BIOMETRIC STUDIES ON THE STRATIGRAPHIC EVOLUTION OF *GLOBOCONUSA DAUBJERGENSIS* (BRÖNNIMANN) FROM THE DANIAN OF DENMARK

HANS JØRGEN HANSEN

HANSEN, H. J.: Biometric studies on the stratigraphic evolution of *Globoconusa daubjergensis* (Brönnimann) from the Danian of Denmark. *Bull. geol. Soc. Denmark,* vol. 19, pp. 341–360. Copenhagen, February, ~~1969.~~ 1970.

The genus *Globoconusa* Khalilov, 1956 is discussed. It is concluded that *Globoconusa* is readily distinguished from the genera *Globigerina, Globigerinoides* and *Catapsydrax* by its wall surface structure.

Biometric and statistical studies of the following characters of *Globoconusa daubjergensis* from Danish Danian deposits are made: proloculus diameter, diameter of the final whorl, number of chambers and coiling directions. There is a tendency for more chambers to be developed at successively higher horizons in the Danian. Comparison is made with a population of *Globoconusa kozlowskii* from the Pamietowo boring in Poland.

Hofker's biometric studies of Globoconusa daubjergensis are discussed.

It is concluded that *Globoconusa kozlowskii* cannot be separated from *Globoconusa daubjergensis.*

The scope of this paper is to throw light on the taxonomic position and evolution of *Globoconusa daubjergensis* in its type region and to demonstrate the relationship between *Globoconusa daubjergensis* and *Globoconusa kozlowskii.*

Globoconusa daubjergensis has attracted great interest since the species is used as guide fossil for Danian deposits over most of the world. In recent years, however, some doubt has been expressed on both the generic classification of the species and its distinction from *Globoconusa kozlowskii.*

The genus *Globoconusa* Khalilov, 1956

Since Brönnimann gescribed the foraminiferal species *Globigerina daubjergensis* in 1953, conflicting points of view as to the generic position and delimitation of the species have been published. Brönnimann placed the species in the genus *Globigerina* d'Orbigny, 1826.

In 1956 Khalilov established a new genus, *Globoconusa,* with *Globoconusa conusa* Khalilov, 1956, as type species. This species was later shown to be identical with *Globigerina daubjergensis* Brönnimann, 1953, by *e.g.* El-Naggar (1966).

Khalilov distinguished the genus by its high spiral side. However, the generic value of this character was rejected by El-Naggar (1966) since it shows considerable variation within the type species of the genus.

Troelsen (1957) described small supplementary apertures along the spiral suture in specimens of *Globoconusa daubjergensis* from the Danian of Denmark. It was presumably this which led Loeblich & Tappan (1957), Olsson (1960), Hillebrandt (1962) and Nogan (1964) to place the species in the genus *Globigerinoides* Cushman, 1927.

Troelsen (1957), Bolli (1957), Hofker (1959, 1960a, b, c, d, 1962, 1966), Bolli & Cita (1960a, b), Berggren (1962) and El-Naggar (1966) followed Brönnimann in placing the species in the genus *Globigerina*, while Bang (1969) placed it in *Globoconusa.*

Hofker (1960a, b, c, d, 1962, 1966) and Berggren (1962) described the evolution of *Globoconusa daubjergensis.* These authors ascribed the supplementary apertures to the evolutionary development of the species which they maintained in the genus *Globigerina.*

The results of Hofker's and Berggren's studies of the evolution were summarised by Berggren (1962) as: "a) general increase in size of test; b) development in younger forms of supplementary apertures on spiral side; c) high degree of infraspecific variability; d) development in advanced forms of bulla-like last chamber ("Catapsydrax stage"); e) constancy in size of pores during evolutionary development."

In 1964 Loeblich & Tappan emended the diagnosis of *Globoconusa* Khalilov, 1956, stating that the genus is distinguished by its characteristically spinose wall.

If the genus *Globoconusa* sensu Loeblich & Tappan is not recognised, it follows that *Globoconusa daubjergensis* must be referred to three different genera during its evolution through the Danian of Denmark. In the Lower Danian the species is not very high spired (pl. 1, figs 1–2) and should be referred to the genus *Globigerina* d'Orbigny, 1826. Already in the Lower Danian biozone of *Tylocidaris abildgaardi* specimens of *Globoconusa daubjergensis* are found with supplementary apertures along the spiral suture (pl. 2, figs 1–2) which should be referred at this stage of evolution to the genus *Globigerinoides* Cushman, 1927. In the stratigraphically younger evolutionary stage in the Upper Danian some specimens develop an umbilical bulla-like chamber (pl. 3, figs 1–2) and must accordingly be recognised as belonging to the genus *Catapsydrax* Bolli, Loeblich & Tappan, 1957.

Therefore, in the case *Globoconusa,* the sutural apertures and bulla-like umbilical chamber cannot be recognised as being of value for generic classification. However, the characteristically spinose wall (pl. 4, figs 1–2) clearly distinguishes the genus *Globoconusa* from the genera *Globigerina* (pl. 5, fig. 1) and *Globigerinoides* (pl. 5, fig. 2) as pointed out by Loeblich & Tappan (1964).

The supplementary apertures in *Globigerinoides* are of a different nature from those found in *Globoconusa daubjergensis.* The supplementary apertures in *Globigerinoides* are, in comparison with those in *Globoconusa*, large and exclusively situated at the spiral suture where two chambers of the same whorl meet, while those in *Globoconusa* (pl. 6, fig. 2) are irregularly placed along the spiral suture and not confined to the junction between two chambers and the corresponding spiral suture.

The wall of *Globoconusa daubjergensis* (pl. 4, figs 1–2) is primarily smooth with scattered pores. Between the pores are scattered blunt spines each of which is only slightly higher than the width of its base. This structure must be seen in contrast to that of the wall in *Globigerina* and *Globigerinoides*, which in both cases has a reticulate surface (pl. 5, figs 1–2) and delicate spines.

The spines of *Globigerina bulloides* d'Orbigny, 1826, were illustrated by Bartlett (1968) and the spine bases of *Globigerinoides* are shown here on pl. 5, fig. 2. The wall of *Catapsydrax* was described by Bolli, Loeblich & Tappan (1957) as smooth or pitted and would therefore seem to be distinguishable by the same character.

Globigerina kozlowskii Brotzen & Pozaryska has the same wall structure as *Globoconusa daubjergensis* (pl. 6, figs 1–2) and is therefore referred here to the same genus.

