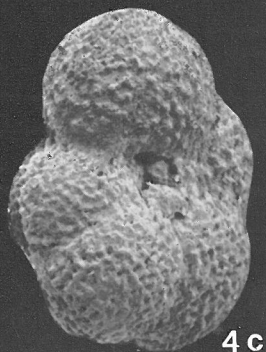
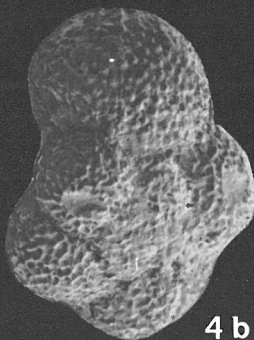
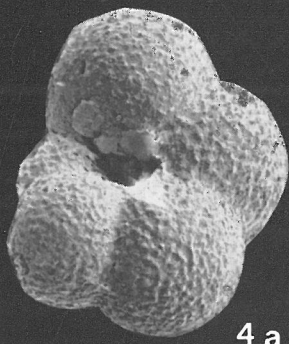
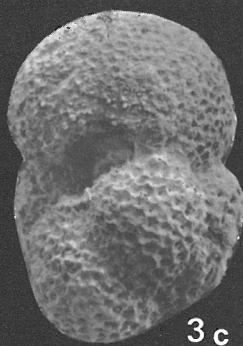
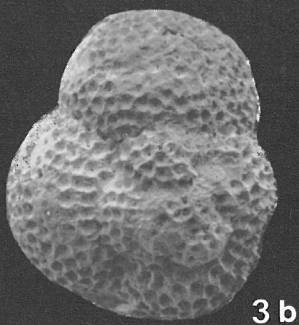
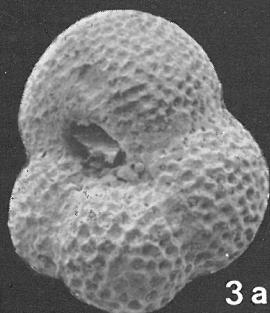
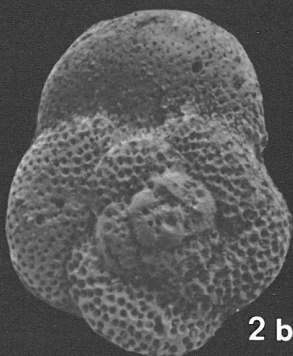
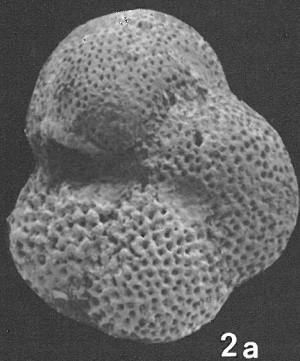
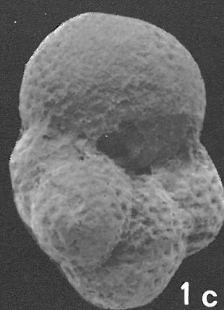
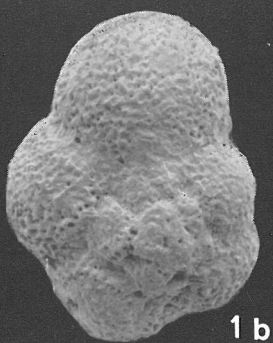
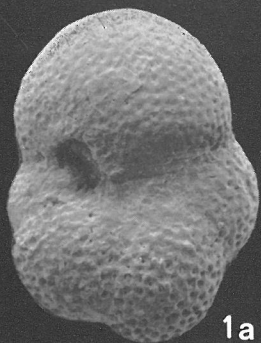


PLATE 4

FIG. 1 : *Globigerina anguliofficialis* BLOW, 1969

- a. Umbilical view — Edegem Sands, Antwerpen-Zuidstation section.
× 150.
- b. Spiral view — idem
× 150.
- c. Axial view — idem
× 165.

FIG. 2 : *Globigerina bulloides* d'ORBIGNY, 1826

- a. Umbilical view — Deurne Sands, Deurne-Rivierenhof section.
× 100.
- b. Axial view — idem
× 95.
- c. Axial view — idem
× 95.

FIG. 3 : *Globigerina druryi* AKERS, 1955

- a. Umbilical view — Antwerpen Sands, Borgerhout-Kleine Ring section.
× 140.
- b. Spiral view — idem
× 135.
- c. Axial view — idem
× 145.

FIG. 4 : *Globigerina eamesi* BLOW, 1959

- a. Umbilical view — Antwerpen Sands, Borgerhout-Kleine Ring section.
× 145.
- b. Spiral view — idem
× 170.
- c. Axial view — idem
× 170.

