

The growth spiral in some planktonic foraminifera from the Eocene of Denmark

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The individual growth pattern of the planktonic foraminifera *Globigerinatheka index* (Finlay) is extremely variable, and the taxonomical problems involved are very complex. The different morphotypes displayed by some Danish material of *G. index* are presented in this paper.

The growth spiral is analysed and compared with the spiral of other taxa referred to as *Globigerina* sp., *Globigerina* ex gr. *bulloides* d'Orbigny, and *Globigerina patagonica* Todd & Kniker. The appearance of the ultimate chamber is illustrated by graphs of its dimensions, absolutely and relatively. In many specimens the ultimate chamber is displaced from the 'normal' growth spiral. The growth lines representing length *versus* Breadth of the 'normal' growth spiral are constructed and statistically tested.

Some intervals of the Eocene "Plastic Clay" Group of Denmark contain rich faunas of planktonic foraminifera (Berggren, 1960, 1969; Dinesen, 1972). The taxonomic units involved are characterized by a wide phenotypic variation. Therefore, the result of a conventional break-down in "central types" could easily resemble that to which Drooger (1966, p. 41) alluded with the following comment: "Practically none of the described species and subspecies corresponds to what could have been Mendelian populations. They are no more than clusters and types from such populations, which often had a very wide variation".

In a study of the quantitative composition of the faunas the "transitional types" have to be included as well as the "central types". In order to provide a base for a useful discrimination, the application of biometric methods seems to be indispensable. Thereby the phenotypic variation in the samples can be mapped and compared from one sample to another.

The evaluation of the statistical results depends on the procedure applied during the selection of the samples. In previous biometric studies on planktonic foraminifera the statistical samples are selected according to different rules of procedure.

Scott (1966, 1967, 1970) and Lindenberg (1969), for instance, selected their statistical samples on the basis of a sharp and precise definition of an "experimental class". The experimental class of Scott (1966, p. 515) includes "all individuals within the family Globigerinidae Carpenter that possess more than one aperture", and that of Lindenberg (1969, p. 343) contains "all tests of the material investigated which had more than 3 and less than 5, more or less globular chambers in the last-formed whorl, and which had a coarsely cancellate surface and a distinct apertural lip". From a theoretical point of view the consideration of a single or a few characteristics, and not of the entire shell, may produce a statistical sample from which some parts of the infraspecific variation has been omitted, and/or it may produce a sample in which specimens with a heterogenous phyletic background have been pooled. The same conclusion is found in the following statement by Lindenberg (1969, p. 344): "Discrimination of sample populations is ambiguous with respect to its biologic, taxonomic and phyletic meaning."

On the other hand Berggren & Kurtén (1961) did not define any experimental class, but their samples were picked from supposedly Mendelian populations. Although a strong element of subjectivity is introduced by this type of statistical sample, it may be more suitable than a sample representing a well-defined experimental class when the actual purpose is to procure a taxonomic interpretation.

The procedure followed by Quilty (1969) apparently combined valuable elements from the studies mentioned above. Quilty studied samples selected from different groups of morphotypes, all of which were supposed to belong to a single species, and at least some of his groups were well-defined like experimental classes.

The present study is a preliminary attempt to make a comparison of some few species of Globigerinidae from the Danish Eocene. The eight samples investigated were selected from supposedly Mendelian populations without a precise definition of the experimental classes.

Data on the origin of the statistical samples

Sample 1 *Globigerinatheka index*, 50 (in part of the study only 49) specimens.

Locality: A marl pit about 0.3 km SW of the church of Søvind, East Jutland. Formation: Søvind Marl (Upper Eocene). Remarks: The rock sample consists of a sticky, light olive grey marl. It is the same sample as referred to as S-1-3 by Tank (1963) and Dinesen (1972).

Sample 2 *Globigerinatheka index*, 39 specimens.

Locality: A bore hole at Rodstenseje, about 1.2 km SE of the church of Odder, East Jutland. Formation: Søvind Marl (Upper Eocene). Remarks: The boring was made in 1972 by the Micropaleontological Department, Geological Institute, University of Aarhus. The rock sample (No. 35) consist of a sticky, light olive grey marl, and it was taken at a depth of 10.85–10.95 m below ground.

Sample 3 *Globigerinatheka index*, 50 specimens.

Locality: The Viborg No. 1 core hole (DGU File No. 66.318), about 1.5 km WSW of the cathedral of Viborg, Mid Jutland. Formation: Søvind Marl (Upper Eocene). Remarks: The core hole was drilled in 1939 by Danish American Prospecting Company. The rock sample (AD No. 143) consists of a sticky, light olive grey marl, and the depth is about 292 m below ground.

Sample 4 *Globigerinatheka index*, 50 specimens.

Locality: A borehole at Hesselho (DGU File No. 113.30), about 5 km NW of the church of Skovlund, West Jutland. Formation: Søvind Marl (Upper Eocene), as a floe in the Quaternary deposits. Remarks: The borehole was drilled in 1951 by the Geological Survey. The rock sample consist of a sticky, light olive grey marl, and the depth is 30 m below ground.

Sample 5 *Globigerina* sp., 50 specimens.

Locality: A marl pit at Toftum, about 1.5 km WNW of the church of Søvind, East Jutland. Formation: Søvind Marl (Upper Eocene). Remarks: The rock sample consists of a sticky, light olive grey marl.

Sample 6A *Globigerina* ex. gr. *bulloides*, 50 (in part of the study only 34) specimens.

Locality: A marl pit about 0.3 km SW of the church of Søvind, East Jutland. Formation: Søvind Marl (Upper Eocene). Remarks: The rock sample consists of a sticky, light olive grey marl. The sample is the same one as referred to as S-1-1 by Tank (1963) and Dinesen (1969), and it was collected about 6 m below sample S-1-3 (statistical sample 1).

Sample 6B *Globigerina* ex gr. *bulloides*, 50 specimens.

The specimens were picked from the same residue as sample 6A.

Sample 7 *Globigerina patagonica*, 50 (in part of the study only 49) specimens.

Locality: A clay pit about 800 m WSW of the church of Ulstrup, West Zealand. Formation: Røsnæs Clay (Lower Eocene). Remarks: The rock sample consists of a sticky, reddish brown, calcareous clay.

The localities of the eight samples are shown on the map, fig. 1.

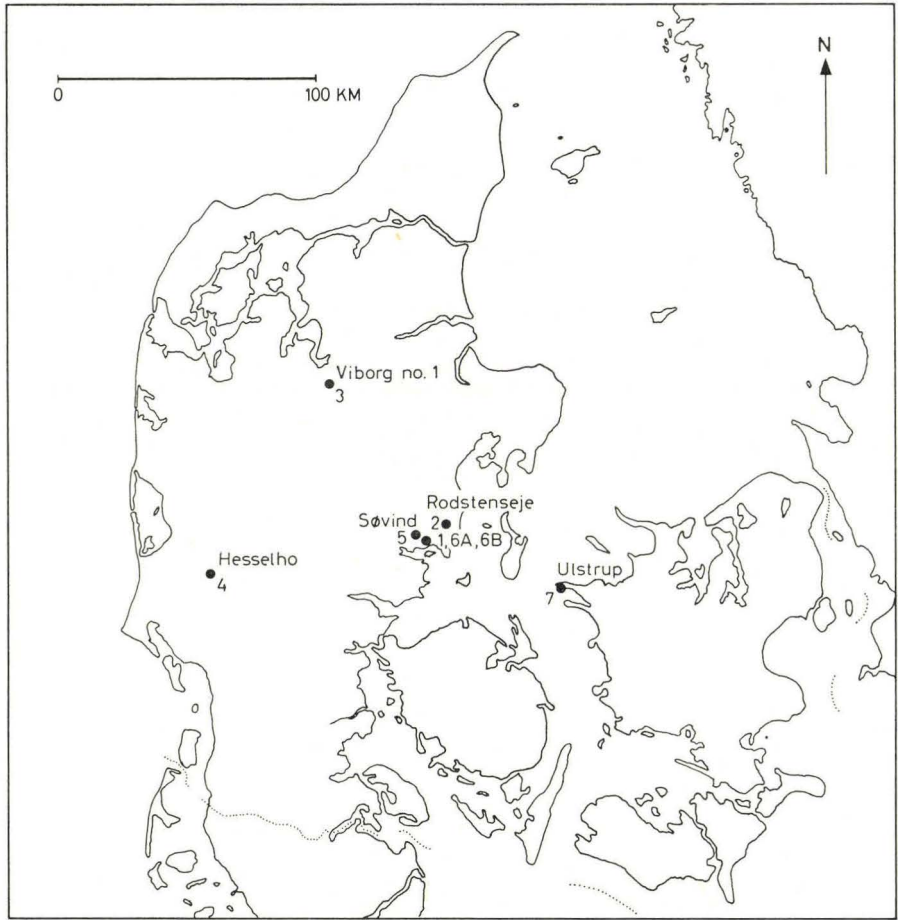


Fig. 1. Locality map. Localities of the samples 1–7 indicated.

Palaeontological notes

Globigerinatheka index (Finlay)

Pl. 3, figs. 1–8; pl. 4, figs. 1–7.

- 1939 *Globigerinoides index*; Finlay, pp. 125, 127, pl. 14, figs. 85–88.
1957b *Globigerapsis index* (Finlay); Bolli, p. 165, pl. 36, figs. 14a–18b.
1958 *Globigerinoides index* Finlay; Hornibrook, p. 34, pl. 1, figs. 11–14.
1959 *Globigerina ampliapertura* Bolli; Drooger & Batjes, p. 174, pl. 1, fig. 1.
1962 *Globigerapsis index* (Finlay); Blow & Banner, pl. 15, figs. G–H.
1962 *Globigerapsis tropicalis*; Blow & Banner, p. 124, pl. 15, figs. D–F.
1969 *Globigerapsis index* (Finlay); Berggren, p. 125, pl. 2, figs. 22–24.

- 1969 *Globigerapsis index* (Finlay); Blow, p. 330, pl. 27, figs. 1–2.
1969 *Globigerapsis tropicalis* Blow & Banner; Blow, p. 331, pl. 27, figs. 5–6.
1969 *Globigerapsis index* (Finlay); Quilty, p. 47, fig. 7, No. 42–48; text fig. 3.
1971 *Globigerinatheka (Globigerapsis) index index* (Finlay); Jenkins, p. 187, pl. 22, figs. 641–645.
1972 *Globigerinatheka index index* (Finlay); Bolli, p. 124, pl. 1, figs. 1–4, 6–7; text figs. 51–57, 63–64.
1972 *Globigerinatheka index tropicalis* (Blow); Bolli, p. 127, pl. 3, figs. 1–24, pl. 4, figs. 7–12; text figs. 58–60.

(For further synonyms: see the papers by Quilty, Jenkins and Bolli.)

Description. The material shows a wide phenotypic variation due to the representation of different ontogenetic stages and also due to the disturbances which often appear during the growth of the individuals.

In the majority of the specimens the growth ceased at a “*Globigerina*-like” stage with 3, 3½ or 4 chambers in the final whorl and with a single umbilical aperture from the ultimate chamber. As far as the sutures can be observed from the dorsal side the specimens with 3 chambers in the final whorl have 4 chambers per whorl in the initial stage of the growth.

In “4-chambered” specimens the ultimate chamber often has a characteristic flattened, beret-like form. Such a specimen is shown on pl. 3, fig. 1.

On the other hand there are relatively few specimens with 2 apertures from the ultimate chamber. In these specimens the aperture spanning over the penultimate chamber is normally the largest one. Almost all specimens with 2 apertures have 4 chambers in the whorl to which the ultimate chamber is added. Specimens with 3 apertures occur but they are very seldom and not represented in the statistical samples.

The ultimate chamber may be more or less reduced in size and dislocated out of the “normal” growth spiral in the “*Globigerina*-like” specimens as well as in the specimens with more than one aperture. In a few cases the specimens with two apertures have a small “bulla-like” chamber above one or both of the two apertures.

The frequencies of the different morphotypes represented in the statistical samples are recorded in table 1.

The preferred direction of coiling is dextral. The percentages of dextrally coiled specimens in sample 1–4 are 96 %, 97.4 %, 86.0 % and 82.0 % respectively.

The texture of the wall represents another variable feature, and the texture seems to be strongly dependent on the development and the thickness of the calcite crust (cp. Hemleben, 1969, fig. 4). In the specimen shown on pl. 3, fig. 2 the crust is lacking in parts of the ultimate chamber.

Table 1: The frequencies (in percentages) of the morphotypes of *Globigerinatheka* index in sample 1 - 4.

Sample	1	2	3	4
Number of specimens	50	39	50	50
A. 1 aperture, 3 chambers in the final whorl, ultimate chamber 'normal'	8.0	25.6	10.0	14.0
B. 1 aperture, 3½ chambers in the final whorl, ultimate chamber 'normal'	2.0	15.4	20.0	20.0
C. 1 aperture, 4 chambers in the final whorl, ultimate chamber 'normal'	26.0	30.8	40.0	30.0
D. 1 aperture, 4 chambers in the final whorl, ultimate chamber 'reduced'	38.0	12.8	28.0	16.0
E. 2 aperture, ultimate chamber 'normal'	2.0	2.6	0.0	0.0
F. 2 apertures, ultimate chamber more or less 'reduced'	22.0	12.8	2.0	20.0
G. 2 apertures, with a 'bulla-like' structure added to one or both of the 2 apertures	2.0	0.0	0.0	0.0

Remarks. According to Bolli (1972, p. 123) "all Middle to Late Eocene planktonic foraminifera that possess a trochospiral globigerinid stage whose umbilical area is covered by a final chamber with two or more sutural apertures which may or may not be covered by bullae" are now included in *Globigerinatheka* Brönnimann 1952, emended by Proto Decima & Bolli 1970.