Globoconusa daubjergensis (Brönnimann, 1953)

1953 *Globigerina daubjergensis* Brönnimann: p. 340, textfig. 1.
1956 *Globoconusa conusa* Khalilov: p. 249, pl. 5, figs 2a-c.
1956 *Globigerina linaperta* Finlay; Hofker (pars): p. 53, textfig. 15, non fig. 11.
1956 *Globigerina daubjergensis* Brönnimann; Hofker: p. 53, textfig. 19–20.
1957 *Globigerina daubjergensis* Brönnimann; Bolli: p. 70, pl. 16, figs 13–15.
1957 *Globigerina daubjergensis* Brönnimann; Troelsen: p. 128, pl. 30, figs 1a-2c.
1957 *Globigerinoides daubjergensis* (Brönnimann); Loeblich & Tappan: p. 184, pl. 40, figs 1a-c; 8a-c; pl. 41, figs 9a-c; pl. 42, figs 6a-7c; pl. 43, figs 1a-c; pl. 44, figs 7–8c.
1959 *Globigerina daubjergensis* Brönnimann; Hofker: p. 22, fig. 5.
1960 *Globigerinoides daubjergensis* (Brönnimann); Olsson: p. 43, figs 4–6.
1960a *Globigerina daubjergensis* Brönnimann *primitiva* Hofker (pars): p. 226, ? textfig. 25, p. 228, fig. 34.
1960a *Globigerina cf. daubjergensis* Brönnimann; Hofker: p. 228, fig. 36.
1960b *Globigerina daubjergensis* Brönnimann; Hofker: p. 38, fig. B.
1960b *Globigerina daubjergensis* Brönnimann; Hofker: development series (pars) p. 40, pl. 3, all forms except specimens from White Chalk from Denmark. Not specimen from Mc.Not specimens from Cr4.
1960c *Globigerina daubjergensis* Brönnimann; Hofker: p. 74, textfig. 29a–34b, tav. 4.
1960d *Globigerina daubjergensis* Brönnimann; Hofker: p. 119, pl. 1, figs 1–8.
1960a *Globigerina daubjergensis* Brönnimann; Bolli & Cita: p. 370, pl. 34, figs 1a-c.
1961 »*Globigerina*« *kozlowskii* Brotzen & Pozaryska: p. 162, pl. 1, figs 1–14; pl. 2, figs 1–17; pl. 3.
1962 *Globigerina daubjergensis* Brönnimann; Berggren: p. 81, textpl. 11, figs 1–7; pl. 13, figs 3–7.
1962 *Globigerina kozlowskii* Brotzen & Pozaryska; Hofker: p. 129, textfig. on p. 130.
1964 *Globigerinoides daubjergensis* (Brönnimann); Nogan: p. 38, pl. 4, figs 10–12.

1964 *Globigerina daubjergensis* Brönnimann; Bertels: p. 177, pl. 7, fig. 7.
1965 *Globigerina daubjergensis* Brönnimann; Pozaryska: p. 121, pl. 23, figs 4a-c.
1965 *Globigerina kozlowskii* Brotzen & Pozaryska; Pozaryska: p. 122, pl. 23, figs 1a-c.
1966 *Globigerina daubjergensis* Brönnimann; Hofker: p. 314, pl. 86, figs 245, 247, 250, 251, 254, 257–259.
1966 »*Globigerina*« cf. »*Globigerina*« *kozlowskii* Brotzen & Pozaryska; Mendez: p. 149, pl. 3, fig. 1.
1966 »*Globigerina*« sp. Mendez: p. 150, pl. 3, fig. 4.
1966 *Globigerina daubjergensis* Brönnimann; El-Naggar: p. 161, pl. 15, figs 3a-c.
1966 *Globigerina kozlowskii* Brotzen & Pozaryska; El-Naggar: p. 168, pl. 15, figs 1a-c, 2.
1969 *Globoconusa daubjergensis gigantea* Bang: pl. 4, figs 1–3b.

General description

Test small, coiled in a generally high trochospire. Spiral side conical with the proloculus forming the apex. The chambers of the youngest whorl are strongly inflated and almost globular. The final whorl, of 3½–4 chambers, normally constitutes the main part of the test. Umbilical side inflated with a narrow and shallow umbilicus. A bulla-like smooth chamber may cover the umbilicus. Sutures distinct and depressed especially in the final whorl. Aperture a simple arched opening in the final chamber, umbilical in position and sometimes with a narrow lip. Supplementary apertures may be present along the spiral suture. Test wall composed of radiate, perforate calcite. Test surface distinctly spinose, with scattered spines which are only slightly higher than the width of their base.

Studies on the stratigraphical variation of *Globoconusa daubjergensis* through the Danian of Denmark and of *Globoconusa kozlowskii* from the Pamietowo boring in Poland

A series of populations of *Globoconusa daubjergensis* and a single population of *Globoconusa kozlowskii* have been measured for proloculus diameters and largest diameter. The coiling directions of all measured specimens have been recorded together with the total number of chambers.

Globoconusa daubjergensis is a common species in most of the Danian limestones of Denmark. However, the state of preservation is generally rather poor in the stratigraphically older parts.

The biostratigraphical zonation of the Danian of Denmark is based on the occurrence of four species of the genus *Tylocidaris*. They are in ascending order: *Tylocidaris oedumi* – *T. abildgaardi* – *T. bruennichi* – *T. vexillifera*.

The biozones represented by these forms are in the following referred to as Zone I, II, III, and IV respectively.

The oldest part of the Danian *i.e.* the Fiskeler (Fish Clay) and *Cerithium*

Kalk (*Cerithium* Limestone), which are well exposed in Stevns Klint in southern Sjælland, did not yield material in sufficiently good preservation for variation studies and has therefore not been considered in the present study. The Fiskeler and Cerithium Kalk represent the oldest Danian rocks and underlie the biozone of *Tylocidaris oedumi.*

The tests of *Globoconusa daubjergensis* from the rocks of the varying facies exposed in eastern Sjælland are in general not well preserved, and have therefore been avoided for measurements. In a westerly direction (*i.e.* in Jylland) is a monotonous series of bryozoan limestones belonging to Zones I and II, while Zones III and IV are developed as soft, loose limestones (so-called Coccolith Limestone or "Blegekridt"). Populations of *Globoconusa daubjergensis* from five localities in Jylland have been used for measurements in the present study:

Zone I:	Nyvang Gaard
Zone II:	Løgsted Kalkværk
Zone III:	Skovvad Bro
Transition Zone III–IV:	Voldum
Zone IV:	Hvalløse

Professor K. Pozaryska kindly sent a large population of *Globoconusa kozlowskii* from the Pamietowo boring in Poland (depth 263.8 m). The stratigraphical level is Montian according to Pozaryska (1965).

Method of measurement

The tests were mounted on their umbilical side with gum tragantum on a glass slide. When dry they were cleared with benzylalcohol to make the tests transparent. The different parameters were measured with a Leitz Dialux-Pol light transmission microscope. The proloculus diameters were measured at 400 times magnification allowing a measuring error of $\pm\ 1\mu$. The total diameters of the tests were measured at 100 times magnification allowing a measuring error of $\pm\ 2\mu$.

The difference in number of observations of the different parameters of the same population is due to difficulty in measuring some of the characters. The diameter of the youngest whorl could always be measured, but the proloculus and the number of chambers were not observable in all specimens. When the proloculus diameter of a specimen could not be measured with the desired accuracy, it was left out, while the same specimen, in spite of this, appears in the distribution of total diameter of the youngest whorl.

Variation of proloculus diameter

The distribution of proloculus diameters of the six measured populations is shown in figures 1–6. The data have been treated statistically and the results are shown in table I. Abbreviations for the statistical terms are explained in the caption to that table. The mean values ($\bar{X}$) show no def-

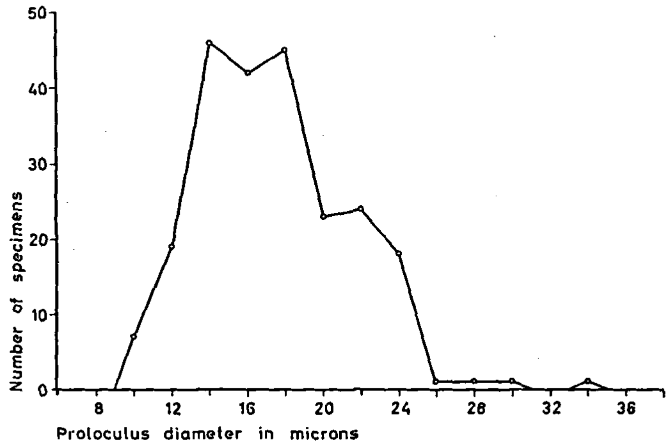


Fig. 1. Size-frequency distribution of proloculus diameters of 228 specimens of *Globoconusa daubjergensis* (Brönnimann) from Nyvang Gaard, Danian (Zone I).