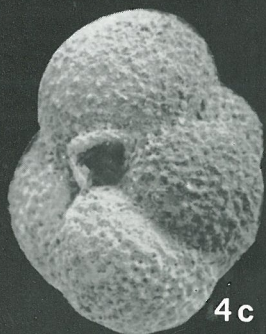
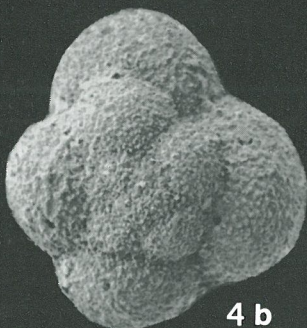
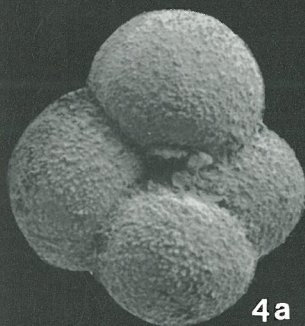
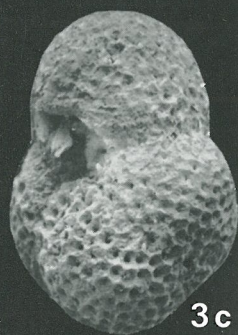
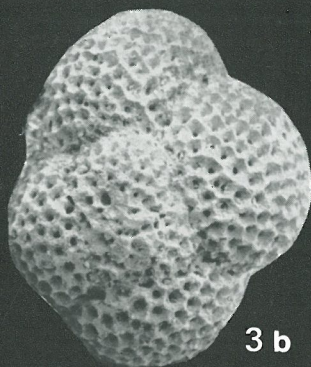
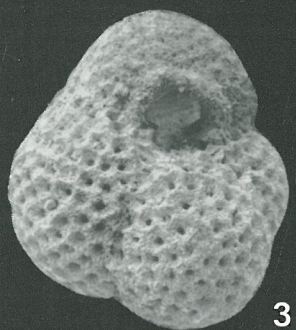
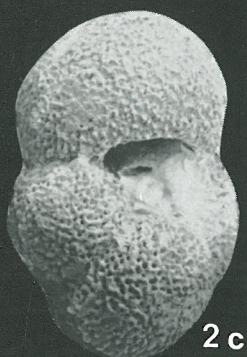
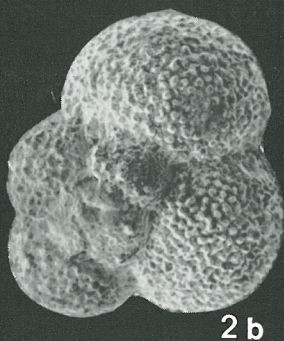
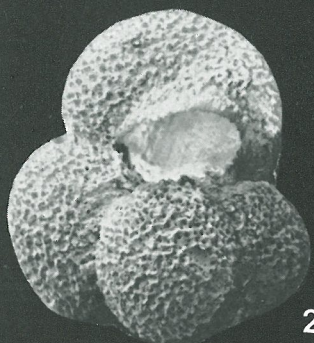
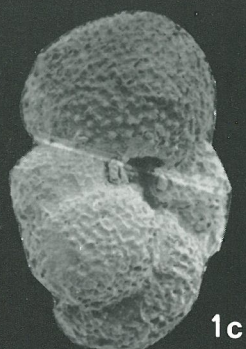
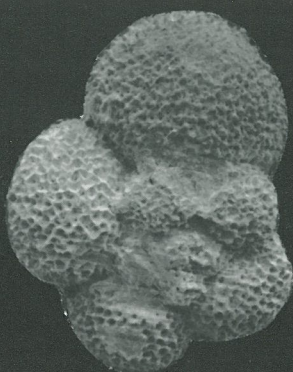
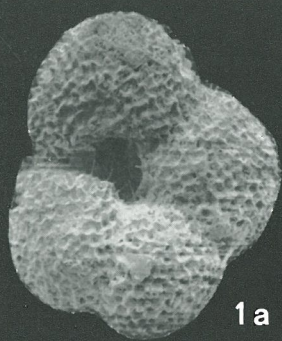


PLATE 5

FIG. 1 : *Globigerina globorotaloidea* COLOM, 1954

- a. Umbilical view — Antwerpen Sands, Borgerhout-Kleine Ring section.
× 155.
- b. Spiral view — idem
× 155.
- c. Axial view — idem
× 145.

FIG. 2 : *Globigerina gortanii* (BORSETTI, 1959)

- a. Umbilical view — Edegem Sands, Antwerpen-Zuidstation section.
× 125.
- b. Spiral view — idem
× 175.
- c. Axial view — idem
× 125.

FIG. 3 : *Globigerina juvenilis* BOLLI, 1957

- a. Umbilical view — Antwerpen Sands, Borgerhout-Kleine Ring section.
× 190.
- b. Spiral view — idem
× 170.
- c. Axial view — idem
× 170.

FIG. 4 : *Globigerina officinalis* SUBBOTINA, 1953

- a. Umbilical view — Houthalen Sands, Wijnshagen deepboring.
× 155.
- b. Spiral view — Edegem Sands, Antwerpen-Zuidstation section.
× 200.
- c. Axial view — idem
× 170.