Before this emendation was undertaken the specimens in which the sutural apertures are not covered by bullae were referred to the genus *Globigerapsis* Bolli, Loeblich & Tappan 1957. In the diagnosis of *Globigerapsis* it was stated by Bolli et al. (1957, p. 34) that the ultimate chamber is "embracing and covering the umbilical region of the early coil", and that the primary aperture is "interiomarginal, umbilical in the young stage, covered in the adult by an enveloping final chamber", that there are "two or more arched secondary apertures at the lower margin of the final chamber, at the contact with the sutures of the earlier whorl". Furthermore it was stated that "*Globigerapsis* . . . differs from *Globigerinatheka* Brönnimann in lacking the small angular bullae covering the secondary apertures. It differs from *Globigerinoides* Cushman in the absence of an umbilical primary aperture in the adult. *Globigerapsis* does not show the multiple apertures on the earlier chambers as does *Globigerinoides* and *Porticulasphaera*, new genus".

The different growth stages represented in a sample (436 specimens) of *Globigerapsis index* (Finlay) from the Upper Eocene of Western Australia were studied on a quantitative basis by Quilty (1969). Depending on the size and the position of the ultimate chamber, the presence or the absence of bulla(e), and the number of apertures, his material was grouped in 5 "genera" ("*Globigerina*", "*Globigerinoides*", "*Globigerapsis*", "*Globigerinita*" and "*Globigerinatheka*"). The statistical tests of Height versus Breadth in the "normal" growth spiral suggested that all the specimens belonged to a single population. This result gave occasion for Quilty to emphasize the importance of defining genera in terms of phylogeny and not only in terms of a set of morphological characters. Quilty considered the genera *Globigerinoides* and *Globigerinita* to represent monophyletic groups different from *Globigerapsis*, and *Globigerina* was supposed to be the ancestral root stock from which one of the lineages gave rise to *Globigerapsis*. Although Quilty observed another texture in the walls of the bullae of "*Globigerinita*" and "*Globigerinatheka*" than in the walls of the earlier parts of the shells and in the wall of the modified, ultimate chamber of "*Globigerapsis*", he did not attach any weight to the bulla as a specific character. The five "generically different" groups were considered to be biologically conspecific, and *Globigerinatheka* was named as one of the genera which "are probably all only

complex variants of populations belonging to species of previously defined genera and as such must be rejected”.

Bolli (1972, p. 111), however, stated that “a bulla may vary from thin walled with fine pores, clearly contrasting with earlier chambers, to thick and coarsely pored, like preceeding chambers, the distinction between an umbilical bulla and a final chamber in the same position clearly rests on size alone”, and he figured such a variation in *Globigerinatheka index tropicalis* (pl. 3) and in *G. subconglobata luterbacheri* (pl. 7). It was also stated by Bolli that neither the original definition of a bulla (given by Bolli, Loeblich & Tappan 1957, p. 13), nor the redefinition (given by Banner & Blow 1959, p. 26) include any “size limits or characteristics of the wall”. Instead of suppressing *Globigerinatheka*, as done by Quilty, Bolli rejected *Globigerapsis* as the junior synonym of the two genera.

According to these quotations it seems to be fully justified to refer the present material to the genus *Globigerinatheka*, although several specimens have not passed the globigerinid stage, represented by the morphotypes A, B, C and D. The combined percentages of the morphotypes A–D are 74.0 % in sample 1, 84.6 % in sample 2, 98.0 % in sample 3, and 80.0 % in sample 4. A dominance of the globigerinid stage was also observed in the Australian sample examined by Quilty (1969), who stated that the ratio between “*Globigerina*”, “*Globigerinoides*”, “*Globigerapsis*”, “*Globigerinita*” and “*Globigerinatheka*” is 49:9:10½:7:1, i.e. the globigerinid stage (“*Globigerina*”) amounted to about 64 %. From the Middle Eocene Porangan stage of New Zealand Jenkins (1971) has reported on samples of *G. (G.) index index* where the specimens “lack the umbilical bulla and the multiple apertures”, i.e. the globigerinid stage amounts to 100 %.

On the other hand the taxonomic interpretation at the species level is problematical due to the variation in the number of chambers per whorl and the variation in the coarseness of the wall texture exhibited by the present material. In a letter (dated April 14th 1964) Berggren expressed his opinion on specimens picked from the same residue as sample 1. According to Berggren some of these specimens with a relatively fine wall surface are close to *G. tropicalis* Blow, whereas some other specimens with a coarser wall surface are closer to *G. index* Finlay, but despite these similarities Berggren would not exclude the possibility that a “new form” could be represented. The presence of *G. index* was reported by Berggren (1969) in some other samples of the Søvind Marl from a locality at Moesgård Strand, East Jutland, and this determination was confirmed by Blow (1969).

The relationship between *G. index* and *G. tropicalis* is not finally settled. Blow (1969) still considered *G. tropicalis* as a separate species and figured an ideotype (pl. 27, figs. 5–6) looking quite different from the figured

hypotype of *G. index* (pl. 27, figs. 1–2); both specimens came from the same sample from Tanzania. Bolli (1972, p. 125) stated: "It is often difficult, however, to assign specimens of intermediate character to one of the two species". Jenkins (1971, p. 187) observed "a wide morphological variation from high- to low-spined tests with rough- and smooth-walled forms" in a sample of *G. (G.) index index* from the Middle Eocene Bortonian stage of New Zealand. *G. tropicalis* was suggested by Jenkins to be the "tropical equivalent" of *G. index index*, but he did not define how to discriminate the smoothwalled forms of *G. index* from *G. tropicalis*. The writer has examined 11 specimens of *G. index* from the Uppermost Eocene of New Zealand (sample S 136/887, Oamaru Diatomite, Jackson's Pad-dock, Oamaru), kindly put at my disposal by Dr. Hornibrook. As shown on pl. 4, figs. 6–7 these specimens have a rather smooth wall surface, not at all as rough as the holotype and the paratypes (refigured by Hornibrook (1958) and Jenkins (1971)).

The classification of the Danish material as shown in table 1 deviates in some respects from the classification of *G. index* used by Quilty (1969). "*Globigerina*" as defined by Quilty has only 3 chambers in the final whorl and corresponds to morphotype A. Quilty did not register any forms similar to the morphotypes B, C and D which are strongly represented in the Danish material. The "*Globigerinoides*" of Quilty corresponds to the present morphotype E from which there is a gradual transition to "*Globigerapsis*". The Danish specimens of the "*Globigerapsis*" type as well as of the "*Globigerinita*" type are included in morphotype F, because, as also observed by Bolli (1972), there is no sharp boundary between the bulla of "*Globigerinita*" and the ultimate chamber of "*Globigerapsis*". The single specimen of morphotype G in sample 1 may be considered as representing a transitional stage from "*Globigerapsis*" to the typical "*Globigerinatheka*". Almost all specimens of the morphotypes E, F and G have 4 chambers in the whorl to which the ultimate chamber (or bulla) is added, but the four "genera" with multiple apertures registered by Quilty have only 3 chambers in the corresponding whorl.

The holotype (a "*Globigerina*") and the paratypes ("*Globigerapsis*") of *G. index* as well as the New Zealand specimens in my collection are all "3-chambered" in the final whorl like Quilty's Australian material. It has not been possible to count the number of chambers in the initial part of the shells in the New Zealand material, but Quilty observed 4 chambers per whorl in the initial part of some glauconitic casts. In most of the Danish specimens the initial part of the shells is obscured. However, some of the specimens of morphotype A undoubtedly show a reduction from 4 to 3 chambers per whorl during growth, and a single specimen of morphotype

D shows a reduction from 5 to 4 chambers. Even a reduction from 5 in the initial part over 4 in a later stage to 3 in the final whorl has been observed in a specimen of morphotype F. One of the specimens figured as *G. (G.) index index* by Jenkins (1971, pl. 22, fig. 644) apparently has 4 chambers in the whorl to which the ultimate chamber with two apertures is added, but it still seems to be remarkable that 4 chambers in the final whorl are much more common in specimens in the Danish material than in specimens from Australia and New Zealand.

The holotype of *G. tropicalis* was described with 5 chambers per whorl in the first two whorls and with 3–4 chambers in the final whorl. Bolli (1957, pl. 36, figs. 14a–18b) figured specimens from Trinidad as *G. index*. Blow & Banner (1962) incorporated these specimens in the list of synonyms for *G. tropicalis*. Bolli (1972) accepted the “adult” specimens (fig. 14–15) as *G. index tropicalis*, but excluded the “juvenile” specimens (figs. 16–17) from his list of synonyms. Nevertheless the “juvenile” specimens are similar to the Danish morphotype C with 4 chambers in the final whorl. Some other specimens from Trinidad figured by Bolli (1972, pl. 3, figs. 7,20) as *G. index tropicalis* unmistakably have 4 chambers in the whorl to which the ultimate chamber with two apertures is added. These few examples may indicate that an essential part of the Danish material is closer to the subspecies *tropicalis* when the number of chambers in the final whorl is taken in consideration.

It is very likely that the specimen figured by Drooger & Batjes (1959, pl. 1, fig. 1) as *Globigerina ampliapertura* from the Søvind Marl (sample Søvind-3, possibly from the same locality as the present sample 1) is identical with the specimens of morphotype C. However, Berggren (1969) registered *G. ampliapertura* in the same samples from Moesgård Strand in which he found *G. index*.

The very high percentage of dextrally coiled specimens is usual in both *tropicalis* and *index*.

It seems to be reasonable to consider the Danish material analyzed in this context as a single biological unit spanning from *Globigerinatheka index index* to *G. index tropicalis*.

Globigerina sp.

Pl. 5, figs. 1–3.

Description. The chambers are subspherical and moderately increasing in size during the growth of the shell. As the overlap of the chambers is moderate, the sutures are distinctly depressed, and the equatorial profile is

lobulate. In the initial part of the shell 5 chambers per whorl may be counted. In the younger stages a whorl is made up of 4 chambers per whorl, or more rarely of only 3 or $3\frac{1}{2}$. On the dorsal side a more or less distinct spire is developed, some specimens being convex, others more flattened. The relative size and the position of the ultimate chamber show some variation, and specimens with a strongly reduced ultimate chamber occur, although they are not very frequent. The aperture is relatively large and usually symmetrically arched. The shape and the size of the aperture are influenced by the size and the position of the chamber. The wall surface is covered by fine spines or pustules.

The percentage of dextrally coiled specimens in sample 5 is 96 %.

Remarks. The present species has not been identified. Some of the specimens appear to resemble *Globigerina ampliapertura* Bolli as illustrated by Bolli (1957a, pl. 22, figs. 5a–b; 1957b, pl. 36, figs. 8a–c), and some others to resemble *Globigerina* cf. *trilocularis* d'Orbigny as illustrated by Bolli (1957a, pl. 22, figs. 8a–c). After examination of some few of the specimens, professor Bolli has kindly informed me in a letter (dated July 19, 1974) that the Danish specimens “differ from *ampliapertura* in more delicate test walls, higher spire, more lobulate peripheral outline and in the aperture being situated more umbilical (in *ampliapertura* it has the tendency to become extraumbilical)”. Compared with *G.* cf. *trilocularis* the Danish specimens “seem to possess a higher spire and a more distinct, higher arched aperture”. Bolli suggests that the Danish specimens are “much closer to *Globigerina praebulloides* or *G. ouachitaensis ouachitaensis* as figured on plate 9, figures O–Q and H–K respectively in Eames et al., 1962”.

Some specimens of *G. ampliapertura* from Trinidad, sent by Prof. Bolli, confirm that the present species is a different one. The wall structure seems, however, not only to differ from the wall structure of *G. ampliapertura*, but also from the wall structure of *G. ouachitaensis* (s.l.) and of *G. praebulloides* (s.l.). The specimens of *G. ampliapertura* from Trinidad, received from professor Bolli, as well as the stereoscan illustrations of the same species given by Blow (1969, pl. 12, figs. 6, 9, 10) show well-developed inter-pore ridges. Well-developed ridges are also seen in *G. ouachitaensis* (s.l.) and *G. praebulloides* s.l.) according to Blow (1969). Although a certain variation in the character of the wall structure of these two “species” occurs, as discussed below under *G. ex gr. bulloides*, the variation can hardly embrace a wall structure as demonstrated by the present species.

Globigerina ex gr. *bulloides* d'Orbigny

Pl. 6, figs. 1–5; pl. 7, figs. 1–5.

Remarks. Several morphotypes are grouped under the preliminary term *G. ex gr. bulloides*, and the problem of whether or not the genetical background of the group is heterogeneous is unsettled. Some of the morphotypes can probably be referred to *Globigerina praebulloides* (s.l.), *G. ouachitaensis* (s.l.), *G. officinalis*, *G. angustiumbilitata* and *Globigerinita univava*, but many specimens show transitional features, and a discrimination has not been possible.

The variable phenotypic appearance is provoked by a variable number of chambers in the final whorl (4, 4½ or 5) and by the variation in the size, the shape and the position of the ultimate chamber. In some specimens the aperture is bordered by a more or less well-developed lip, whereas the size and the shape of the aperture depend on the relative position of the ultimate chamber.

Blow (1969, note to pl. 17, figs. 3, 4) stated that the type of wall structure and texture seen in *G. ouachitaensis* (s.l.) is not the same as that in *G. praebulloides* (s.l.). However, stereoscan illustrations of *G. praebulloides pseudociperoensis* (Blow, 1969, pl. 17, figs. 8, 9) are given in lesser magnification than the illustrations of *G. ouachitaensis ouachitaensis* (pl. 17, figs. 3, 4), and therefore the subjoined note of Blow, that "the pores are seen to be finer, more closely spaced and do not have so well-developed inter-pore ridges as compared to *G. ouachitaensis* (s.s.) and *G. ouachitaensis ciperoensis*" does not convince about the existence of any distinct difference in the type of the wall of *G. ouachitaensis* (s.l.) and *G. praebulloides* (s.l.).