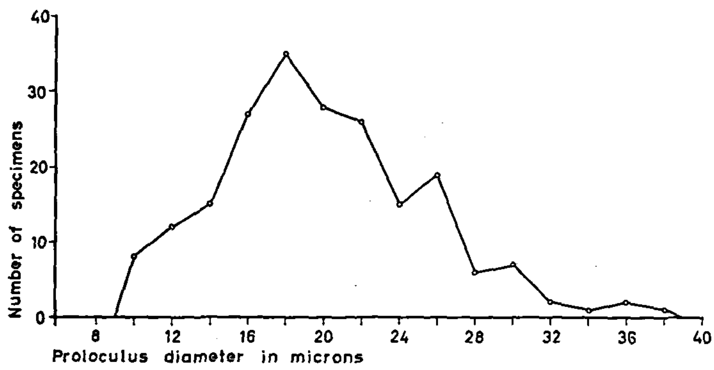


Fig. 2. Size-frequency distribution of proloculus diameters of 203 specimens of *Globoconusa daubjergensis* (Brönnimann) from Løgsted Kalkværk, Danian (Zone II).

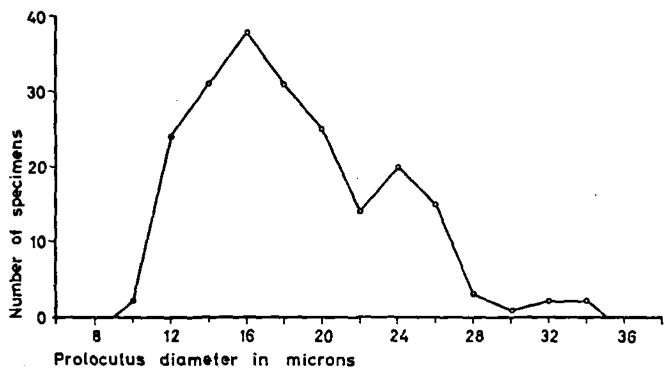


Fig. 3. Size-frequency distribution of proloculus diameters of 208 specimens of *Globoconusa daubjergensis* (Brönnimann) from Skovvad Bro, Danian (Zone III).

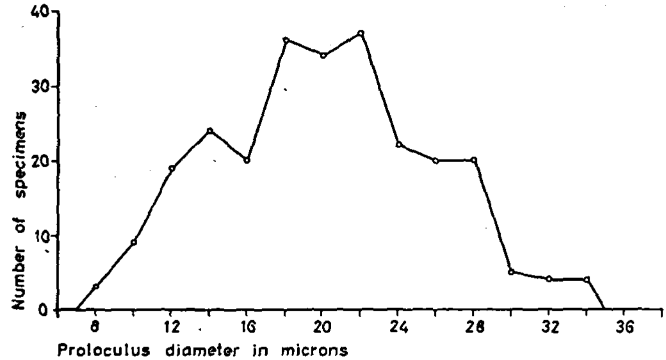


Fig. 4. Size-frequency distribution of proloculus diameters of 259 specimens of *Globoconusa daubjergensis* (Brönnimann) from Voldum, Danian (Zone III–IV).

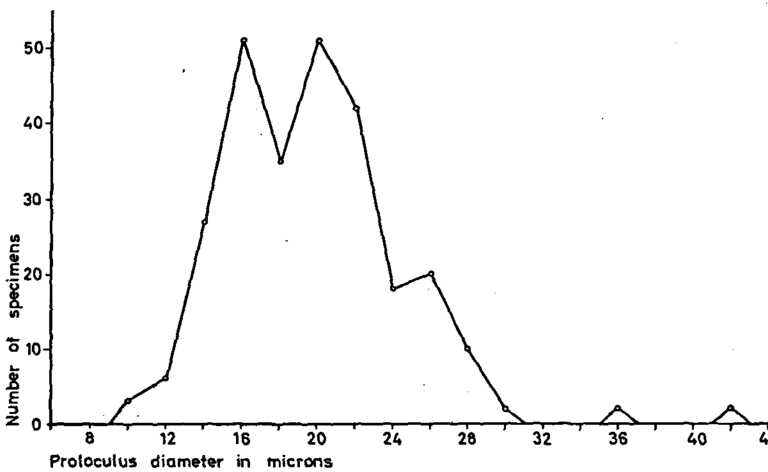


Fig. 5. Size-frequency distribution of proloculus diameters of 269 specimens of *Globoconusa daubjergensis* (Brönnimann) from Hvalløse, Danian (Zone IV).

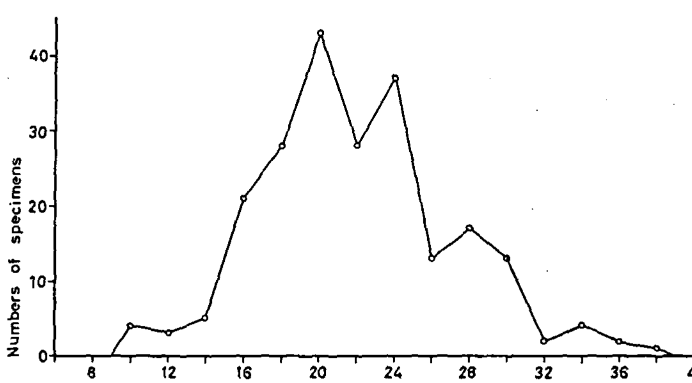


Fig. 6. Size-frequency distribution of proloculus diameters of 221 specimens of *Globoconusa daubjergensis* (Brönnimann) from Pamietowo boring (depth 263.8 m) Paleocene, Poland.

Table I. Statistical values calculated from the data shown in figs 1–6.

	n	$\bar{X}$	s	C.V.	F	P_F	t	P_t
I	228	17.38	4.00	23.01				
					1.18	>10	5.41	<0.1
II	202	19.85	5.37	27.05				
					1.02	>10	2.81	0.5-1
III	208	18.42	4.89	26.55				
					1.07	>10	3.04	<0.5
III-IV	259	19.93	5.65	28.30				
					1.17	>10	0.38	70
IV	275	19.76	4.77	24.13				
					1.04	>10	5.04	<0.1
Pamietowo	221	22.00	5.13	23.31				

$$\bar{x} = \frac{\Sigma \text{ observations in } \mu}{n}$$

$$s = \text{standard deviation} = \frac{\sqrt{(x-\bar{x})^2}}{n-1}$$

$$\text{C.V.} = \text{Coefficient of variation} = \frac{100 \cdot s}{\bar{x}}$$

$$F = \frac{s_A{}^2}{s_B{}^2}$$

P_F = Probability of higher F-value in percentage.

$$t = \frac{(\bar{x}_A - \bar{x}_B)\sqrt{\dfrac{n_A n_B}{n_A + n_B}}}{\sqrt{\dfrac{(n_A - 1)s_A{}^2 + (n_B - 1)s_B{}^2}{n_A + n_B - 2}}}$$

P_t = probability of higher t-value in percentage

A and B are samples within concerned populations.

inite tendency towards increase or decrease in proloculus diameters of the measured populations as the Danian is ascended. The standard deviation (s) and the values of coefficient of variation (C.V.) likewise show no such tendency. As each of the F values corresponds to a probability value (P_F) higher than 10 % the t-test has been applied. The t-test showed significant difference between the proloculus diameter distribution of the populations from Zone I, II, III, and III–IV but not between the populations from Zone III–IV and IV. There is significant difference between the populations from Zone IV and Pamietowo.