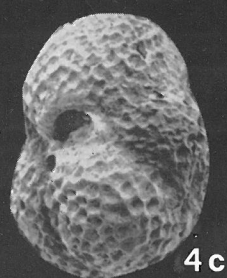
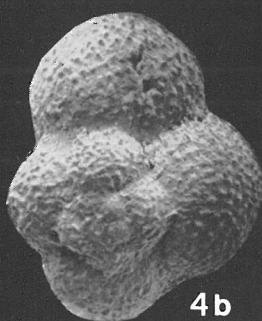
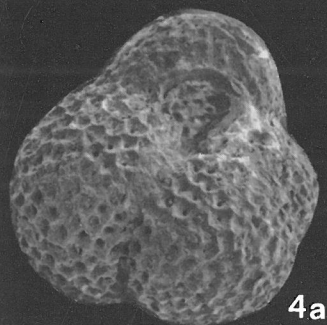
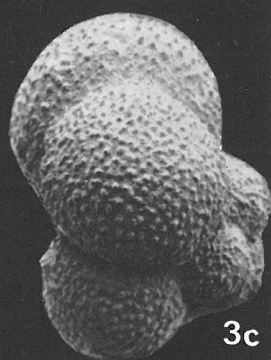
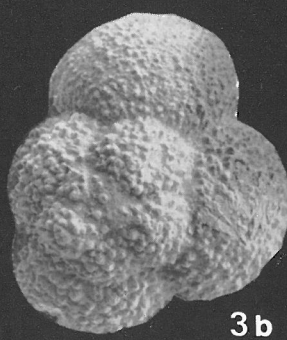
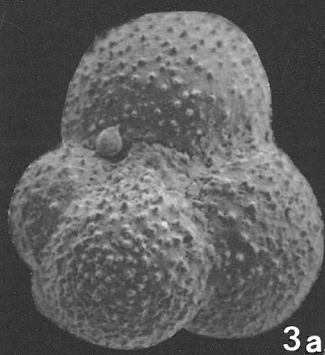
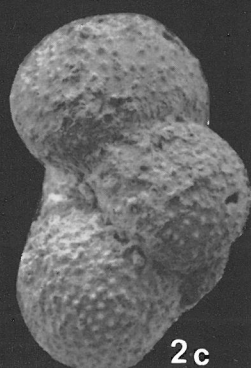
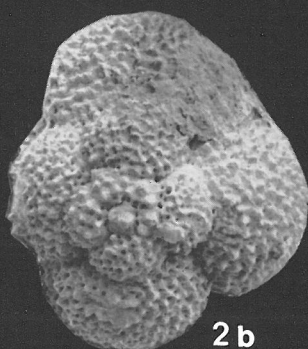
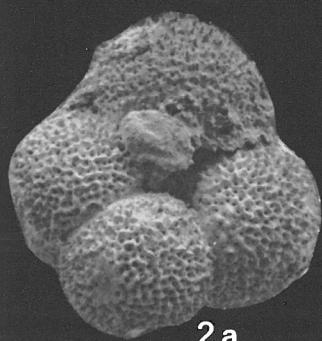
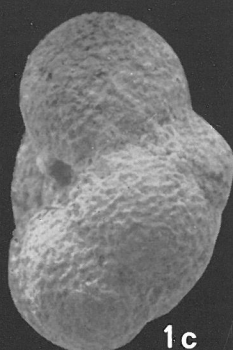
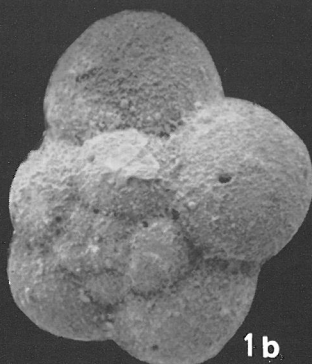
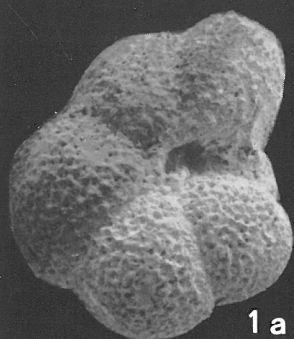


PLATE 6

FIG. 1 : *Globigerina ouachitaensis ciperoensis* BOLLI, 1954

- a. Umbilical view — Houthalen Sands, Helchteren deepboring.
× 140.
- b. Spiral view — idem
× 135.
- c. Axial view — idem
× 135.

FIG. 2 : *Globigerina ouachitaensis gnaucki* BANNER & BLOW, 1962

- 1. Umbilical view — Houthalen Sands, Helchteren deepboring.
× 120.
- b. Spiral view — idem
× 145.
- c. Axial view — idem
× 120.

FIG. 3 : *Globigerina ouachitaensis ouachitaensis* HOWE & WALLACE, 1932.

- a. Umbilical view — Edegem Sands, Antwerpen-Zuidstation.
× 130.
- b. Spiral view — idem
× 135.
- c. Axial view — idem
× 135.

FIG. 4 : *Globigerina pachyderma* (EHRENBERG, 1861)

- a. Umbilical view — Deurne Sands, Deurne-Rivierenhof section.
× 105.
- b. Spiral view — idem
× 130.
- c. Axial view — idem
× 165.