The present material displays various types of wall structures. In some specimens the wall is pustulate, whereas some other specimens have more or less well-developed inter-pore ridges or a "crystalline" surface as if covered with a calcite crust. As more than one type of wall may be represented in one and the same specimen, and as long as the taxonomic value of these different types is unknown, I have preferred to lump the material in the "bulloides-group".

The percentages of dextrally coiled specimens in sample 6A and 6B respectively are 50 % and 58 %.

Globigerina patagonica Todd & Kniker

Pl. 5, figs. 4–9.

1952 *Globigerina patagonica*; Todd & Kniker, p. 26, pl. 4, fig. 32.

1960 *Globigerina yeguaensis* Weinzerl & Applin; Berggren, p. 73, pl. 2, figs. 1a–4c; pl. 3, figs. 1a–3c; pl. 4, figs. 1a–2c; pl. 8, figs. 1a–5c; text fig. 11.

1969 *Globigerina patagonica* Todd & Kniker; Berggren, p. 149, pl. 1, figs. 1–6.

Remarks. *Globigerina patagonica* was intensively studied by Berggren (1960) and Berggren & Kurtén (1961). The percentage of dextrally coiled specimens in sample 7 is 58 %.

Biometry

General remarks on the measurements

The individual growth met with in planktonic genera such as *Globigerina* and *Globigerinatheka* complicates the utilization of biometrical methods. Owing to the mutual arrangement of subglobular chambers it is difficult to define a precise site of an axis or a plane according to which a repeatable orientation of the shell can take place, and owing to the changes in the increase of the chamber size and the changes in the relative position of the chambers during the growth it is difficult to find quite adequate characteristics.

Berger (1969) stated that the 'basic building plan' of a Globigerinacean shell is controlled by the following three characteristics: (1) the ratio between successive chamber radii ('q-ratio'), (2) the angle of advance between the lines connecting the center of the test with two successive chamber midpoints ('a-angle') and (3) the ratio of the radius of a chamber to the distance between its midpoint and the one of the succeeding chamber ('overlap'), and these three characteristics were used by Berger for the construction of two-dimensional, geometric models. Whereas the constructed models have a constant number of chambers per whorl in the total shell, natural specimens very often show a decrease in the number of chambers per whorl during growth. For instance, the specimens figured by Blow & Banner (1962) as *Globigerina praebulloides praebulloides* (pl. IX, figs. O-Q), *G. praebulloides leroyi* (pl. IX, figs. R-T), *G. tripartita tapuriensis* (pl. X, figs. H-K), *G. ampliapertura ampliapertura* (pl. XI, figs. A-C), *G. ampliapertura euapertura* (pl. XI, figs. E-G) show a decrease from 5 or 4 chambers per whorl in the older part of the shell to 4 or 3 chambers per whorl in the younger part, and a similar pattern is observed in many specimens in the present material. On the other hand, an increase in the number of chambers per whorl during growth seems to be much more seldom, but an example is demonstrated by Blow (1969, p. 381, pl. 17, figs. 8-9) in his description and illustration of *G. praebulloides pseudociperoensis* with 4 chambers per whorl in the older part and 5 chambers in the final whorl. This difference between the models and the natural specimens can hardly be explained otherwise than by the fact that the constant values of the three characteristics applied for the construction of the models

do not match exactly with the natural growth. In fact, characteristics like the 'q-ratio', the 'a-angle' and the 'o-lap' may change during growth, and, if the characteristics are to be absolutely comparable, they have to be measured at identical stages of growth.

The 'p-ratio' studied statistically in several samples of globigerinid foraminifera by Scott (1966) and Lindenberg (1969) is similar to Berger's 'q-ratio', but p (or $\log p$) was calculated by means of the formula $Z_n = a \cdot p^{n-1}$ in which Z is n^{th} chamber, a is the first chamber, and p is the common ratio of a geometric series represented by the chambers. Scott calculated $\log p$ and the diameter of the penultimate chamber (D_{n-1}) from the diameter of the ultimate (D_n) and antepenultimate (D_{n-2}) chamber

($p = \sqrt[2]{\frac{D_n}{D_{n-2}}}$; $D_{n-1} = D_{n-2} \cdot p$). Lindenberg calculated $\log p$ and the diameters of the second (D_2) and the fourth ($D_4 =$ the ultimate) chamber of the last-formed whorl from the diameter of the first (D_1) and the third

(D_3) chamber of this whorl ($p = \sqrt[2]{\frac{D_3}{D_1}}$; $D_2 = D_1 \cdot p$; $D_4 = D_3 \cdot p$).

The reason for Lindenberg to omit the ultimate chamber from the calculation of $\log p$ was that this chamber "quite often seemed to be irregularly shaped". The method used by Scott and Lindenberg allowed a comparison between the observed (O) and the calculated (or expected, E) diameter of a chamber, and different types of distributions were indicated from the curves representing $\log p$, O-E, and O-E irrespective of signs. Since the curves for $\log p$ were skewed in some of the samples analysed by Scott, and since the curves for O-E of the ultimate chamber did not always fit with a Poisson distribution, the instability of the 'p-ratio' seems to be clearly demonstrated by these two authors. Especially, the deviations of the plots for D_2 and D_4 from the expected regression line for $Z_n = a \cdot p^{n-1}$ as illustrated by Lindenberg (1969, p. 250, fig. 5), may serve to indicate the lack of stability of the 'p-ratio'.

By measuring the length and the breadth of the 'normal growth spiral' in *Globigerapsis index*, Quilty (1969) tried to find a comparable starting point for his studies. However, at the same time Quilty (p. 51) stated that "it is often difficult to decide whether or not the ultimate chamber is, or is not, a little displaced from the normal growth spiral". Furthermore, the problem is accentuated for this genus according to the description given by Blow & Banner (1962, p. 123), because even earlier chambers in *Globigerapsis* than the ultimate one may be displaced from the 'normal' growth spiral. Blow & Banner stated that "the early whorls of regularly enlarging, trochospirally coiled, *Globigerina*-like chambers are followed in the last whorl by chambers which abruptly start to enlarge very rapidly, become

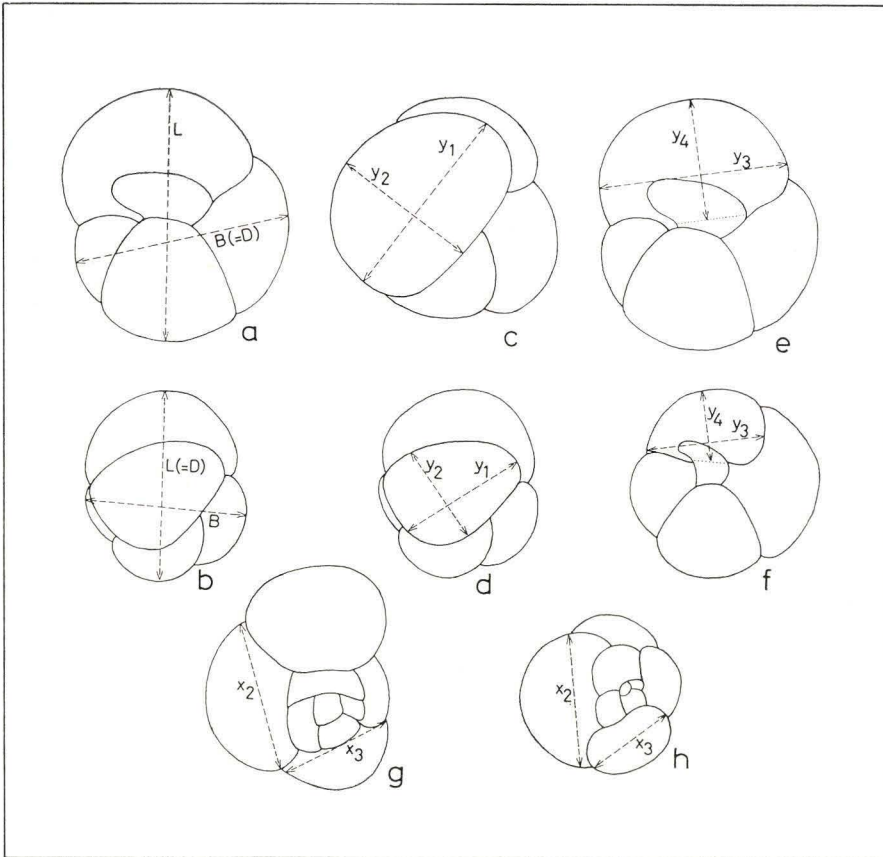


Fig. 2. Contour outlines with indication of the measured characteristics. a, c, e, g: specimen with the ultimate chamber included in the 'normal' growth spiral. b, d, f, h: specimen with the ultimate chamber displaced from the 'normal' growth spiral. a, e, f: ventral view, ultimate chamber 'northwards'. b, c, d: ventral view, penultimate chamber 'northwards'. g, h: dorsal view along the axis of the 'normal' growth spiral.

more ventrally extensive (more tightly coiled), and increasingly embrace the umbilicus of the earlier whorls".

In the present study the length and the breadth of the 'normal' growth spiral are analyzed by means of growth lines, following the method outlined by Quilty (1969), although these characteristics may have a restricted value as expressions for the 'basic shape'. The variability of the ultimate chamber and its relation to the 'normal' growth spiral are illustrated by some other methods.

The following characteristics are measured:

- L the maximum distance from the distal extremity of the ultimate chamber in the 'normal' growth spiral to the distal extremity of the antepenultimate chamber (modified from Quilty, 1969). Orientation of the shell: perpendicular to the axis of the 'normal' growth spiral, i.e. ventral view along the axis. See fig. 2a, b.
- B The maximum distance from the distal extremity of the penultimate chamber in the 'normal' growth spiral to the distal extremity of the ante- antepenultimate chamber (in specimens where this chamber is visible from the ventral side) *or* to the angle between the antepenultimate and the ultimate chambers (in specimens with 3 chambers in the last whorl) (modified from Quilty, 1969). Orientation of the shell: as for L. See fig. 2a, b.
- D the diameter of the shell exclusive of the ultimate chamber. D is equal to B in specimens with a 'normal' growth throughout, and D is equal to L in specimens with a more less reduced ultimate chamber. See fig. 2a, b.
- x_2 the largest diameter visible on the penultimate chamber (equal to Scott, 1970). Orientation of the shell: perpendicular to the axis of the 'normal' growth spiral, i.e. dorsal view along the axis. See fig. 2g, h.
- x_3 the largest diameter visible on the antepenultimate chamber (equal to Scott, 1970). Orientation of the shell: as for x_2 . See fig. 2g, h.
- y_1 the maximum diameter of the ultimate chamber measured parallel to the width of the (primary) aperture. Orientation of the shell: perpendicular to the axis of a spire in which the penultimate chamber is considered as the ultimate one, i.e. ventral view, neglecting the ultimate chamber even if not reduced in size. See fig. 2c, d.
- y_2 the maximum diameter of the ultimate chamber measured normal to y_1 . Orientation of the shell: as for y_1 . See fig. 2c, d.
- y_3 the maximum diameter of the ultimate chamber measured parallel to the width of the (primary) aperture. Orientation of the shell: perpendicular to the axis of a spire in which the ultimate chamber is considered as belonging to the 'normal' growth spiral even if reduced in size, i.e. ventral view, including the ultimate chamber even if reduced in size. See fig. 2e, f.
- y_4 the maximum diameter of the ultimate chamber measured normal to y_3 , i.e. the distance from a line through the junctions of the (primary) apertural rim with the ante-antepenultimate and the penultimate chamber *or* from a line through the junctions of the (primary) apertural rim with the antepenultimate and the penultimate chambers to the distal point of the ultimate chamber. Orientation of the shell: as for y_3 . See fig. 2e, f.

The measurements were undertaken in a binocular microscope (magnifications: objective 8x, ocular 10x) by means of an ocular scale, the units of which are 0.0135 mm. The error of the readings may amount to ± 0.5 unit.