Variation of diameter of final whorl

The test diameter was measured as the diameter of the smallest circle in which the test was inscribable, observed at right angles to the plane on which the test was mounted. The specimens were mounted on a glass slide resting on their umbilical side. The largest diameter was found to be the distance from the youngest chamber (fig. 7 (1)) to the antepenultimate (3). As new chambers are added in a descending spiral the four chambers of the youngest whorl are not level with each other and the specimen may therefore tilt when it is placed on the glass slide. As the axis of tilt

Erratum.

Meddelelser fra Dansk geologisk Forening bind 19, hæfte 4, pp. 341–360.

H.J.Hansen: Biometric studies on the stratigraphic evolution of Globoconusa daubjergensis (Brönnimann) from the Danian of Denmark.

In Tables I–IV a general error in the calculation of the F values and consequently also in the P_F values has been introduced. The correct values are as follows:

Table I		Table II		Table III		Table IV	
F	P_F	F	P_F	F	P_F	F	P_F
1.80	< 0.1%	1.69	< 0.1%	1.63	<0.1%	1.98	<0.1%
1.2	> 10%	1.26	5–10%	1.03	>10%	1.36	2.5–5%
1.33	2.5–5%	1.29	5–10%	1.01	>10%	1.26	5–10%
1.40	1%	3.13	<0.1%	1.15	>10%	1.86	<0.1%
1.15	> 10%	1.94	<0.1%	1.18	>10%		

All t-tests made between populations where the corresponding P_F value is lower than 5% should not be taken into consideration. This does, however, not alter the main conclusions arrived at in the paper.

H.J.Hansen

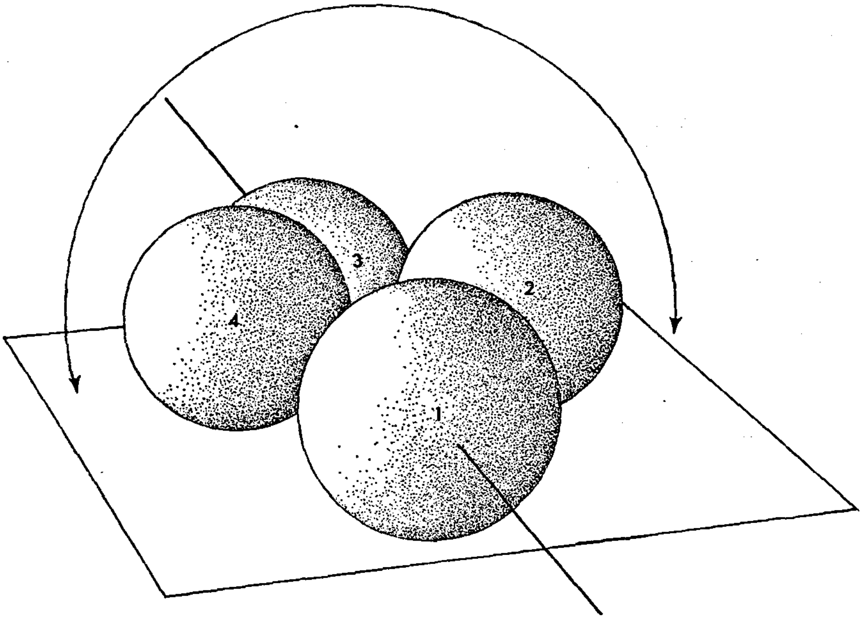


Fig. 7. Idealised model of the youngest whorl of *Globoconusa daubjergensis*. 1: Youngest chamber. 2: Penultimate chamber. 3: Antepenultimate chamber; 4: etc. T: The possible axes of tilt.

(fig. 7 (T)) passes through the last (1) and the antepenultimate chamber (3), and as the other possible axis passes through the penultimate (2) and the last but three chamber (4), this second axis lies at a higher level relative to the mounting plane, and the measurement of the diameter will therefore not be effected by the tilt.

The distribution of test diameters of the six measured populations is shown in diagrams 8–13. The data have been treated statistically and the results are shown in table II.

Table II. Statistical values calculated from the data shown in figs 8–13. For explanation of abbrevations see table I.

	n	$\bar{X}$	s	C.V.	F	P_F
I	228	118.81	18.20	15.32		
					1.33	1-2.5
II	202	116.28	23.70	20.38		
					1.45	<1
III	208	150.46	21.10	14.02		
					1.31	2.5
III-IV	259	131.02	24.00	18.32		
					1.35	1-2.5
IV	275	172.10	42.50	24.69		
					1.59	<0.1
Pamietowo	278	197.50	30.50	15.44		

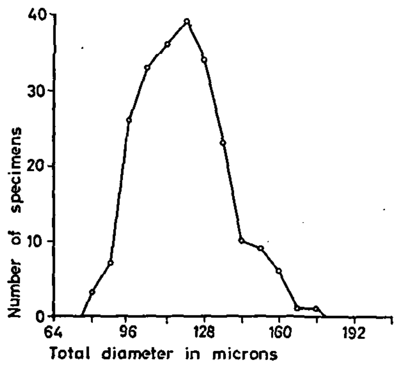


Fig. 8. Size-frequency distribution of total diameter of 228 specimens of *Globoconusa daubjergensis* (Brönnimann) from Nyvang Gaard, Danian (Zone I).

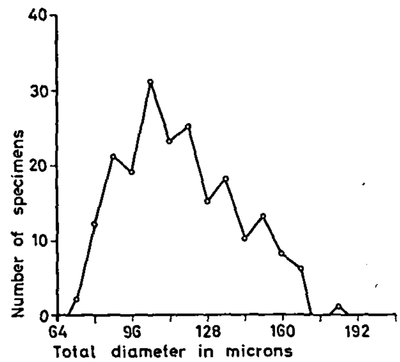


Fig. 9. Size-frequency distribution of total diameter of 203 specimens of *Globoconusa daubjergensis* (Brönnimann) from Løgsted Kalkværk, Danian (Zone II).

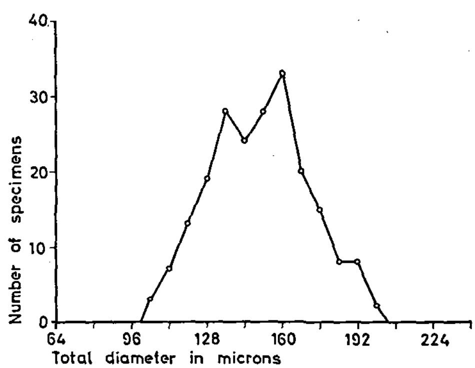


Fig. 10. Size-frequency distribution of total diameter of 208 specimens of *Globoconusa daubjergensis* (Brönnimann) from Skovvad Bro, Danian (Zone III).