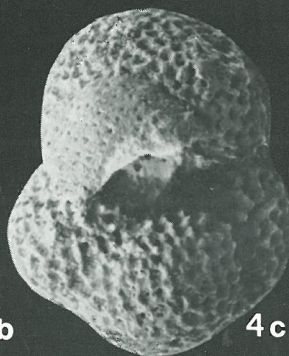
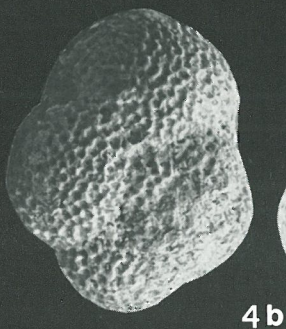
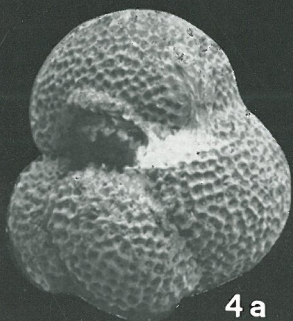
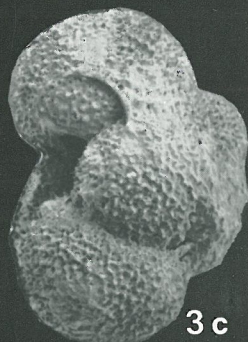
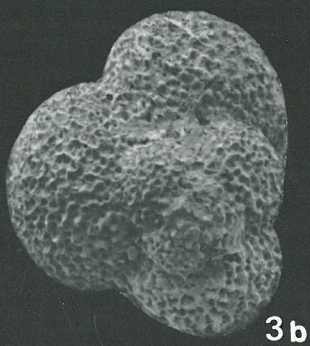
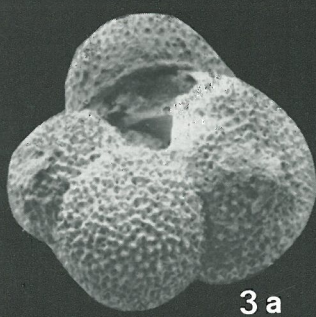
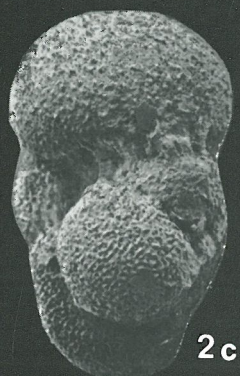
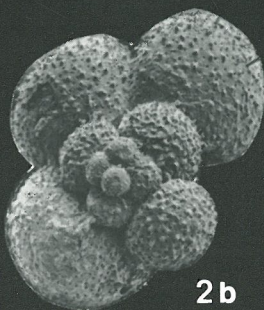
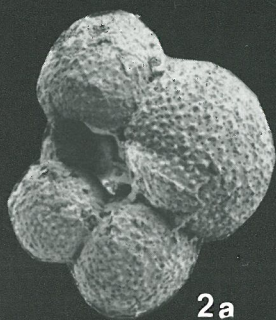
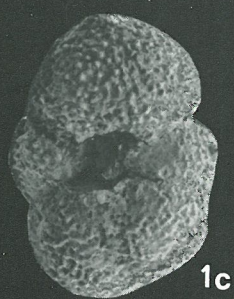
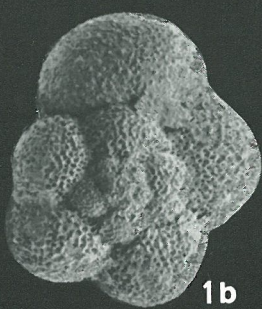
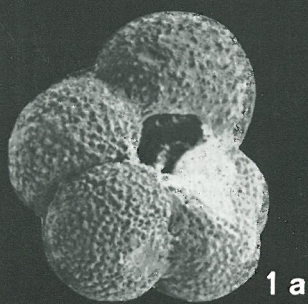


PLATE 7

FIG. 1 : *Globigerina paraboloides* BLOW, 1959

- a. Umbilical view — Antwerpen Sands, Borgerhout-Kleine Ring section.
× 165.
- b. Spiral view — idem
× 125.
- c. Axial view — idem
× 125.

FIG. 2 : *Globigerina praebuloides leroyi* BLOW & BANNER, 1962

- a. Umbilical view — Houthalen Sands, Helchteren deepboring.
× 165.
- b. Spiral view — idem
× 160.
- c. Axial view — idem
× 135.

FIG. 3 : *Globigerina praebuloides occlusa* BLOW & BANNER, 1962

- a. Umbilical view — Houthalen Sands, Helchteren deepboring.
× 125.
- b. Spiral view — idem
× 105.
- c. Axial view — idem
× 100.

FIG. 4 : *Globigerina praebuloides praebuloides* BLOW, 1959

- a. Umbilical view — Houthalen Sands, Helchteren deepboring.
× 130.
- b. Spiral view — idem
× 130.
- c. Axial view — idem
× 160.