The ultimate chamber and its relation to the 'normal' growth spiral

The phenotypic appearance of the individuals is strongly influenced by the relation between the ultimate chamber and the preceding part of the shell. The ultimate chamber displays a wide variation with respect to its relative size and position in the samples 1, 2, 3, and 4 (*Globigerinatheka index*) as

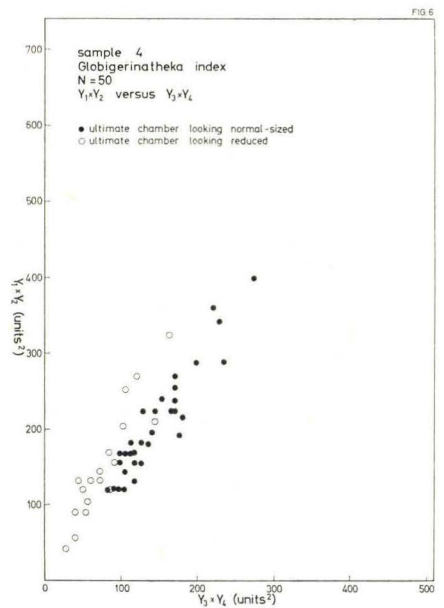
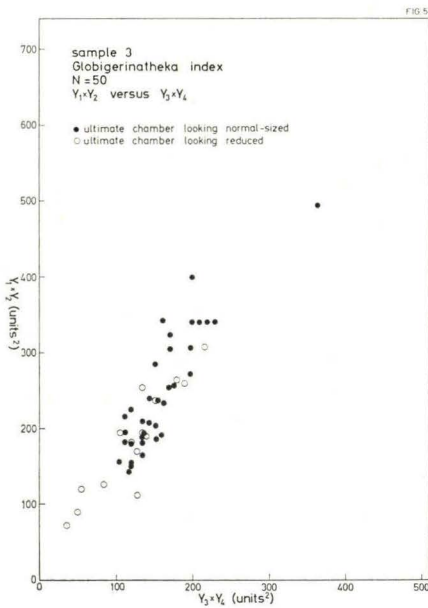
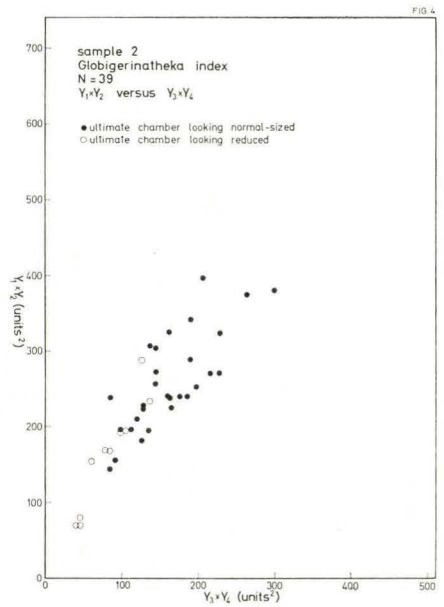
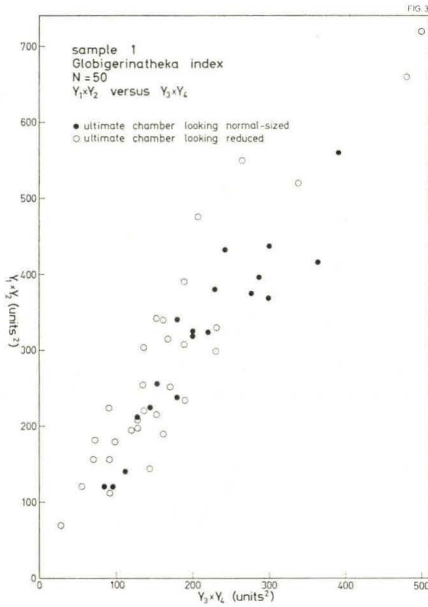
well as in the samples 6A and 6B (*Globigerina* ex gr. *bulloides*). On the other hand, in the samples 5 (*Globigerina* sp.) and 7 (*Globigerina patagonica*) the ultimate chamber is – with only a few exceptions – included in the ‘normal’ growth spiral. The following graphs (figs. 3–34) may serve to illustrate the variability observed in the 8 samples.

The first set of graphs (figs. 3–10) demonstrates the variation in the absolute size of the ultimate chamber. The graphs show the rectangle in which the ultimate chamber can be inscribed when the shell is oriented with the penultimate chamber turned ‘northwards’ ($y_1 \cdot y_2$) as a function of the rectangle in which the ultimate chamber can be inscribed with this chamber turned ‘northwards’ ($y_3 \cdot y_4$). The plots will approximately reflect to what extent the ultimate chamber is inflated. Because the dimension y_4 will often be small compared with the dimension y_2 in specimens with distinctly reduced and displaced ultimate chambers, the ratio $y_1 \cdot y_2 : y_3 \cdot y_4$ will normally give relatively high values in such specimens.

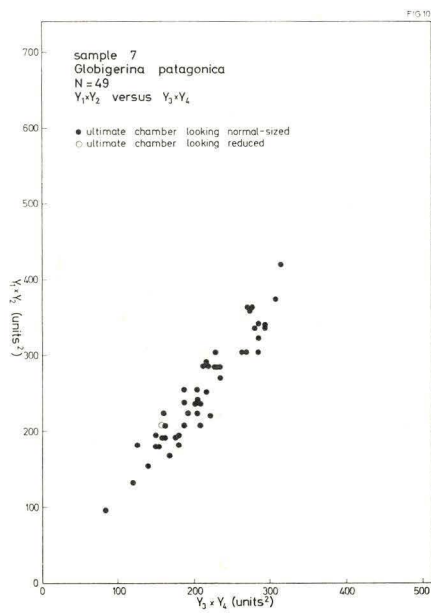
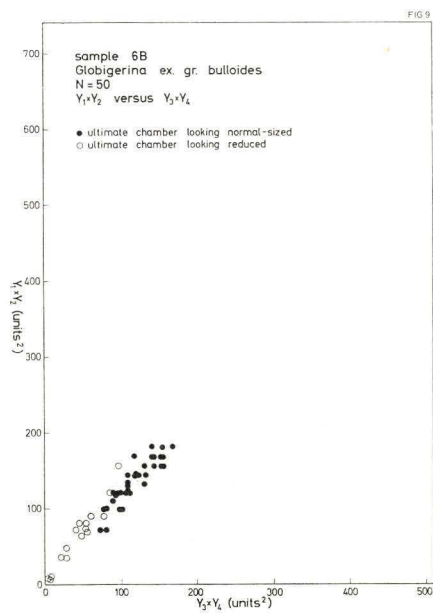
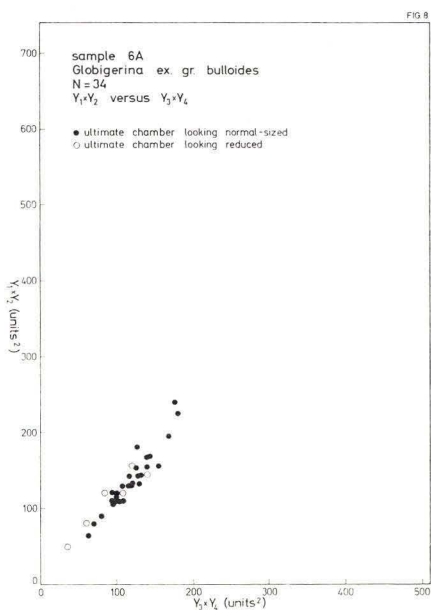
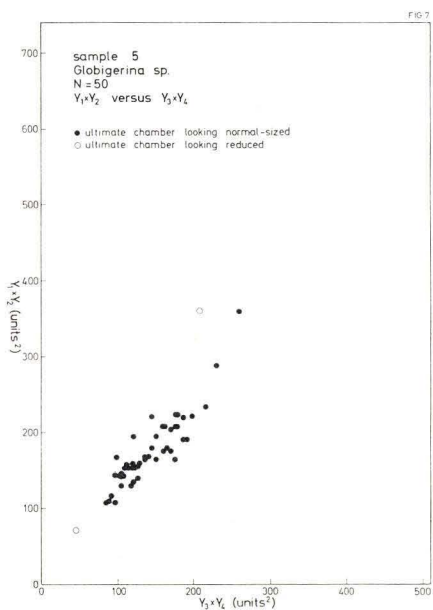
The relation between the dimension y_4 of the ultimate chamber and the preceding part of the shell is illustrated by the next set of graphs (figs. 11–18). The dimension y_4 as a function of D tends to have a linear distribution in samples 5 and 7, whereas the other samples are characterized by more scattered plots. In almost all the cases in which the ultimate chamber was judged to be excluded from the ‘normal’ growth spiral, the specimens have a low ratio $y_4 : D$, but there is a gradual transition between the specimens with respectively a normal-sized and a reduced ultimate chamber (cp. the statement by Quilty cited p. 118 on the ultimate chamber).

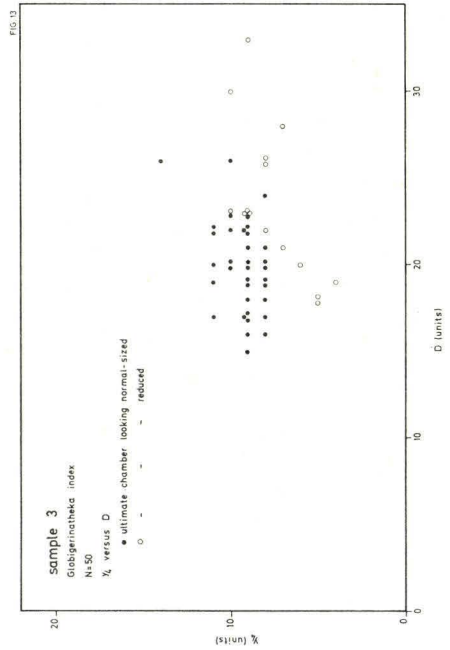
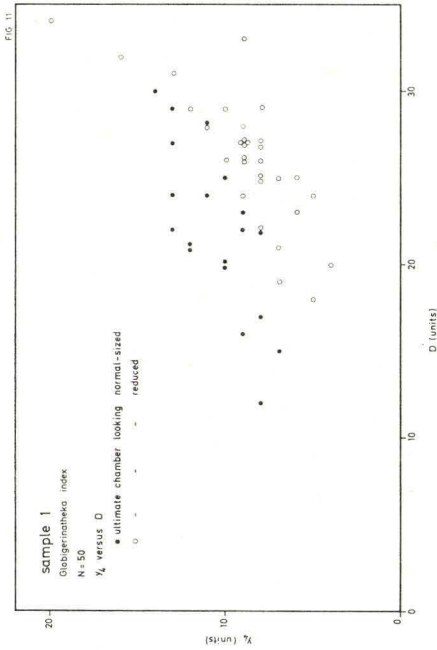
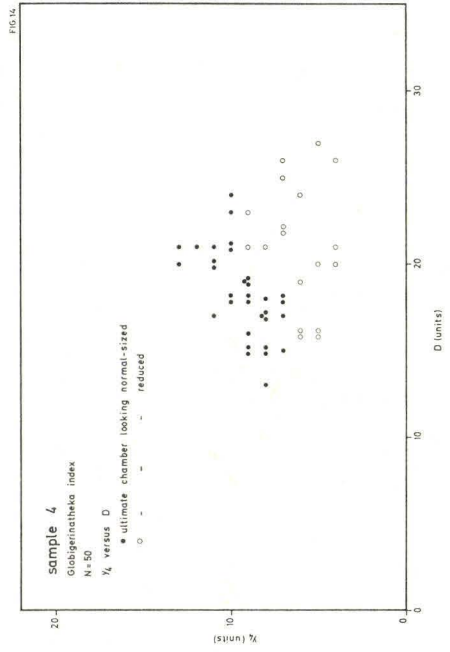
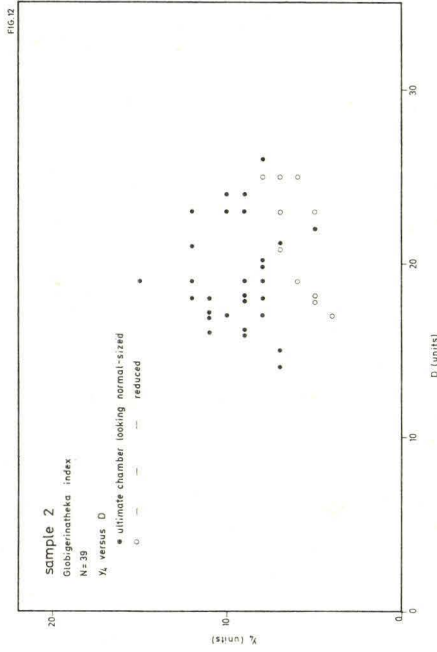
In their studies on the rate of chamber expansion mentioned p. 118 Scott (1966) and Lindenberg (1969) measured the chamber diameters from the dorsal side before calculating $\log p$. In the present study the diameter of the ultimate chamber was measured from the ventral side (y_3) and p' is defined as $\sqrt[2]{\frac{y_3}{x_3}}$. The graphs (figs. 19–26) illustrate the distribution of $\log p'$. When the sum functions are studied by means of probability paper the plots do not follow a straight line as expected if the distribution were normal. The skew distribution seems to be very pronounced in the samples 1, 2, 3, 4, 6A and 6B.

The specimens of *Globigerina* sp. and *G. patagonica* studied respectively in samples 5 and 7 are characterized by a relatively regular growth. This is well demonstrated by the graphs (figs. 27–34) of the observed diameter of the penultimate chamber ($O_{X_2} = x_2$) minus the expected diameter of the same chamber $E_{X_2} = p' \cdot x_3$). The mean figure for $O_{X_2} - E_{X_2}$ is close to zero in samples 5 and 7, whereas the means of the other six samples are definitely displaced to the positive side.



Figs. 3–10. The dimensions of the ultimate chamber. Ordinate ($y_1 \cdot y_2$, see fig. 2): with ultimate chamber 'northwards'. Absciss ($y_3 \cdot y_4$, see fig. 2): with penultimate chamber 'northwards'.





Figs. 11–18. The height (y_4 , see fig. 2) of the ultimate chamber versus the diameter (D, see fig. 2) of the preceding part of the shell.