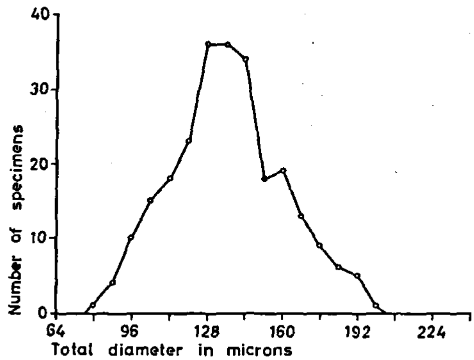


Fig. 11. Size-frequency distribution of total diameter of 259 specimens of Globoconusa daubjergensis (Brönnimann) from Voldum, Danian (Zone III–IV).

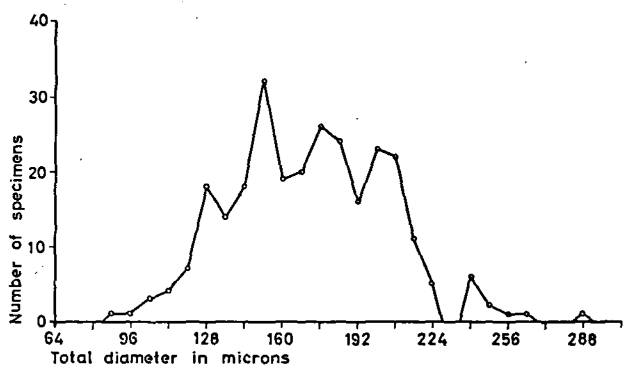


Fig. 12. Size-frequency distribution of total diameter of 275 specimens of *Globoconusa daubjergensis* (Brönnimann) from Hvalløse, Danian (Zone IV).

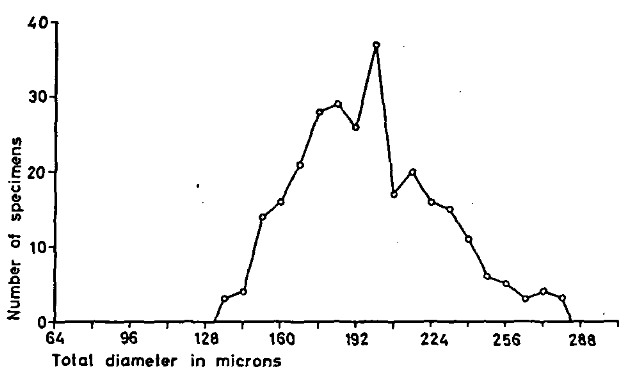


Fig. 13. Size-frequency distribution of total diameter of 278 specimens of *Globoconusa daubjergensis* (Brönnimann) from Pamietowo boring (depth 263.8 m) Paleocene, Poland.

The $\bar{X}$ values show a tendency towards larger test diameter in the stratigraphically youngest population. The standard deviation shows a definite tendency towards higher values in the stratigraphically younger populations.

Based on these figures it can be stated that the test diameter of *G. daubjergensis* shows an increase and also an increase in standard deviation from the older towards the younger populations.

Variation in number of chambers

The distribution of the total number of chambers of the six measured populations is shown in figures 14–19. The data have been treated statistically and the results are shown in table III.

Table III. Statistical values calculated from the data shown in figs 14–19. For explanation of abbrevation see table I.

	n	$\bar{X}$	s	C.V.	F	P_F	t	P_t
I	153	6.83	1.06	15.52				
					1.25	5-10	1.22	20-25
II	220	6.99	1.36	19.46				
					1.10	>10	4.08	<0.1
III	173	7.55	1.34	17.74				
					1.01	>10	0.14	80-90
III-IV	176	7.53	1.35	17.93				
					1.07	>10	7.37	<0.1
IV	181	8.63	1.45	18.98				
					1.27	2.5-5	2.02	2.5-5
Pamietowo	221	8.91	1.33	14.90				

The $\bar{X}$ values show the tendency of *G. daubjergensis* to develop more chambers from the older towards the younger part of the Danian. As the F-tests all showed P_F values higher than 5 % the t-test has been applied.

This test showed that there is significant difference between the populations from Zones II and III and between the populations from Zones III–IV and IV. There is no significant difference between the $\bar{X}$ values of the populations from Zones I and II and between Zones III and III–IV. There is significant difference, although not strong, between the populations from Zone IV and Pamietowo.

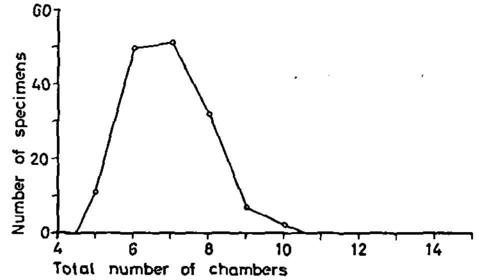


Fig. 14. Size-frequency distribution of total number of chambers of 153 specimens of *Globoconusa daubjergensis* (Brönnimann) from Nyvang Gaard, Danian, (Zone I).

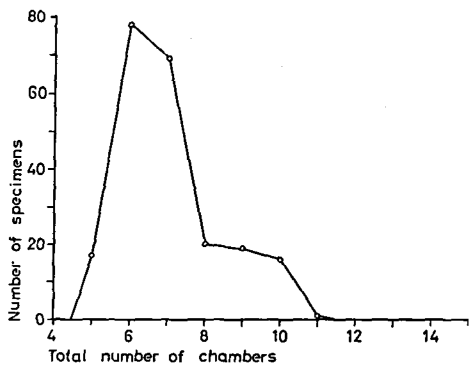


Fig. 15. Size-frequency distribution of total number of chambers of 220 specimens of *Globoconusa daubjergensis* (Brönnimann) from Løgsted Kalkværk, Danian (Zone II).

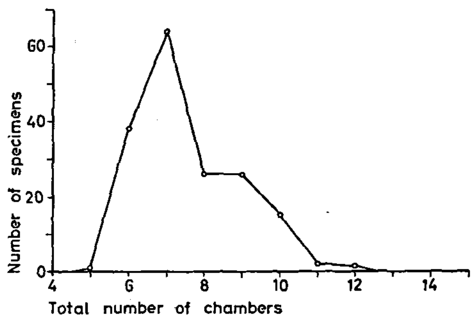


Fig. 16. Size-frequency distribution of total number of chamber of 173 specimens of *Globoconusa daubjergensis* (Brönnimann) from Skovvad Bro, Danian (Zone III).

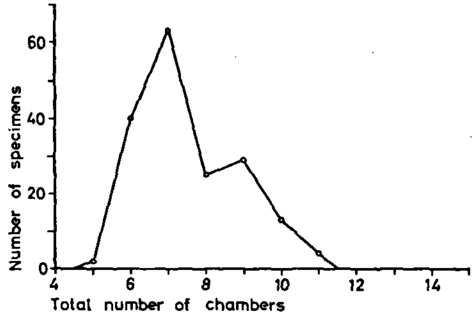


Fig. 17. Size-frequency distribution of total number of chambers of 176 specimens of *Globoconusa daubjergensis* (Brönnimann) from Voldum, Danian (Zone III–IV).