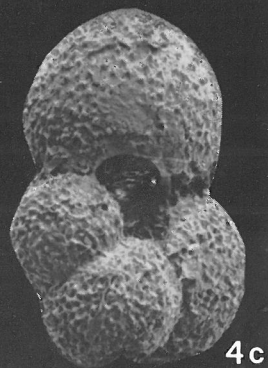
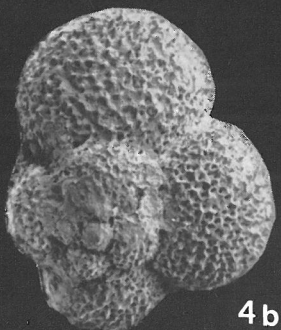
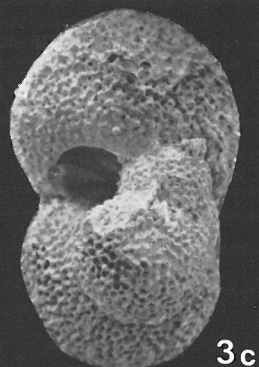
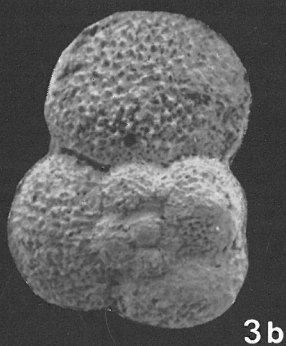
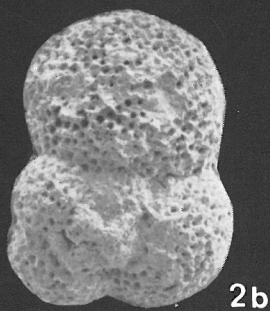
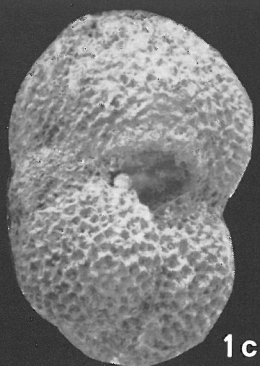
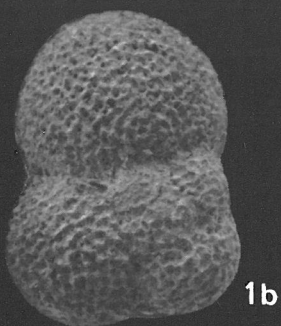
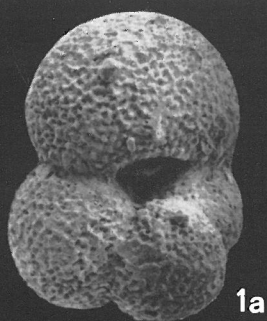


PLATE 8

FIG. 1 : *Globigerina praebulloides pseudociperoensis* BLOW, 1969

- a. Umbilical view — Antwerpen Sands, Borgerhout-Kleine Ring section.
× 120.
- b. Spiral view — idem
× 125.
- c. Axial view — idem
× 125.

FIG. 2 : *Globigerina prasaepis* BLOW, 1969

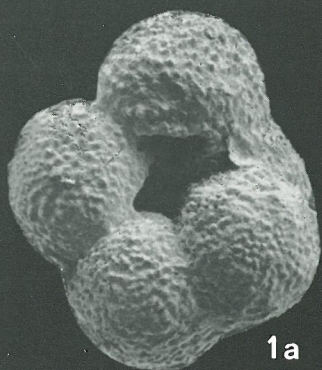
- a. Umbilical view — Edegem Sands, Antwerpen-Zuidstation section.
× 125.
- b. Spiral view — idem
× 135.
- c. Axial view — idem
× 135.

FIG. 3 : *Globigerina quinqueloba* NATLAND, 1938

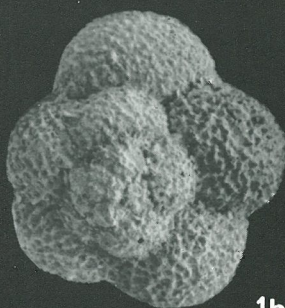
- a. Umbilical view — Antwerpen Sands, Borgerhout-Kleine Ring section.
× 205.
- b. Spiral view — idem
× 175.
- c. Axial view — idem
× 200.

FIG. 4 : *Globigerina woodi* JENKINS, 1960

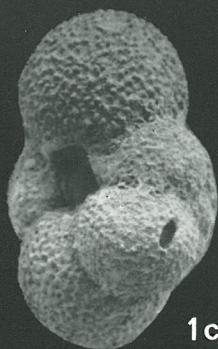
- a. Umbilical view — Houthalen Sands, Wijnshagen deepboring.
× 105.
- b. Spiral view — idem
× 90.
- c. Axial view — idem
× 90.



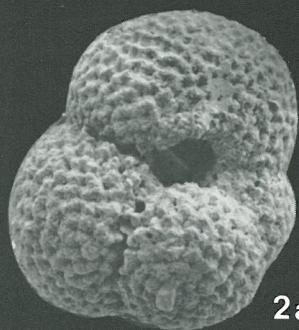
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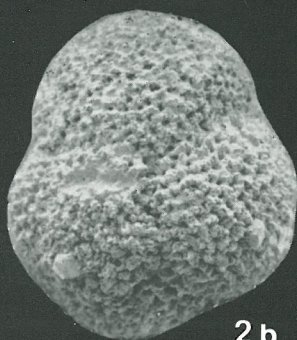
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1c