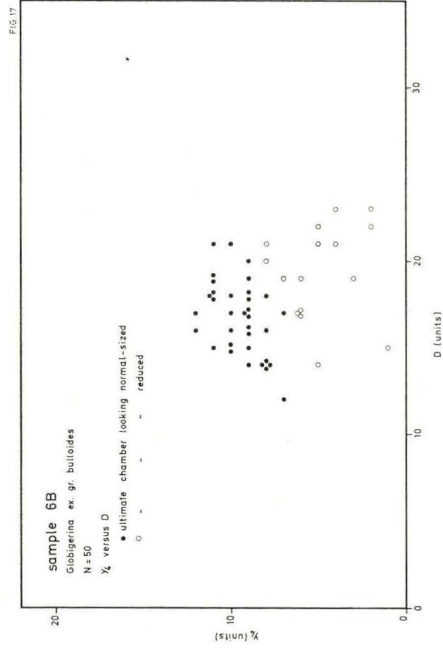
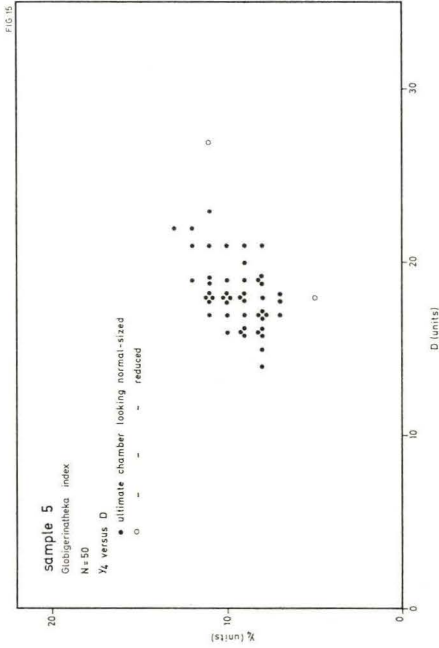
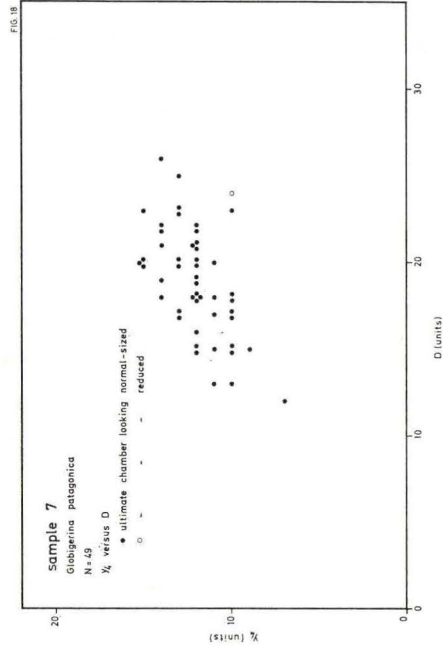
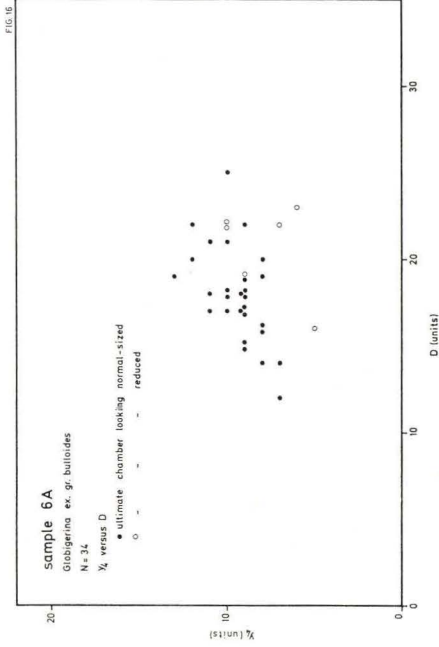


FIG. 20

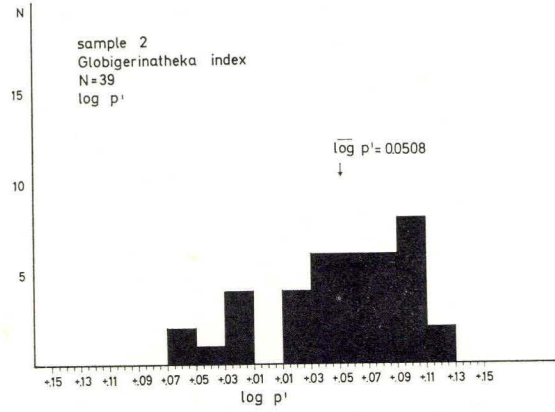


FIG. 22

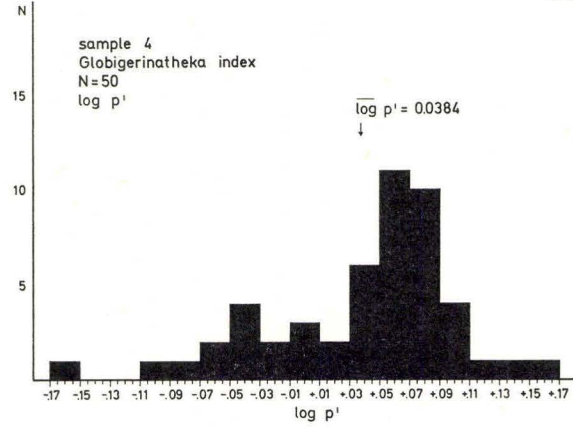


FIG. 19

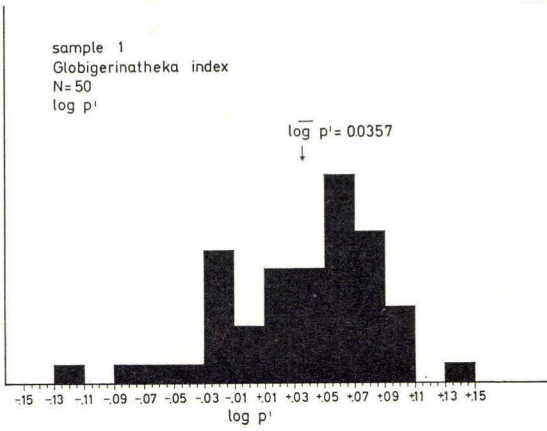
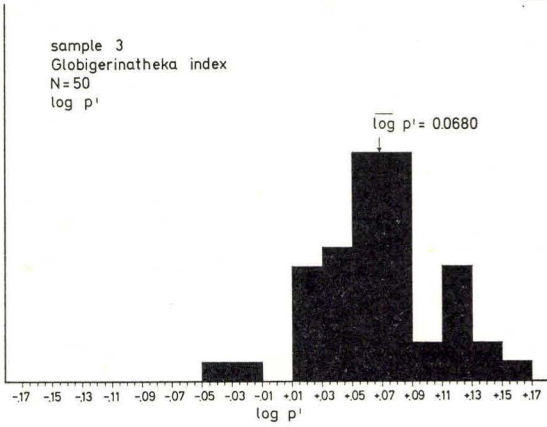


FIG. 21



Figs. 19-26. The distribution of the rate of chamber expansion as expressed by log p' values (see text p. 121 for explanation).

FIG. 24

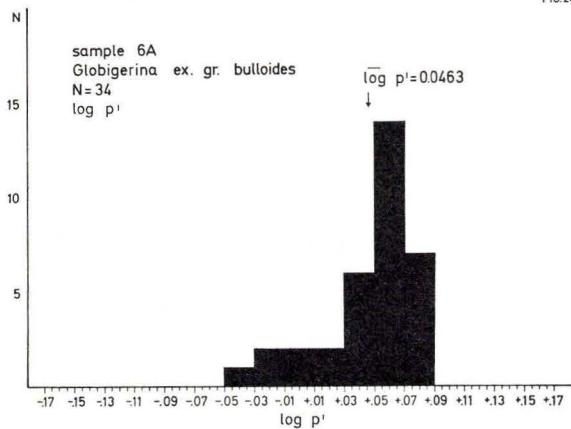


FIG. 26

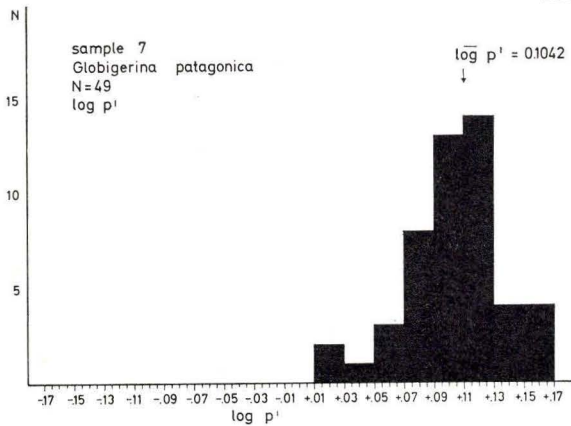


FIG. 23

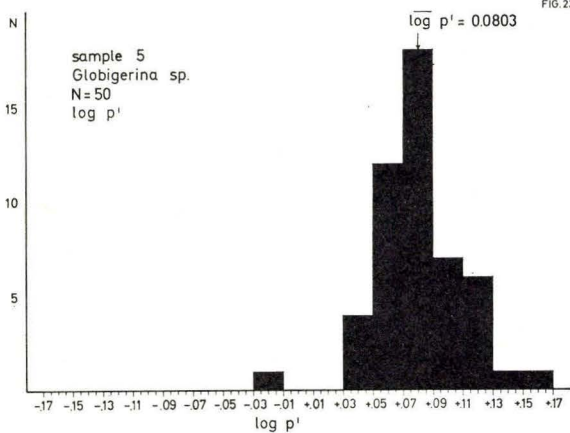
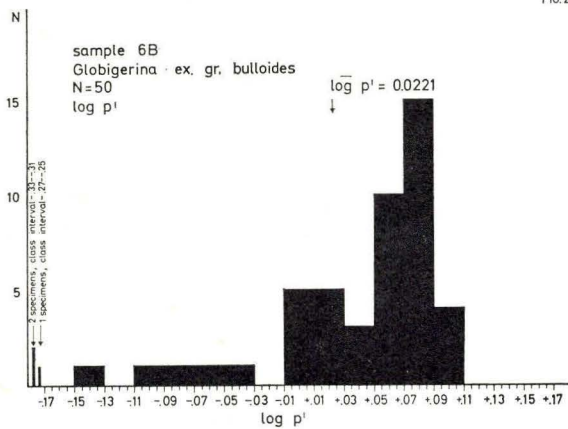
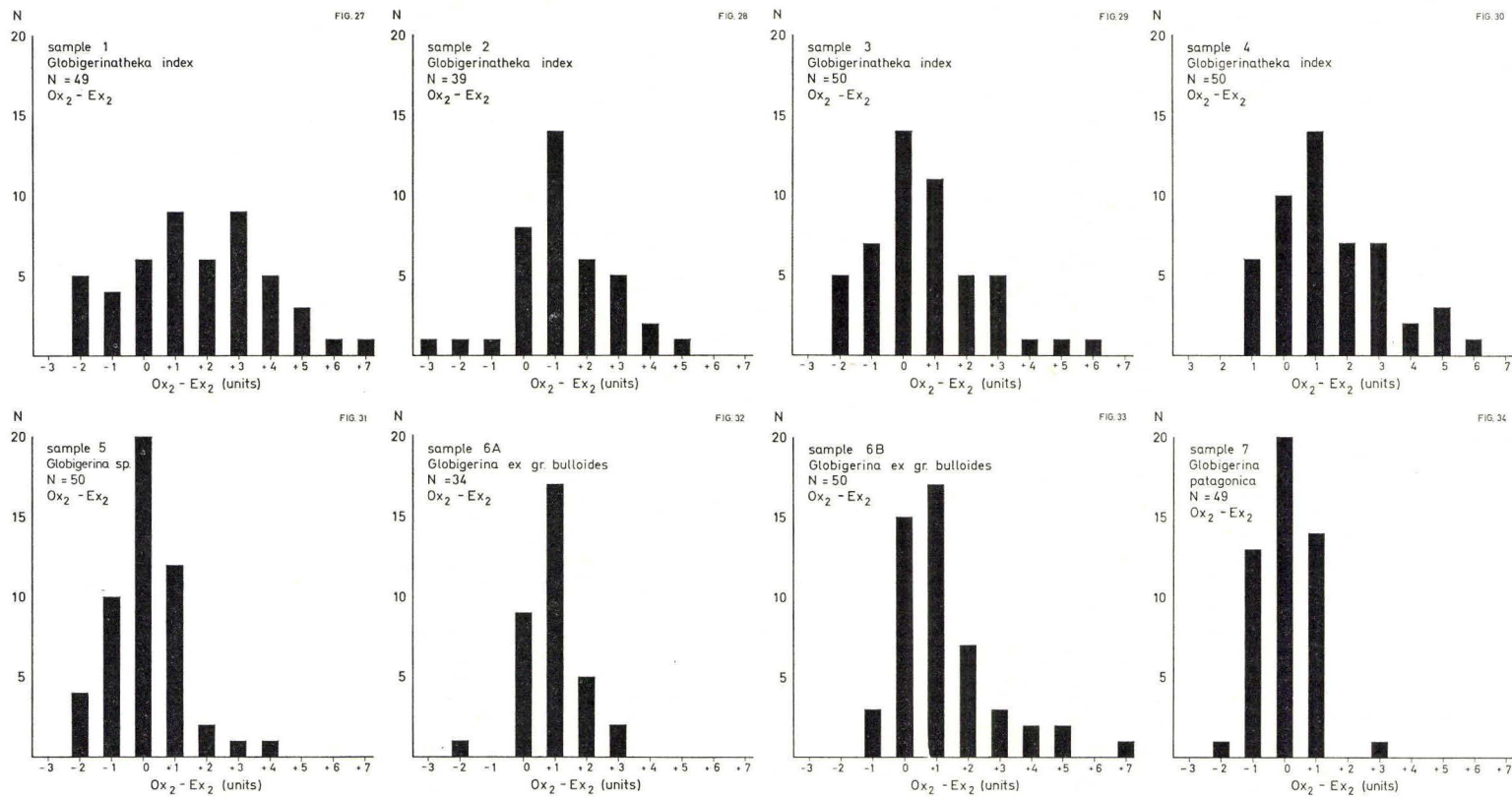


FIG. 25





Figs. 27–34. The distribution of the difference between the observed (Ox_2) and the calculated (Ex_2) diameter of the penultimate chamber (see text p. 121 for explanation).

The 'normal' growth spiral

Quilty (1969) studied the length (L) and the breadth (B) of the 'normal' growth spiral in *Globigerapsis index* according to the statistical method outlined by Imbrie (1956). The growth lines for L and B were constructed and tested as 'reduced major axis', the suitability of which is under current discussion. Christensen (1973) for instance preferred another type of regression line, whereas Hayami & Matsukuma (1970) recommended the reduced major axis as "more reasonable and advantageous in biometrical studies than the conventional regression analysis".