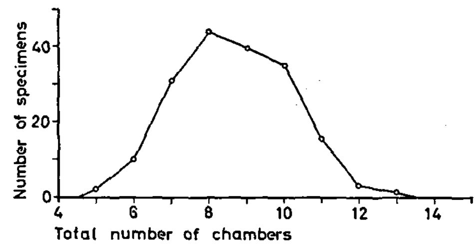


Fig. 18. Size-frequency distribution of total number of chambers of 151 specimens of *Globoconusa daubjergensis* (Brönnimann) from Hvalløse, Danian (Zone IV).

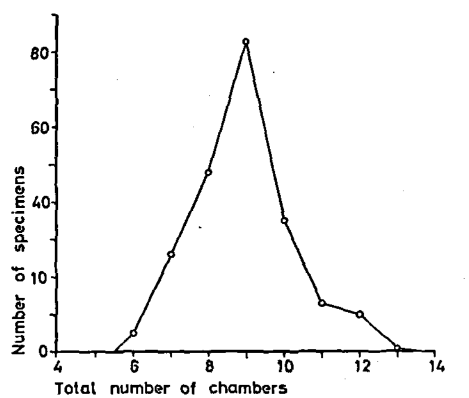


Fig. 19. Size-frequency distribution of total number of chambers of 221 specimens of *Globoconusa daubjergensis* (Brönnimann) from the Pamietowo boring (depth 263.8 m), Paleocene, Poland.

Coiling directions

The coiling directions of *G. daubjergensis* varied between 44 and 51 % sinistral in the measured populations. The species shows no preferred coiling direction.

	% sinistral
Zone I	50
Zone II	46
Zone III	50
Zone III–IV	46
Zone IV	51
Pamietowo	44

Discussion and conclusions

In 1966 Hofker published studies of the evolution of *Globoconusa daubjergensis.* The gradually increasing test diameter is briefly mentioned in this publication. In his paper from 1960c (p. 41, pl. 4) he showed a diagram of the distribution of measurements of test diameters. However, this diagram deals only with the size intervals of the distribution and it is not known on how many observations the diagram is based. Also shown in the diagram is the distribution of a population of "*G. daubjergensis*" from the Maastrichtian White Chalk of Denmark. This part of the diagram must be omitted from consideration since the form according to Berggren (1962) and El-Naggar (1966) is wrongly identified.

With some reservation on account of the missing information concerning the number of observations, Hofker's diagram illustrates a tendency in *Globoconusa daubjergensis* to develop a larger test diameter during the Danian. This tendency is in agreement with the results obtained by the present author (see table II).

The results of Hofker's investigations (1966, p. 315) on the development of proloculus diameter distribution of successive populations of Globoconusa daubjergensis were given in the form of diagrams; these illustrate the relationship between proloculus diameter and number of chambers. In the caption to the diagrams it is stated that they are based on a total of 206 individuals while the actual number of points is 209. In the diagram in the lower right corner showing the ratio between proloculus and test diameter based on the population from Zone IV, there is one specimen with a proloculus of 18.9 μ and a diameter of 175.5 μ which is not recorded in the corresponding diagram (middle row Zone IV). The diagram in the upper left corner showing the ratio between proloculus and average chamber diameter based on the same material shows 29 specimens while the diagram in the middle (Zone IV) shows only 26 specimens. When examined more closely, the upper left diagram is seen to show 4 specimens which are not recorded in the middle diagram (Zone IV) while one of the specimens recorded there is missing in the upper left diagram. It would thus appear that about 20 % of the observations from Zone IV are of doubtful value.

Hofker's measurements of proloculus diameters have been extracted from his diagrams and treated statistically by the present author. The resulting values are recorded in table IV.

Table IV. Statistical values calculated from the data published by Hofker (1966, p. 315, fig. 173). For explanation of abbrevations see table I.

	n	$\overline{X}$	s	C.V.	F	P_F	t	P_t
I	11	23.54	3.64	15.47				
					1.62	>10	1.88	5-10
II	41	20.41	5.13	25.13				
					1.13	>10	0.61	50-60
III	34	21.20	5.99	28.28				
					1.14	>10	0.11	>90
III-IV	23	21.00	6.75	32.13				
					1.22	>10	1.13	25-30
IV	26	23.65	9.23	39.04				

The $\overline{X}$ values are higher than the ones found by the present author (compare table I). There does not seem to be any tendency towards larger or smaller $\overline{X}$ values through the Danian.

The standard deviation shows a definite tendency towards higher values in the Upper Danian. The same tendency is found in the coefficients of variance. As, however, the s and C.V. values are dependent on the numbers of observations and as these numbers are very low in Hofker's material, the importance of the tendency found in both the s and the C.V. values cannot be stressed (compare the corresponding values in tables I and IV).

As all the P_F values were higher than 10 % the t-test has been applied. The P_t values show no significant difference between the successive populations in the measured character. This result does not agree well with the P_t values arrived at by the present author (see table I).

Hofker's statement (1966, p. 314) that: "It is obvious from fig. 173 that the variation of the proloculus-diametres increased during time; . . ." is correct when based on his own measured populations, but this tendency would appear to be wrong when larger populations are studied.

Globoconusa daubjergensis from the type locality, *i.e.* Daubjerg in Jylland, includes specimens with supplementary apertures. The type locality has been assigned by Brönnimann to Zone D (*i.e.* Zone IV) of the biozones based on the occurrence of *Tylocidaris*. This correlation is not correct. Ødum (1926) placed the locality in the biozone characterized by *Tylocidaris vexillifera beta* (later called *T. vexillifera* var. *bruennichi* by Ravn, 1927, p. 33, and considered an independent species by Rosenkrantz (1937)). The type locality of *G. daubjergensis* therefore belongs to the Zone III and not to Zone IV.

There is some confusion as to the delimitation of *G. kozlowskii* from *G. daubjergensis*. El-Naggar (1966) stressed that the holotype of *G. daubjergensis* has no supplementary apertures, quoting a personal communication from Brönnimann. As shown above, supplementary apertures had already developed in *G. daubjergensis* from Zone II of the Danian and cannot therefore be regarded as a distinguishing character between the two species.

The umbilical bulla described from specimens of *G. kozlowskii* (but not present in the holotype) also seems to be a doubtful distinguishing character. The umbilical bulla is relatively seldom met with in the population of *G. kozlovskii* from its type locality. As specimens with an umbilical bulla are found, although not commonly, in the population of *G. daubjergensis* from Zone IV the presence of an umbilical bulla is without value for distinguishing *G. kozlowskii* from *G. daubjergensis.*

Moreover, the very high trochospire in *G. kozlowskii* is not developed in all specimens from the type locality. A high trochospire is commonly found in the population of *Globoconusa daubjergensis* from Zone IV and therefore this character also seems to be without value for distinguishing *Globoconusa kozlowskii* from *Globoconusa daubjergensis.*

Based on the statistical studies it is evident that in the measured characters there is no greater difference between *Globoconusa daubjergensis* from Zone IV and *Globoconusa kozlowskii* from Pamietowo than *e.g.* between *Globoconusa daubjergensis* from Zones II and III. To retain *Globoconusa kozlowskii* as an independent species would thus seem to be unjustified as it can only be distinguished from *Globoconusa daubjergensis* from Zone IV when a sufficiently large population is measured. It would further seem undesirable to regard *Globoconusa kozlowskii* as a chronological subspecies of *Globoconusa daubjergensis,* as in that case it would be necessary also with equal justification to divide *Globoconusa daubjergensis* into four chronological subspecies, *i.e.* one from each of the four *Tylocidaris* zones of the Danian. Because of this, *Globoconusa kozlowskii* is here regarded as a synonym of *Globoconusa daubjergensis.*

Consequently, the stratigraphic range of *Globoconusa daubjergensis* must be extended to include not only the Danian but also the lower part of the Middle Paleocene as stated earlier by the present author (Hansen, 1968).