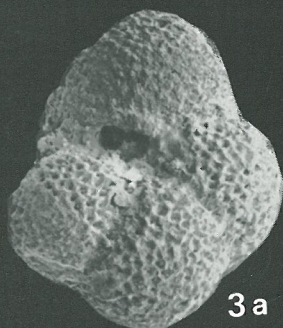
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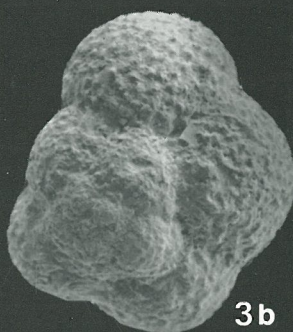
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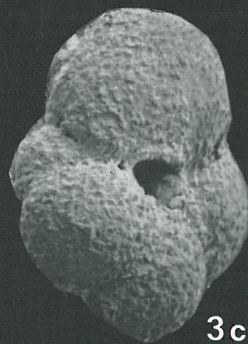
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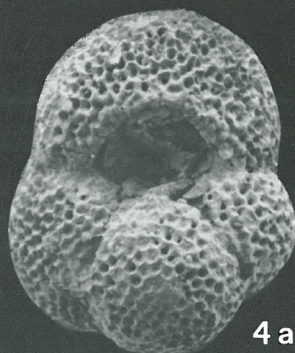
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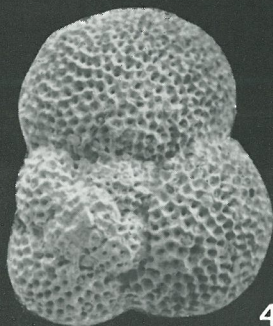
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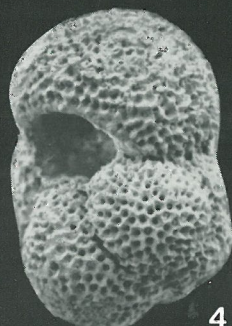
3c



4a



4b



4c

PLATE 9

FIG. 1 : *Globigerinoides bollii* BLOW, 1959

- a. Umbilical view — Antwerpen Sands, Borgerhout-Kleine Ring section.
× 115.
- b. Spiral view — idem
× 130.
- c. Axial view — idem
× 120.

FIG. 2 : *Globigerinoides quadrilobatus altiaperlurus* BOLLI, 1957

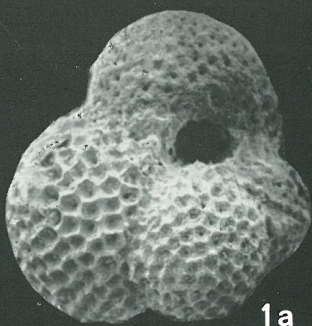
- a. Umbilical view — Houthalen Sands, Wijshagen deepboring.
× 100.
- b. Spiral view — idem
× 95.
- c. Axial view — idem
× 135.

FIG. 3 : *Globigerinoides quadrilobatus primordius* BANNER & BLOW, 1962

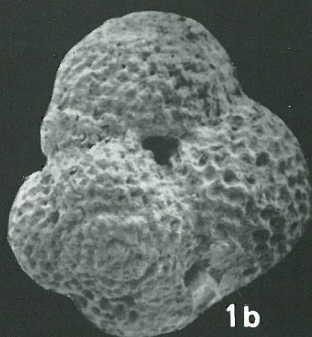
- a. Umbilical view — Houthalen Sands, Helchteren deepboring.
× 105.
- b. Spiral view — idem
× 85.
- c. Axial view — idem
× 85.

FIG. 4 : *Globigerinoides quadrilobatus quadrilobatus* BANNER & BLOW, 1960

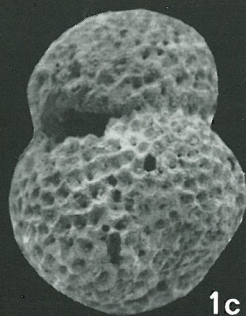
- a. Umbilical view — Houthalen Sands, Helchteren deepboring.
× 70.
- b. Spiral view — idem
× 75.
- c. Axial view — idem
× 95.



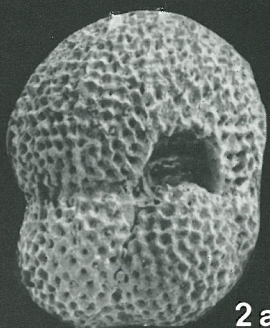
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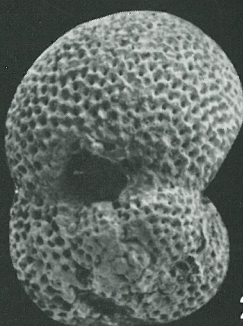
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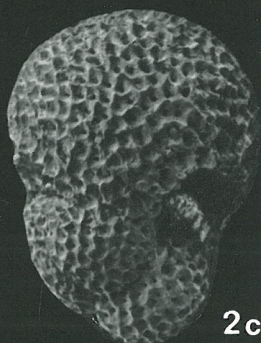
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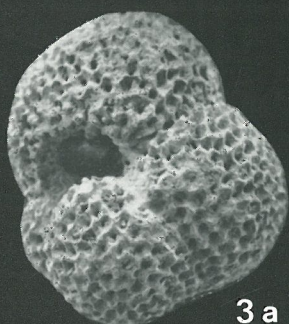
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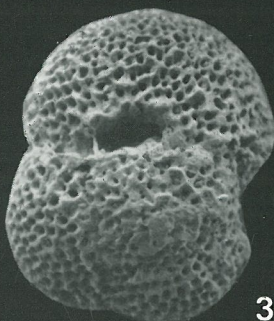
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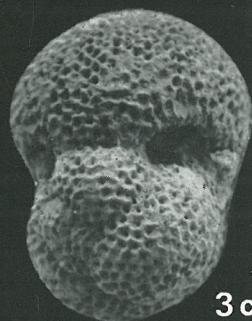
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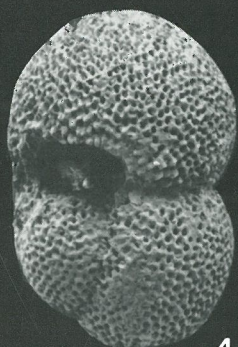
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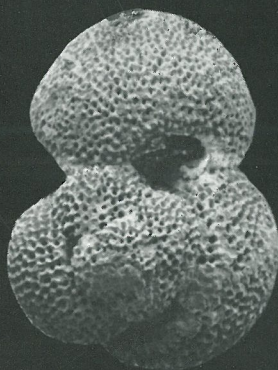
3b