In the present context the same statistical procedure as applied by Quilty (1969) has been followed. However, Quilty defined L as the maximum distance from the distal extremity of the ultimate chamber in the normal growth spiral to the distal extremities of the antepenultimate and penultimate chambers in a line through the umbilicus, and B as the maximum diameter at right angles to L. It will be noted that the present definitions (see p. 120) have been slightly modified from the definitions used by Quilty.

The statistics given in table 2 stand for:

N	number of individuals in the sample	
OR _L	observed range of L	
OR _B	observed range of B	
\bar{L}	mean value of L	$\frac{\Sigma (L)}{N}$
\bar{B}	mean value of B	$\frac{\Sigma (B)}{N}$
S _L	standard deviation of L	$\sqrt{\frac{\Sigma (L - \bar{L})^2}{N - 1}}$
S _B	standard deviation of B	$\sqrt{\frac{\Sigma (B - \bar{B})^2}{N - 1}}$
a	growth ratio	$\frac{S_L}{S_B}$
b	initial growth index	$\bar{L} - \bar{B}a$
r	coefficient of correlation	$\frac{\Sigma (B - \bar{B})(L - \bar{L})}{\sqrt{\Sigma (B - \bar{B})^2 \Sigma (L - \bar{L})^2}}$
σ_a	standard error of a	$a \sqrt{\frac{1 - r^2}{N}}$

E	equation of growth line	$L = aB + b$
S _d	coefficient of absolute dispersion around reduced major axis	$\sqrt[2]{2(1-r)(S_B^2 + S_L^2)}$
D _d	coefficient of relative dispersion around reduced major axis	$\frac{100 S_d}{\sqrt[2]{B^2 + L^2}}$

The growth lines (figs. 35–43) are tested with respect to the slopes and the positions. The slope tests are based on the formula

$$z_1 = \frac{[a_1 - a_2]}{\sqrt[2]{\sigma_{a_1}^2 + \sigma_{a_2}^2}}$$

and the results are given in table 3. The position tests are based on the formula

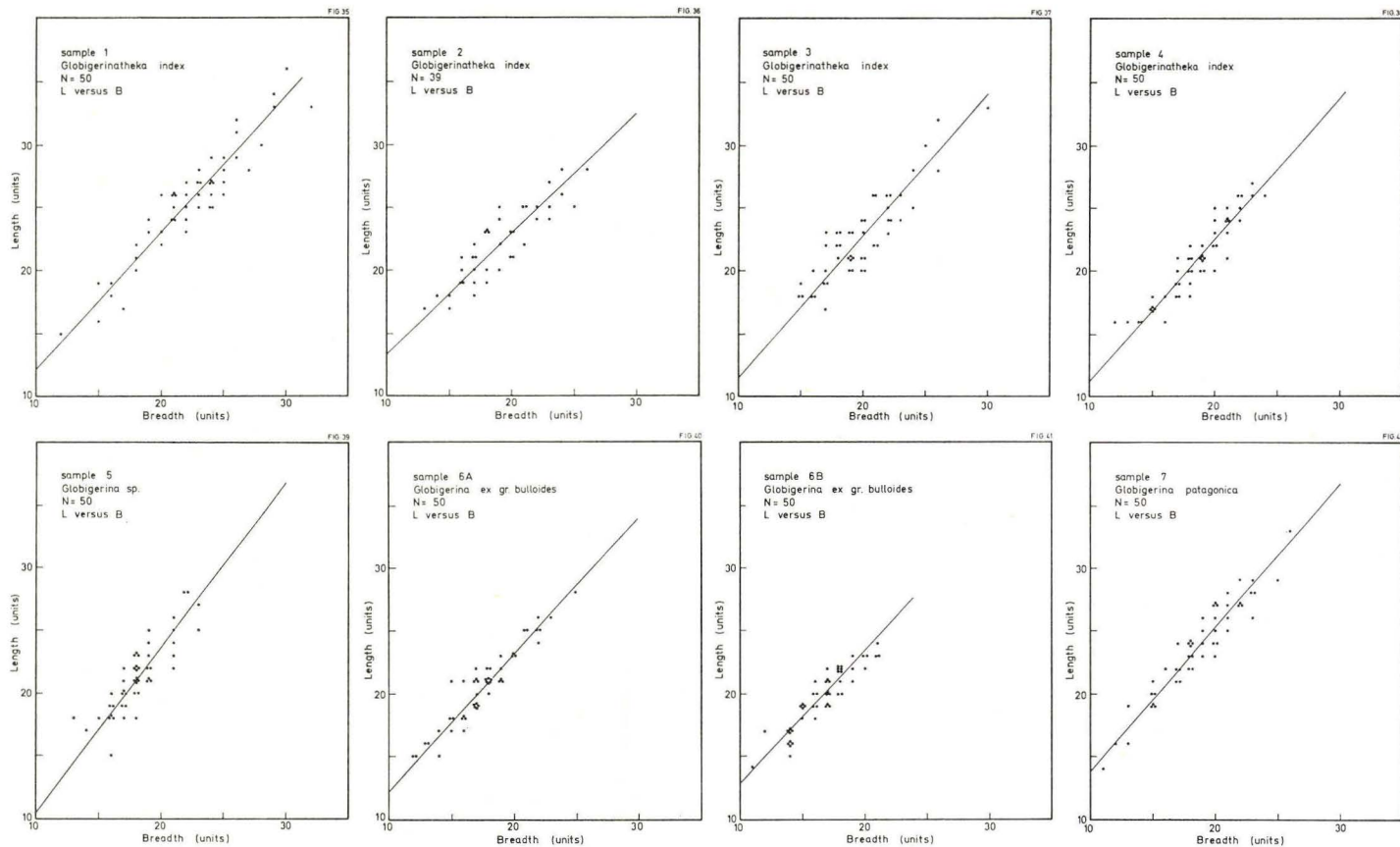
$$z_2 = \frac{B(a_1 - a_2) + (b_1 - b_2)}{\sigma_{a_1}^2(B - \bar{B}_1)^2 + \sigma_{a_2}^2(B - \bar{B}_2)^2}$$

and – calculating with such values of B that the vertical distance between the two growth lines concerned is at a maximum inside the observed range – the results are given in table 4.

In table 3 and 4 the values greater than 1.96 indicate that the observed differences in the slope and/or the position of two growth lines are significant, i.e. the probability that the difference arose purely by chance is less

Table 2.

sample statistics	1	2	3	4	5	6A	6B	7
N	50	39	50	50	50	50	50	50
OR _L	15-36u	17-28u	17-33u	16-27u	15-28u	15-28u	14-24u	14-33u
OR _B	12-32u	13-26u	15-30u	12-24u	13-23u	12-25u	11-21u	11-26u
\bar{L}	25.5u	22.1u	22.7u	20.9u	21.3u	20.6u	19.8u	23.8u
\bar{B}	22.3u	19.1u	19.9u	18.5u	18.2u	17.7u	16.6u	18.7u
S _L	4.5u	3.0u	3.5u	3.2u	2.8u	3.0u	2.4u	3.8u
S _B	4.1u	3.1u	3.1u	2.8u	2.1u	2.8u	2.3u	3.3u
a	1.096	0.951	1.123	1.123	1.313	1.083	1.056	1.150
b	+1.1u	+3.9u	+0.4u	+0.1u	-2.6u	+1.4u	+2.3u	+2.3u
r	0.940	0.882	0.890	0.932	0.846	0.944	0.914	0.948
o _a	0.053	0.072	0.064	0.057	0.099	0.051	0.061	0.052
E	L=1.096B+1.1	L=0.951B+3.9	L=1.123B+0.4	L=1.123B+0.1	L=1.313B-2.6	L=1.083B+1.4	L=1.056B+2.3	L=1.150+2.3
S _d	2.096	2.105	2.203	1.565	1.955	1.961	1.383	1.615
D _d	6.186	7.208	7.297	5.607	6.979	7.221	5.352	5.335



Figs. 35-42. Scattergrams and growth lines of length (L) versus breadth (B) of the 'normal' growth spiral.

Table 3.

Values of z_1 from significance tests on the slopes of the growth lines.

sample	1	2	3	4	5	6A	6B	7
1	-	1.62	0.32	0.34	1.93	0.17	0.50	0.72
2	1.62	-	1.79	1.87	<u>2.96</u>	1.49	1.11	<u>2.24</u>
3	0.32	1.79	-	0.00	1.61	0.49	0.76	0.33
4	0.34	1.87	0.00	-	1.66	0.52	0.80	0.35
5	1.93	<u>2.96</u>	1.61	1.66	-	<u>2.07</u>	<u>2.21</u>	1.46
6A	0.18	1.49	0.49	0.52	<u>2.07</u>	-	0.34	0.92
6B	0.50	1.11	0.76	0.80	<u>2.21</u>	0.39	-	1.17
7	0.72	<u>2.24</u>	0.33	0.35	1.46	0.92	1.17	-

than 5 %. If the z values are less than 1.96, the probability that the observed difference arose by chance is greater than 5 %.

The results of the significance tests are visualized in fig. 44. There are only a few cases in which the slopes display a significant difference, for instance when sample 5 is compared with samples 6A and 6B. The ratio L:B decreases during growth in all the samples, but it is likely that this ratio decreases more slowly in *Globigerina* sp. than in *Globigerina* ex gr. *bulloides*, because the line of sample 5 is significantly steeper than the lines of sample 6A and 6B. On the other hand, the difference between sample 5 and 7 is non-significant with respect to the slope.

If the initial growth index and the position of the lines are different there will be a difference in the rate of the decrease in the L:B ratio, although the

Table 4.

Values of z_2 from significance tests on the positions of the growth lines.

sample	1	2	3	4	5	6A	6B	7
1	-	1.73	0.51	1.02	<u>2.22</u>	0.70	1.10	<u>3.40</u>
2	1.73	-	1.63	<u>2.75</u>	<u>3.17</u>	1.56	1.49	<u>5.72</u>
3	0.51	1.63	-	0.33	<u>2.02</u>	0.89	1.75	<u>3.10</u>
4	1.02	<u>2.75</u>	0.33	-	<u>2.84</u>	1.74	<u>2.67</u>	<u>5.08</u>
5	<u>2.22</u>	<u>3.17</u>	<u>2.02</u>	<u>2.84</u>	-	<u>2.27</u>	<u>2.75</u>	<u>3.80</u>
6A	0.70	1.56	0.89	1.74	<u>2.27</u>	-	1.25	<u>4.65</u>
6B	1.10	1.49	1.75	<u>2.67</u>	<u>2.75</u>	1.25	-	<u>3.55</u>
7	<u>3.40</u>	<u>5.72</u>	<u>3.10</u>	<u>5.08</u>	<u>3.80</u>	<u>4.65</u>	<u>3.55</u>	-

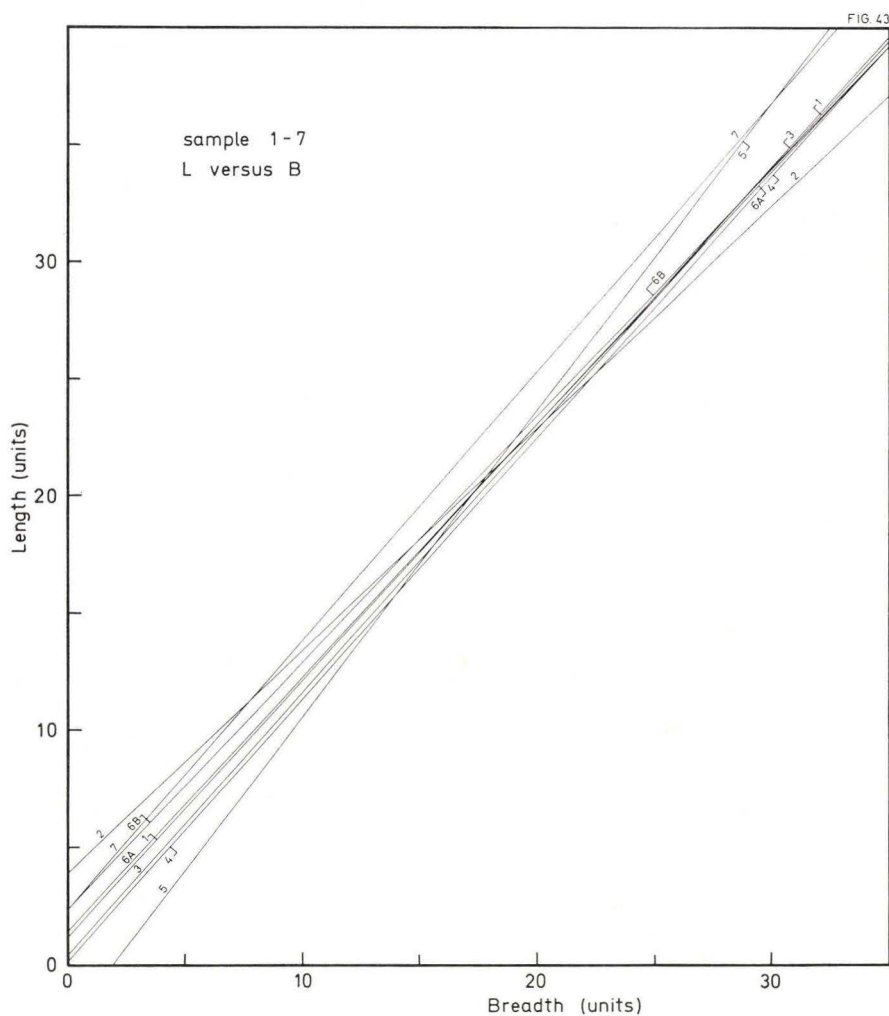


Fig. 43. The growth lines of L versus B in the samples 1-7.

observed difference in the slope is non-significant. By the z_2 -test it is found that the position of the line of sample 5 differs significantly from the line of sample 7. The line of sample 5 is situated below the line of sample 7, and it is likely that the L:B ratio decreases more rapidly with growth in *Globigerina* sp. than in *Globigerina patagonica*.