Recently Bang (1969) published a biozonation of the Danish Danian deposits encountered in the borings from Storebælt. She established four biozones (No. I–IV) based on planktonic foraminifera covering Danian as well as Selandian deposits. Bang's biozones do not correspond to the classical biozonation of the Danian based on the occurrence of *Tylocidaris* (Ødum, 1926; Rosenkrantz, 1937). Since it is unknown where the *Tylocidaris*-zones should be placed within the biozones of Bang it is also unknown where the type locality of the Danian (*i.e.* Fakse quarry) is to be placed.

Bang's new subspecies of *Globoconusa daubjergensis* named *Globoconusa daubjergensis gigantea* definitely falls within the variation width of *Globoconusa daubjergensis* and is accordingly listed here as a synonym of *Globoconusa daubjergensis.* Bang distinguished the subspecies by its larger diameter and the presence of a bulla-like final chamber and even by great variability.

The range of *Globoconusa daubjergensis* shown on Bang's range chart (p. 63) does not correspond to the range of the species found by the present author. In outcrops *Globoconusa daubjergensis* is found to extend upwards to the very top of the Danian and specimens corresponding to *Globoconusa kozlowskii* are found in the Lower Selandian in Jylland. In the present investigation *Globoconusa kozlowskii* is not considered an independent species and consequently the range of *Globoconusa daubjergensis* must be extended to include the lower part of the Selandian which has been correlated with the *Globorotalia angulata* zone (Hansen, 1968).

Acknowledgments. The author is greatly indepted to Professor K. Pozaryska, Poland for material of *Globoconusa kozlowskii* from the Pamietowo boring.

For valuable advice concerning the statistical treatment of the data the author is indepted to Dr. E. Andresen, Department of Animal Genetics, the Royal Veterinary and Agricultural University, Copenhagen.

The electron micrographs were made in a Stereoscan scanning electron microscope housed in the Geological Institutes of the University of Copenhagen.

Mrs. R. Larsen prepared the figures in the text except figure 7 which was made by Mr. R. Egelund.

Dr. R. G. Bromley kindly improved the English language.

Dansk sammendrag

Slægten *Globoconusa* Khalilov, 1956 diskuteres, og det konkluderes, at denne slægt er veladskilt fra slægterne *Globigerina, Globigerinoides* samt *Catapsydrax* ved skallens overfladestruktur.

Fem populationer af *Globoconusa daubjergensis* fra jyske Danien lokaliteter er blevet undersøgt ved biometriske og statistiske metoder. Følgende karakterer er blevet målt: Begyndelseskammerets diameter, diameteren af den yngste vinding, antallet af kamre samt snoningsretningen. Det kan herved konstateres, at der hos arten er en tendens til at udvikle flere kamre hos de stratigrafisk yngste repræsentanter. *Globoconusa daubjergensis* bliver sammenlignet med *Globoconusa kozlowskii* fra Pamietowo boringen i Polen. Det konkluderes, at de to arter ikke kan holdes adskilt.

Til slut diskuteres Hofkers biometriske studier af *Globoconusa daubjergensis* fra det danske Danien, og det vises, at de af ham påviste udviklingstendenser delvis er misledende, idet hans undersøgelser er baseret på et talmæssigt ringe materiale.

Institut for historisk Geologi og Palæontologi,
Østervoldgade 5–7, 1350 København K, Denmark.
September 9th, 1969.

References

Bang, I. 1969: Planktonic foraminifera and biostratigraphy of the type Danian. *Proc. 1st Intern. Conference Planktonic Microfossils.* Geneva 1967, **1**, 58–65, Leiden.

Bartlett, G. A. 1968: Planktonic foraminifera – new dimensions with the scanning electron microscope. *Can. J. Earth Sci.* **5**, 2, 231–233.

Berggren, W. A. 1962: Some planktonic foraminifera from the Maestrichtian and type Danian stages of southern Scandinavia. *Stockh. Contr. Geol.* **9**, 1–106.

Bertels, A. 1964: Micropaleontologia del Paleoceno de General Roca (Provincia de Rio Negro). *Revista del Museo de la Plata,* N.S. **4**, Paleont, 23, 125–184.

Bolli, H. M. 1957: The genera Globigerina and Globorotalia in the Paleocene – Lower Eocene Lizard Springs Formation of Trinidad B.W.I. *Bull. U.S. natn. Mus.* **215**, 61–81.

Bolli, H. M. & Cita, M. B. 1960a: Globigerine e Globorotalie del Paleocene di Paderno d'Adda (Italia). *Riv. Ital. Paleont.* **66**, 361–402.

Bolli H. M. & Cita, M. B. 1960b: Upper Cretaceous and Lower Tertiary planktonic foraminifera from the Paderno d'Adda section, Northern Italy. Rep. 21st Intern. geol. Congr. Norden, **5**, 150–161.

Bolli, H. M., Loeblich, A. R. & Tappan, H. 1957: Planktonic foraminiferal families Hantkeninidae, Orbulinidae, Globorotaliidae, and Globotruncanidae. *Bull. U.S. natn. Mus.* **215**, 3–50.

Brotzen F. & Pozaryska, K. 1961: Foraminiféres du Paleocene et de l'Eocéne inférieur en Pologne septemtrionale; remarques paléogéographiques. *Revue Micropaléont.* **4**, 155–166.

Brönnimann, P. 1953: Note on planktonic foraminifera from Danian localities of Jutland, Denmark. *Eclog. geol. Helv.* **45**, 339–341.

El-Naggar, Z. R. 8 1966: Stratigraphy and planktonic foraminifera of the Upper Cretaceous – Lower Tertiary succession in the Esna – Idfu region, Nile Valley, Egypt, U.A.R. *Bull. Br. Mus. nat. Hist.* Geol. Suppl. **2**, 1–291.

Hansen, H. J. 1968: On the biostratigraphical age of the Lower Selandian of Denmark. *Meddr dansk geol. Foren.* **18**, 277–284.

Hillebrandt, A. von 1962: Das Paleozän und seine Foraminiferenfauna im Becken von Reichenhall und Salzburg. *Abh. bayer. Akad. Wiss. Math.-nat. Kl.* N.F. **108**, 1–182.

Hofker, J. 1956: Foraminifera of the Chalk Tuff of Maastricht and environments. *Natuurh. Maandbl.* **45**, 50–57.

Hofker, J. 1959: Arguments for a Lower Paleocene age of the sediment above the upper Md in the quarry of Curfs, near Houthem. *Natuurh. Maandbl.* **48**, 18–30.

Hofker, J. 1960a: The foraminifera of the lower boundary of the Danish Danian. *Meddr dansk geol. Foren.* **14**, 212–242.