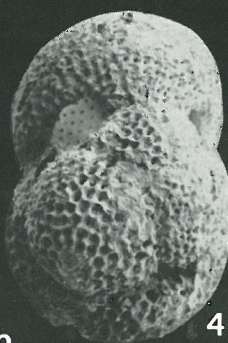
3c



4a



4b



4c

PLATE 10

FIG. 1 : *Globigerinoides sacculifer subsacculifer* CITA, PREMOLI SILVA & ROSSI, 1965

- a. Umbilical view — Houthalen Sands, Helchteren deepboring.
× 140.
- b. Spiral view — idem
× 130.
- c. Axial view — idem
× 115.

FIG. 2 : *Globigerinoides trilobus* (REUSS, 1850)

- a. Umbilical view — Houthalen Sands, Meeuwen deepboring.
× 80.
- b. Spiral view — idem
× 85.
- c. Axial view — idem
× 90.

FIG. 3 : *Globigerinopsis aguasayensis* BOLLI, 1962

- a. Umbilical view — Houthalen Sands, Helchteren deepboring.
× 85.
- b. Spiral view — idem
× 90.
- c. Axial view — Transitional form between *G. aguasayensis* and *Globorotalia pseudobesa* (SALVATORINI, 1966) — idem
× 90.

FIG. 4 : *Globorotaloides suteri* BOLLI, 1957

- a. Umbilical view — Houthalen Sands, Helchteren deepboring.
× 135.
- b. Spiral view — idem
× 190.
- c. Axial view — idem
× 175.

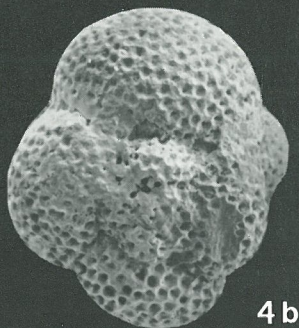
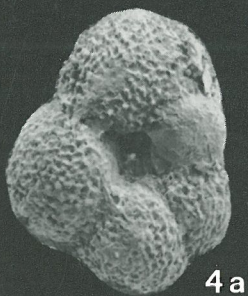
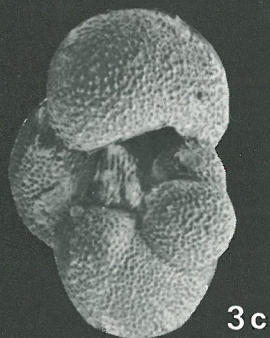
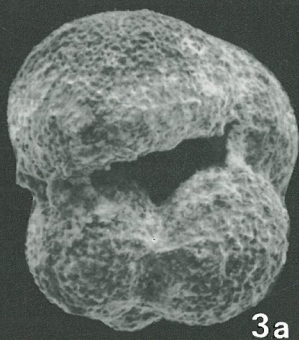
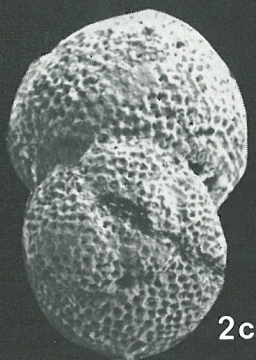
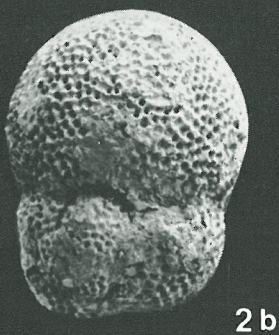
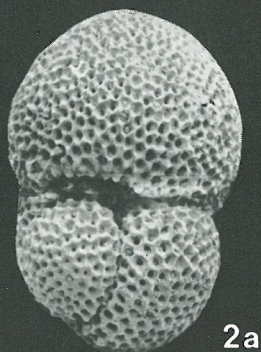
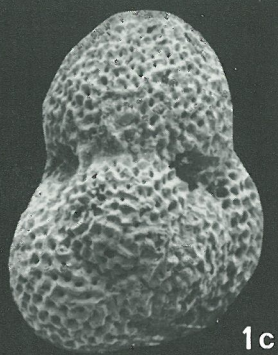
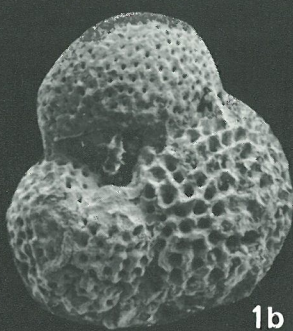
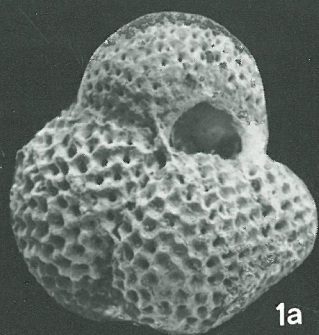