The analysis of L versus B supports the discrimination of *Globigerina* sp. and *G. patagonica* from each other and from *G. ex gr. bulloides* and *Globigerinatheka index*. These latter two units, represented by samples 6A-B and samples 1-4 respectively, are easily discriminated on the basis of

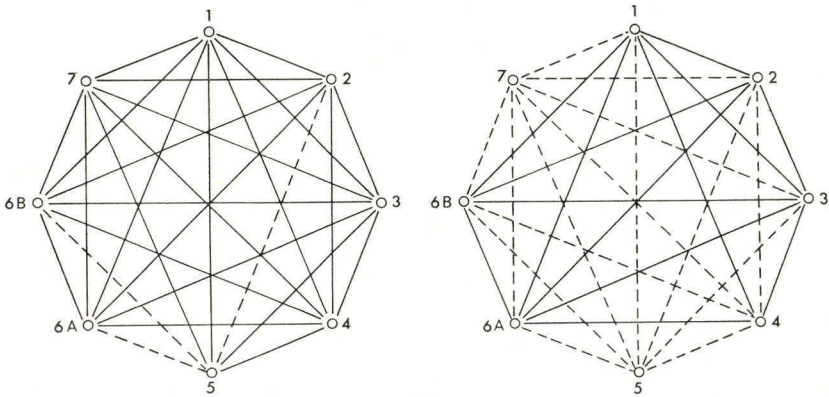


Fig. 44. Comparison of L versus B growth lines of the samples 1-7 with respect to the slopes of the lines (left) and the positions of the lines (right). A full line between two samples indicates values of z_1 and z_2 (see text p. 130) less than 1.96 (non-significant difference), whereas a dashed line indicates z_1 and z_2 values greater than 1.96 (significant difference).

other characters such as the height of the spire, the shape of the chambers, and the structure of the wall, but their growth lines for L versus B are very much alike according to the significance tests. However, sample 2 behaves otherwise than sample 1, 3, and 4 compared with samples 5 and 7 in the slope test, and sample 2 also displays a significant difference from sample 4 with respect to the position of the growth line. The meaning of this heterogeneity within the material referred to *Globigerinatheka index* is unknown.

Acknowledgements. The scanning electron micrographs plate 3, figs. 1-3, 7-8, plate 4, figs. 1, 4, 6-7, and plate 5, figs. 1, 3-9, were taken by Mrs. A. Nørgaard Jensen and Mr. J. Fuglsang at the Institute of Historical Geology and Paleontology, University of Copenhagen. The remaining part of the scanning work was done at the Geological Survey. Photographic development and printing was carried out by Mr. O. Neergaard Rasmussen and Mrs. I. Christiansen, whereas Mrs. H. Christensen and Miss K. Andersen (text-fig. 2) have done the drafting work. The English manuscript was linguistically corrected by Mr. C. M. Robson.

Dansk sammendrag

Indledning

I visse afsnit af Danmarks Eocæn optræder rige planktoniske foraminiferfaunaer (Bergren, 1961, 1969; Dinesen, 1972). Da de planktoniske foraminiferer udviser en betydelig fænotypisk variation, må biometriske metoder søges inddraget til hjælp for artsafgrænsningen. Når de statistiske »samples« udvælges som en præcis defineret »eksperi:

mentel klasse« (jvf. Scott 1966, 1967, 1970; Lindenberg 1969), opstår risiko for at det undersøgte materiale er »skævt«, enten ved kun at rumme en del af variationsformerne, eller ved at repræsentere bestemte variationsformer tilhørende forskellige arter. I det foreliggende arbejde er det statistiske materiale udvalgt fra formodede Mendel'ske populationer, selvom denne fremgangsmåde er klart subjektiv.

De statistiske prøvers oprindelse

Sample 1 (50 eksemplarer, i en del af undersøgelsen dog kun 49 eksemplarer), 2 (39 eks.), 3 (50 eks.) og 4 (50 eks.) repræsenterer materiale, der henføres til *Globigerinatheka index*, og som stammer henholdsvis fra en daglokalitet syd for Søvind og fra borerer ved Rødstenseje nær Odder, ved Viborg og ved Hesselho vest for Grindsted. Sample 5 (50 eks.) med *Globigerina sp.* er fra en daglokalitet vest for Søvind, medens 6A (50 eks., delvis 34 eks.) og 6B (50 eks.) – begge med *Globigerina ex gr. bulloides* – stammer fra en og samme prøve fra et dybere niveau på lokaliteten syd for Søvind. Sample 7 (50 eks., delvis kun 49 eks.) indeholder *Globigerina patagonica* og er fra en daglokalitet ved Ulstrup på Røsnæs.

Bjergartsprøverne svarende til sample 1 – 6B repræsenterer Søvind mergel og prøven svarende til sample 7 repræsenterer Røsnæs ler. Lokaliteternes beliggenhed fremgår af kortet, fig. 1.

Palæontologiske notater

Globigerinatheka index (Finlay) – tavle 3, figs. 1–8; tavle 4, figs. 1–7. Som påpeget af Quilty (1969) og Bolli (1972) foreligger forskellige vækststadier, der også kan skelnes i det danske materiale. I overensstemmelse med Proto Decima & Bolli (1970) betragtes *Globigeropsis* Bolli, Loeblich & Tappan 1957 som »junior synonym« for *Globigerinatheka* Brönnimann 1952. Der synes ikke at være grundlag for at udskille *G. tropicalis* Blow & Banner som en særlig art.

Globigerina sp. – tavle 5, figs. 1–3. Bolli har haft eksemplarer af denne art til undersøgelse og har peget på lighedspunkter med *Globigerina praebulloides* og *G. ouachitaensis ouachitaensis*, men efter min opfattelse har den foreliggende art en vægstruktur, som er forskellig fra de to nævnte arter. Det er derfor foretrukket foreløbig at lade nomenklatur-spørgsmålet stå åbent.

Globigerina ex gr. bulloides – tavle 6, figs. 1–5; tavle 7, figs. 1–5. Det har ikke været muligt at angive et opdelingsgrundlag for materialet, som er henført til denne gruppe. Der er en betydelig variation med hensyn til vægstruktur, men variationen gør sig i nogen grad gældende også inden for et og samme individ.

Globigerina patagonica Todd & Kniker – tavle 5, figs. 4–9. Der henvises til indgående behandlinger af denne art hos Berggren (1960) og hos Berggren & Kurtén (1961), hvor arten henførtes til *G. yeguaensis* Weinzerl & Applin. Berggren (1969) har imidlertid senere ændret artsbetegnelsen.

Biometri

Den individualiserede vækst, som ofte mødes hos planktoniske slægter som *Globigerina* og *Globigerinatheka*, nødvendiggør anvendelsen af biometriske metoder, men samtidig

kompliseres anvendelsen af sådanne metoder netop på grund af vækstformen. I løbet af væksten finder ændringer sted, dels i kamrenes tilvækstrate, dels i et nyt kammers placering i forhold til den ældre del af skallen. Disse ændringer medfører, at karakteristikker, der kan fremskaffes ved en simplere måleprocedure, kun giver tilnærmede udtryk for vækstformen. Desuden er det vanskeligt at fastlægge en akse eller et plan i det enkelte individ, som kan danne et ensartet orienteringsgrundlag for målingerne.

I det foreliggende arbejde er hovedvægten lagt på målinger af skallens længde og bredde, men da skallerne repræsenterer vidt forskellige vækststadier, er det klart at målingerne kun har begrænset værdi som udtryk for vækstformen. I mange eksemplarer falder det afsluttende kammer tydeligt uden for den »normale« vækstspiral. Sådanne »reducerede« kamre er ladet ude af betragtning, og længde og bredde er målt på den »normale« vækstspiral, hvorved sammenlignelighedsgraden forbedres. Da det afsluttende kammer varierer stærkt med hensyn til størrelse og placering i forhold til den ældre del af skallen, vil det i mange tilfælde dog stadig bero på et skøn, om dette kammer regnes med til den »normale« vækstspiral eller ej.

Der er i undersøgelsen benyttet karakteristikker som vist på fig. 2a–h. Det afsluttende kammer og dets relation til den ældre del af skallen er søgt belyst ved forskellige metoder. Figs. 3–10 viser kammerets absolutte størrelsesvariation, idet dimensionerne er målt i to stillinger. Forholdet $y_1 \cdot y_2 : y_3 \cdot y_4$ vil normalt være ret højt i eksemplarer, hvor det afsluttende kammer er af reduceret størrelse. Den relative størrelsesvariation fremgår af figs. 11–18.

Det afsluttende kamms variation kommer indirekte til udtryk på figs. 19–34, hvor log p' angiver et størrelsesforhold mellem kamrene, idet $p' = \sqrt{\frac{y_3}{x_3}}$ (og således er

modificeret fra p -værdien anvendt af Scott (1966) og Lindenberg (1969)), og hvor $O_{x_2} - E_{x_2}$ viser forskellen mellem den målte diameter på det næstsidste kammer og den ved hjælp af p' beregnede diameter for det samme kammer ($E_{x_2} = p' \cdot x_3$). Afbildningerne viser tydeligt, at det afsluttende kammer som oftest er et led i den »normale« vækstspiral hos *Globigerina* sp. (sample 5) og *Globigerina patagonica* (sample 7). Derimod er *Globigerinatheka index* (sample 1, 2, 3 og 4) og *Globigerina* ex gr. *bulloides* (sample 6A og 6B) præget af uregelmæssighed i slutstadiet.

Med forbillende i et arbejde af Quilty (1969), som igen er baseret på den af Imbrie (1956) opstillede statistiske metodik, er »vækstlinierne« (reduced major axis) for længde (L) versus bredde (B) optegnet og sammenlignet indbyrdes (se tabellerne 2–4 samt figs. 35–44). Det fremgår af tabel 3–4 og fig. 44, at vækstlinierne hos *Globigerina* sp. (sample 5) og *G. patagonica* (sample 7) er signifikant ($p = 0.05$) forskellige indbyrdes og fra de øvrige vækstlinier. *Globigerina* ex gr. *bulloides* (samples 6A og 6B) og *Globigerinatheka index* (sample 1, 2, 3 og 4), som let kan skelnes fra hinanden på basis af andre karakterer, synes derimod ikke at være signifikant forskellige med hensyn til længde versus bredde.

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Figs. 1–8. *Globigerinatheka index* (Finlay) p. 108
Søvind Marl. Outcrop about 0.3 km southwest of the church of Søvind.
All specimens derived from the same rock sample as the statistical
sample 1.
× 100

Fig. 1: Ventral view of morphotype C, with moderately developed calcite crust. AD–I–17.

Fig. 2: Ventral view of morphotype C, with calcite crust lacking in the upper part of the ultimate chamber. AD–I–4.

Fig. 3: Peripheral view of morphotype C, with strongly developed calcite crust. AD–I–16.

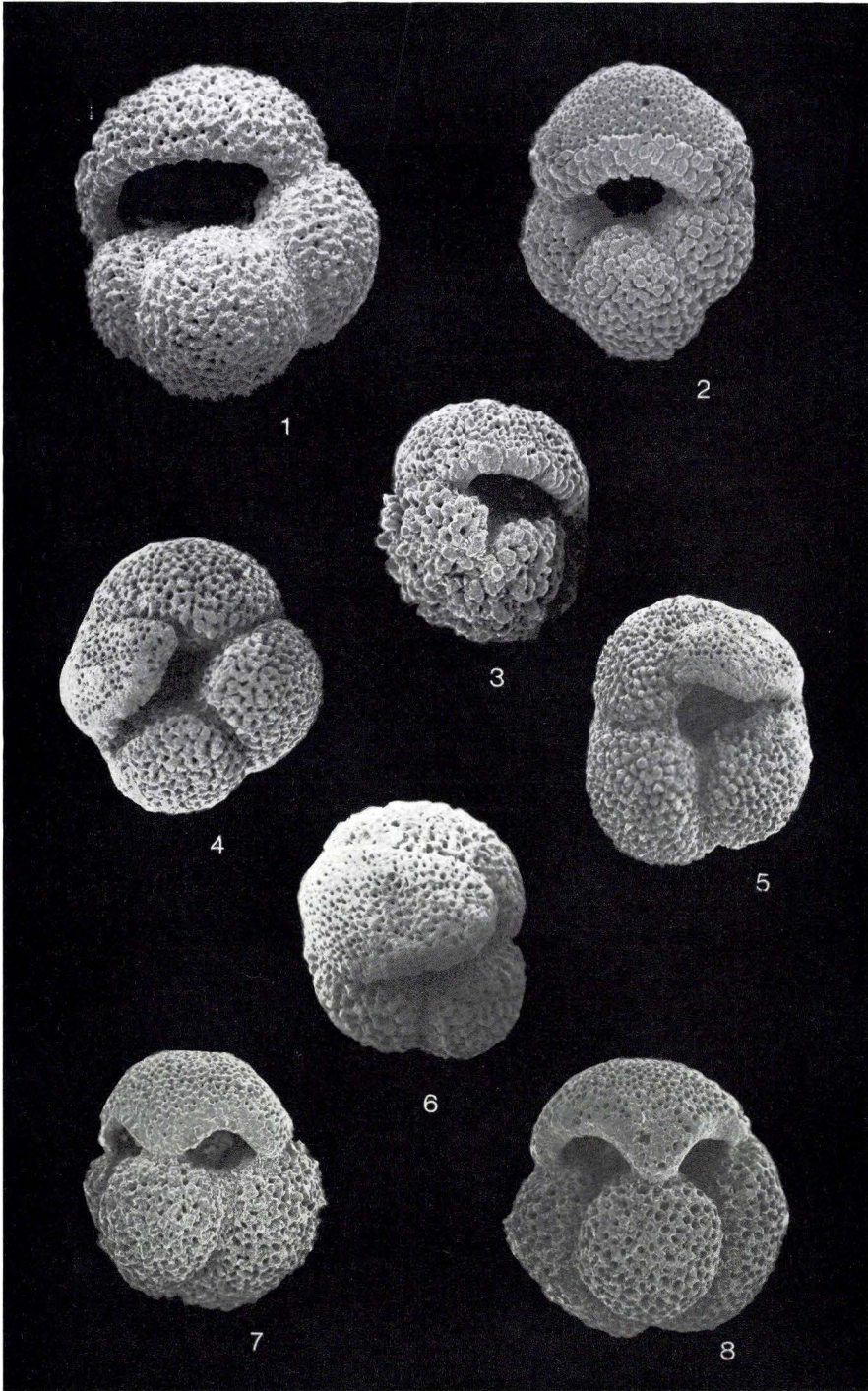
Fig. 4: Ventral view of morphotype D. AD–XXXV–8.

Fig. 5: Ventral view of morphotype D. AD–XXXV–5.

Fig. 6: Ventral view of morphotype D. AD–XXXV–2.

Fig. 7: Morphotype F, with slightly 'reduced' ultimate chamber. AD–I–13.

Fig. 8: Morphotype F, with slightly 'reduced' ultimate chamber and undeveloped (or dissolved ?) calcite crust. AD–I–5.



Figs. 1–5. *Globigerinatheka index* (Finlay) p. 108
Søvind Marl. Outcrop about 0.3 km southwest of the church of Søvind.
All specimens derived from the same rock sample as the statistical
sample 1.
× 100

Fig. 1: Morphotype E, with moderately developed calcite crust and
'incised' sutures. AD–I–19.

Fig. 2: Morphotype F, with strongly 'reduced' ultimate chamber. AD–
XXXV–10.

Fig. 3: Morphotype F, with strongly 'reduced' ultimate chamber and well-
developed calcite crust. AD–XXXV–9.

Fig. 4: Morphotype G, with a single 'reduced' (or 'bulla-like') chamber
added. AD–I–6

Fig. 5: Morphotype G, with 'reduced' ('bulla-like') chambers added to
both of the two apertures. AD–XXXV–4.

Figs. 6–7. *Globigerinatheka index* (Finlay) p. 108
Oamaru Diatomite. Jackson's Paddock, Oamaru, New Zealand. Horni-
brook sample S 136/887.
× 100

Fig. 6: Specimen similar to morphotype E, with undeveloped (or dissolved
?) calcite crust (and with foreign material filling one of the apertures).
AD–II–10.

Fig. 7: Ventral view of specimen similar to morphotype A, with undevel-
oped calcite crust. AD–II–11.



- Figs. 1–3. *Globigerina* sp. p. 114
Søvind Marl. Outcrop at Toftum, about 1.5 km westnorthwest of the church of Søvind. Specimens derived from the same sample as the statistical sample 5.
× 100

Fig. 1: Ventral view. AD–VII–2.

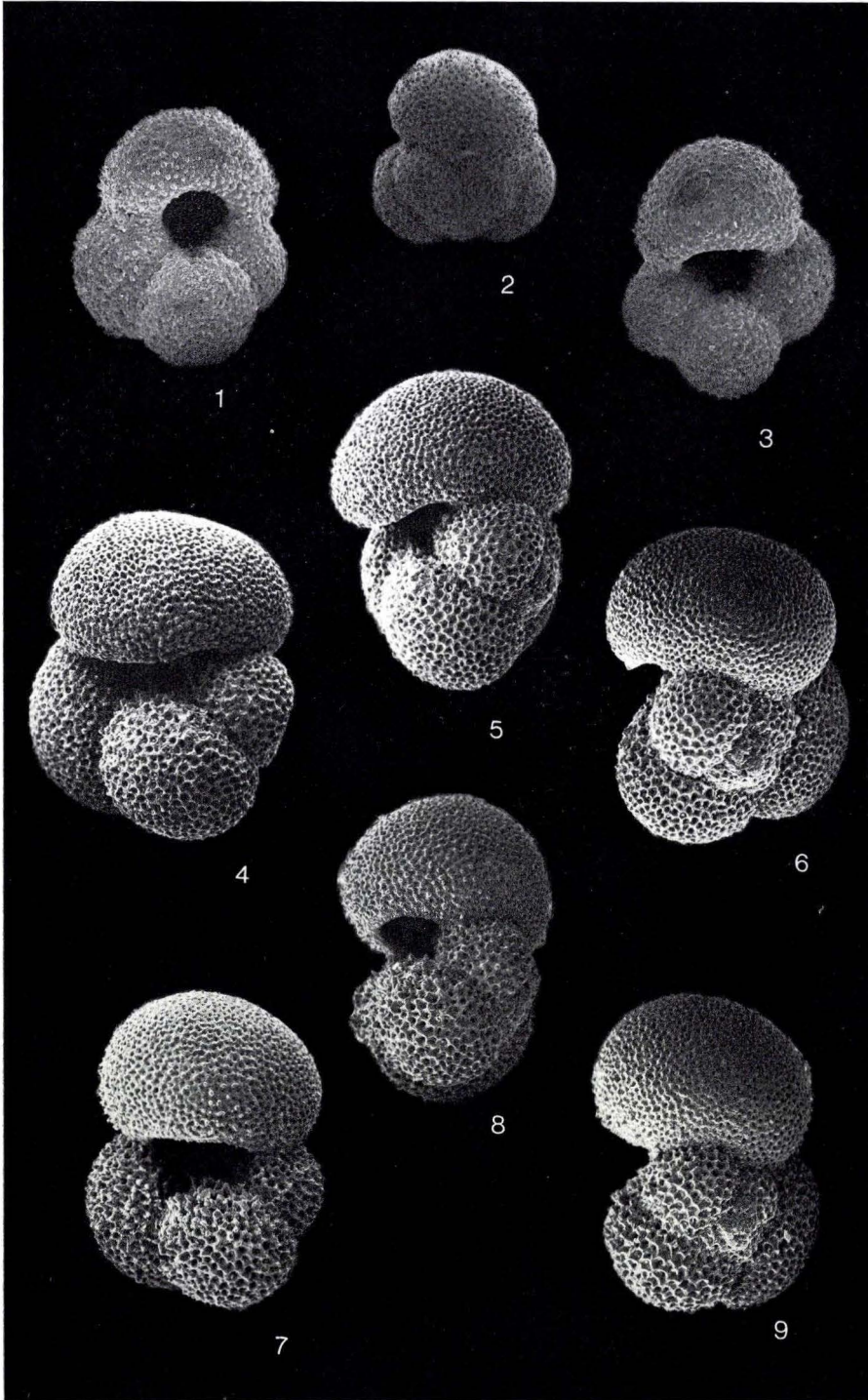
Fig. 2: Dorsal view of another specimen. AD–XXXIII–21.

Fig. 3: Ventral view of a third specimen. AD–VII–1.

- Figs. 4–9. *Globigerina patagonica* Todd & Kniker p. 116
Røsnæs Clay. Outcrop about 0.8 km westsouthwest of the church of Ulstrup. Specimens derived from the same rock sample as the statistical sample 7.
× 100

Figs. 4–6: Ventral, peripheral and (periphero-) dorsal views of a single specimen. AD–XIII–3.

Figs. 7–9: Ventral, peripheral and (periphero-) dorsal views of another specimen. AD–XIII–5.



Figs. 1–5. *Globigerina* ex gr. *bulloides* d'Orbigny p. 115
Søvind Marl. Outcrop about 0.3 km southwest of the church of Søvind.
All specimens derived from the same rock sample as the statistical
samples 6A and 6B
× 150

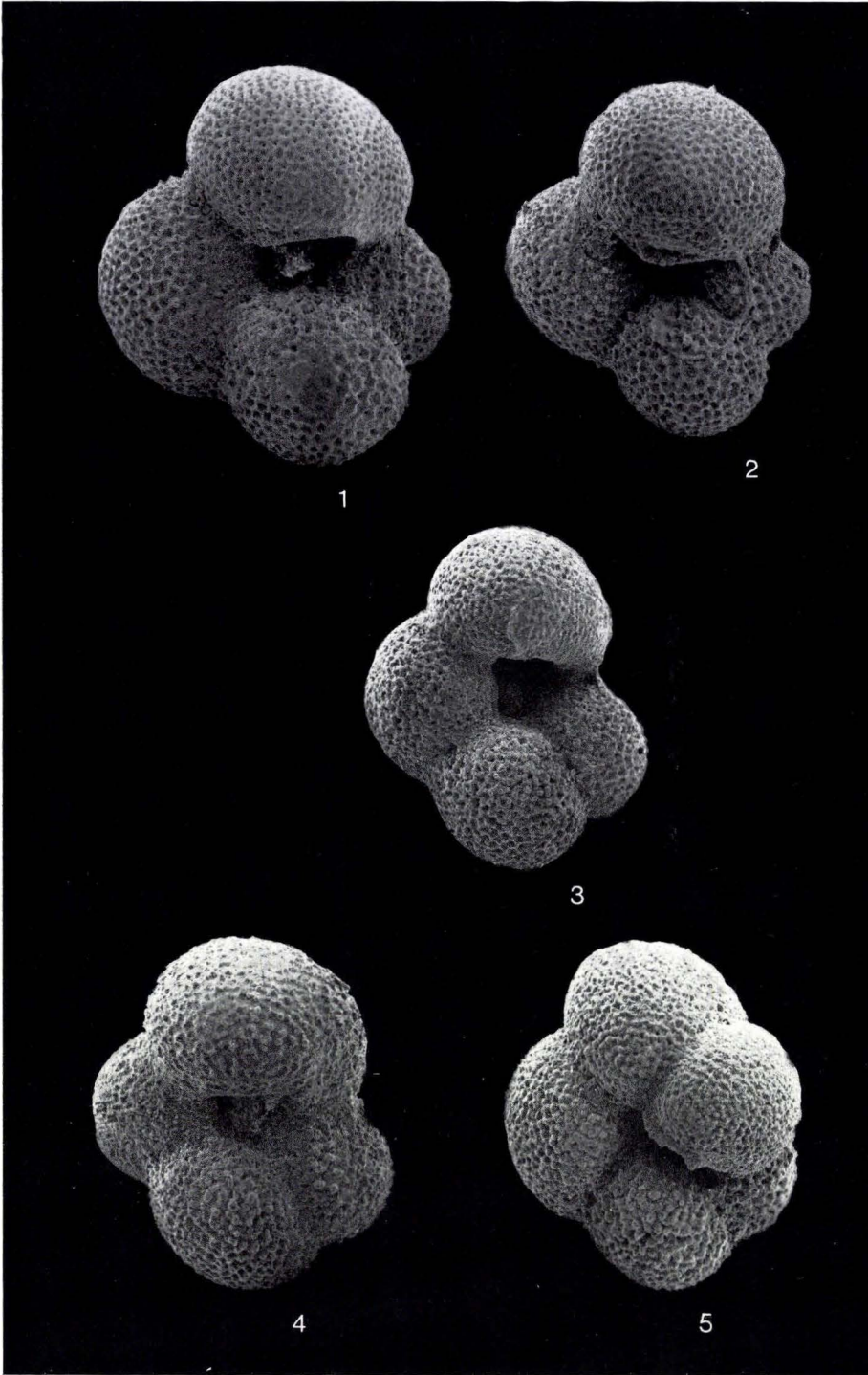
Fig. 1: Ventral view of a specimen with slightly 'reduced' ultimate chamber, rim-bordered aperture, and inter-pore ridges. (Features in common with *G. praebulloides leroyi* Blow & Banner, and with *G. officinalis* Subbotina). AD-XXXIV-5.

Fig. 2: Ventral view of a specimen with slightly 'reduced' penultimate chamber, remnants of a strongly 'reduced' ('bulla-like') ultimate chamber, and with lip-bordered aperture. AD-XXXIV-3.

Fig. 3: Ventral view of a specimen with slightly reduced ultimate (possibly penultimate) chamber, widely open umbilicus, and wall surface partly covered by a calcite crust. (Some of the features in common with *G. ouachitaensis* Howe & Wallace). AD-XXXIV-10.

Fig. 4: Ventral view of a specimen with 'normal' ultimate chamber, and with some variation in the character of the wall surface. AD-XXXIV-7.

Fig. 5: Ventral view of a specimen with strongly 'reduced' ultimate chamber, lip-bordered aperture, and wall surface covered by a calcite crust. AD-XXXIV-11.



Figs. 1–5. *Globigerina* ex gr. *bulloides* d'Orbigny p. 115
Søvind Marl. Outcrop about 0.3 km southwest of the church of Søvind.
All specimens derived from the same rock sample as the statistic samples
6A and 6B.
× 150

Fig. 1: Ventral view of a specimen with 'normal' ultimate chamber, lip-bordered aperture, and interpore ridges. (Features in common with *Globigerina praebulloides leroyi* Blow & Banner). AD-XXXIV-2.

Fig. 2: Ventral view of a specimen with 'normal' penultimate chamber, remnants of strongly 'reduced' ('bulla-like') ultimate chamber, lip-bordered aperture, and inter-pore ridges. AD-XXXIV-1.

Fig. 3: Ventral view of a specimen with 'reduced' ultimate chamber, lip-bordered aperture, and wall surface partly covered by a calcite crust. AD-XXXIV-12.

Fig. 4: Ventral view of a specimen with 'normal' ultimate chamber, lip-bordered aperture, and with some variation in the character of the wall surface. AD-XXXIV-8.

Fig. 5: Ventral view of a specimen with strongly 'reduced' ultimate chamber, and wall surface covered by a calcite crust. AD-XXXIV-15.