PLATE 11

FIG. 1 : *Sphaeroidinellopsis subdehiscens subdehiscens* (BLOW, 1959)

- a. Umbilical view — Antwerpen Sands, Borgerhout-Kleine Ring section.
× 85.
- b. Spiral view — Antwerpen Sands, Antwerpen-Centraalstation section.
× 170.
- c. Axial view — idem
× 170.

FIG. 2 : *Globigerinita martini scandretti* BLOW & BANNER, 1962

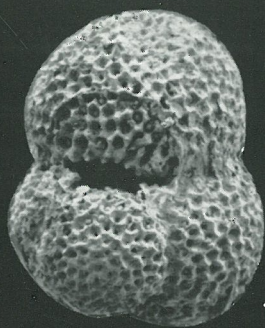
- a. Umbilical view — Edegem Sands, Antwerpen-Zuidstation section.
× 100.
- b. Spiral view — idem
× 90.
- c. Axial view — idem
× 130.

FIG. 3 : *Globigerinita unicava primitiva* BLOW & BANNER, 1962

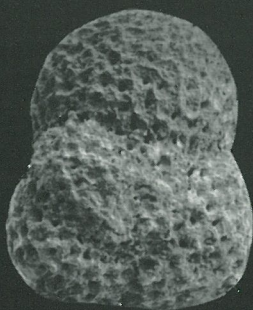
- a. Umbilical view — Edegem Sands, Antwerpen-Zuidstation section.
× 180.
- b. Spiral view — idem
× 190.
- c. Axial view — idem
× 165.

FIG. 4 : *Globigerinita unicava unicava* (BOLLI, LOEBLICH & TAPPAN 1957,)

- a. *Umbilical* view — Edegem Sands, Antwerpen-Zuidstation section.
× 140.
- b. Spiral view — idem
× 130.
- c. Axial view — idem
× 110.



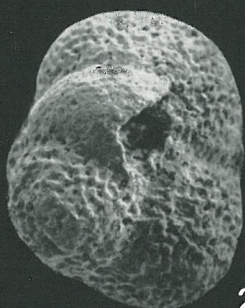
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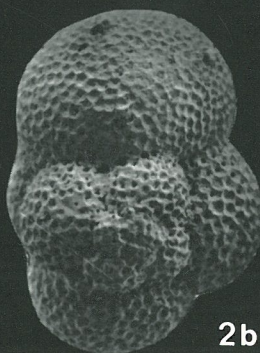
1b



1c



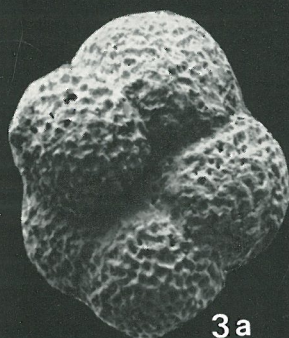
2a



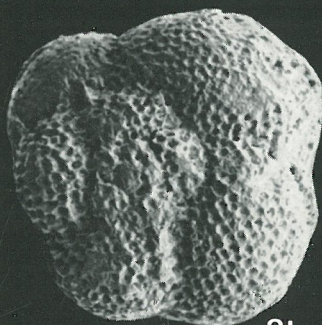
2b



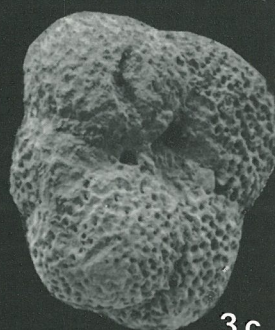
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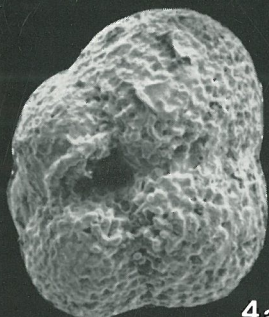
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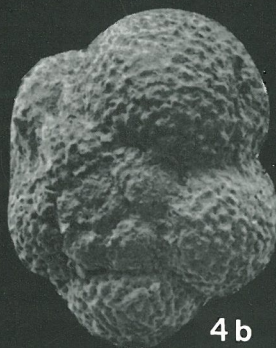
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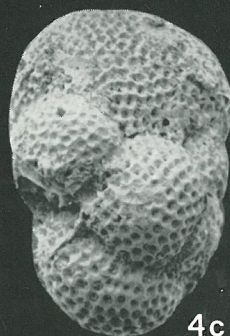
3c



4a



4b



4c

D/1972/0455/6