Hofker, J. 1960b: *Globigerina daubjergensis* Brönnimann and the age of the Mc and Lower Paleocene above the upper Md in the quarry Curfs near Houthem, and the age of the Cr_4 below the Ma. *Natuurh. Maandbl.* **49**, 34–41.

Hofker, J. 1960c: Planktonic foraminifera in the Danian of Denmark. *Contr. Cushman Fdn. foram.* Res. **11**, 73–86.

Hofker, J. 1960d: Le probleme du Dano-Paleocene et le passage Cretace-Tertiaire. *Revue Micropaleont.* **3**, 119–130.

Hofker, J. 1962: Globigerina kozlowskii Brotzen & Pozaryska in the »Post-Maestriction« of the quary Curfs near Houthem and of the Canal Albert in Belgium. *Natuurh. Maandbl.* **51**, 129–130.

Hofker, J. 1966: Maestrichtian, Danian and Paleocene foraminifera. *Palaeontographica,* Suppl. bd. **10**, 1–375.

Khalilov, D. M. 1956: On the planktonic foraminiferal fauna of the Paleogene of Azerbaidzhan. *Trudy Akad. Nauk. Azerb. S.S.R., Inst. Geol. Baku,* **17**, 234–361. (in Russian.)

Loeblich, A. R. & Tappan, H. 1957: Planktonic foraminifera of Paleocene and early Eocene age from the Gulf and Atlantic coastal plains. *Bull. U.S. natn. Mus.* **215**, 173–198.

Loeblich, A. R. & Tappan, H. 1964: *Treatise on invertebrate paleontology.* Part C. Protista 2. Sarcodina chiefly »thecamaebians« and foraminiferida (Moore ed.), 1–900. Univ. Kansas Press.

Mendez, I. A. 1966: Foraminiferos, edad y correlacion estratigrafia del Salamanquense de Punta Peligra. Provincia del Chubut. *Revta. Asoc. geol. Argent.* **21**, 125–157.

Nogan, D. S. 1964: Foraminifera, stratigraphy and paleoecology of the Aquia Formation of Maryland and Virginia. *Contr. Cushman Fdn. foram. Res.* Spec. Publ. **7**, 1–50.

Olsson, R. K. 1960: Foraminifera of the latest Cretaceous and earliest Tertiary age in the New Jersey coastal plain. *J. Paleont.* **34**, 1–58.

Pozaryska, K. 1965: Foraminifera and biostratigraphy of the Danian and Montian in Poland. *Acta Paleont. Pol.* **14**, 1–154.

Ravn, J. P. J. 1927: De irregulære echinider i Danmarks kridtaflejringer. *Skr. Dan. Vid. Selsk. nat.-mat. rk.* **8**, 11, 4, 1–307. (in Danish.)
Rosenkrantz, A. 1937: Bemærkninger om det østsjællandske Daniens stratigrafi og tektonik. *Meddr dansk geol. Foren.* **9**, 199–212. (in Danish.)
Troelsen, J. C. 1957: Some planktonic foraminifera of the type Danian and their stratigraphic importance. *Bull. U.S. natn. Mus.* **215**, 125–132.
Ødum, H. 1926: Studier over Daniet i Jylland og på Fyn. *Danm. geol. Unders.* rk. **2, 45,** 1–279. (in Danish.)

Plates

Plate 1

Fig. 1. *Globoconusa daubjergensis* (Brönnimann). Lower Danian biozone of *Tylocidaris oedumi,* locality Nyvang Gaard. Umbilical view of partially recrystallised specimen. 840 x.
Fig. 2. *Globoconusa daubjergensis* (Brönnimann). Lower Danian, biozone of *Tylocidaris abildgaardi,* locality Løgsted Kalkværk. Oblique umbilical view of specimen with heavy spines. 745 x.

Plate 2

Figs 1 and 2. *Globoconusa daubjergensis* (Brönnimann). Lover Danian, biozone of *Tylocidaris abildgaardi,* locality Løgsted Kalkværk.
Fig. 1. Oblique spiral view of recrystallised specimen. 768 x.
Fig. 2. Detail showing supplementary aperture. 1243 x.

Plate 3

Fig. 1. *Globoconusa daubjergensis* (Brönnimann). Middle-Upper Danian, transition between the biozone of *Tylocidaris brunnichi* and the biozone of *Tylocidaris vexillifera,* locality Voldum. Oblique spiral view showing blunt scattered spines. 560 x.
Fig. 2. *Globoconusa daubjergensis* (Brönnimann). Upper Danian, biozone of *Tylocidaris vexillifera,* locality Hvalløse. Oblique umbilical view of specimen with bulla-like smooth final chamber. Aperture partially covered by excess of mounting material. 576 x.

Plate 4

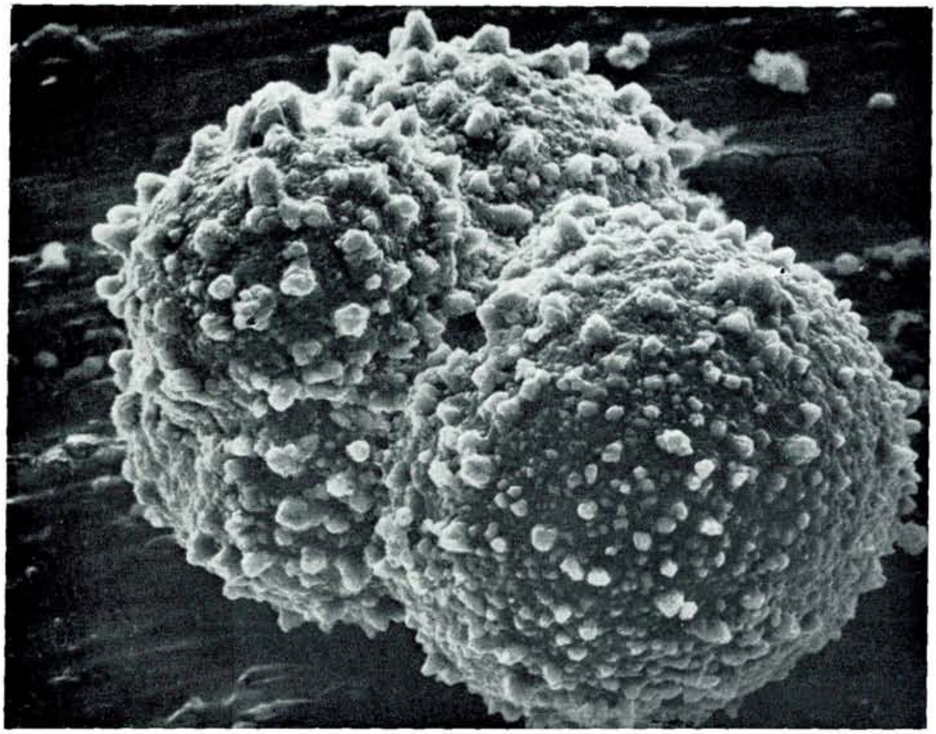
Fig. 1. *Globoconusa daubjergensis* (Brönnimann). Middle Danian, biozone of *Tylocidaris bruennichi.* Locality Daubjerg. Detail of surface showing blunt spines and scattered pores. 4984 x.
Fig. 2. *Globoconusa daubjergensis* (Brönnimann). Upper Danian, biozone of *Tylocidaris vexillifera.* Locality Hvalløse. Detail of surface showing blunt spines. Pores are obscured by excess of mounting medium. 6480 x.

Plate 5

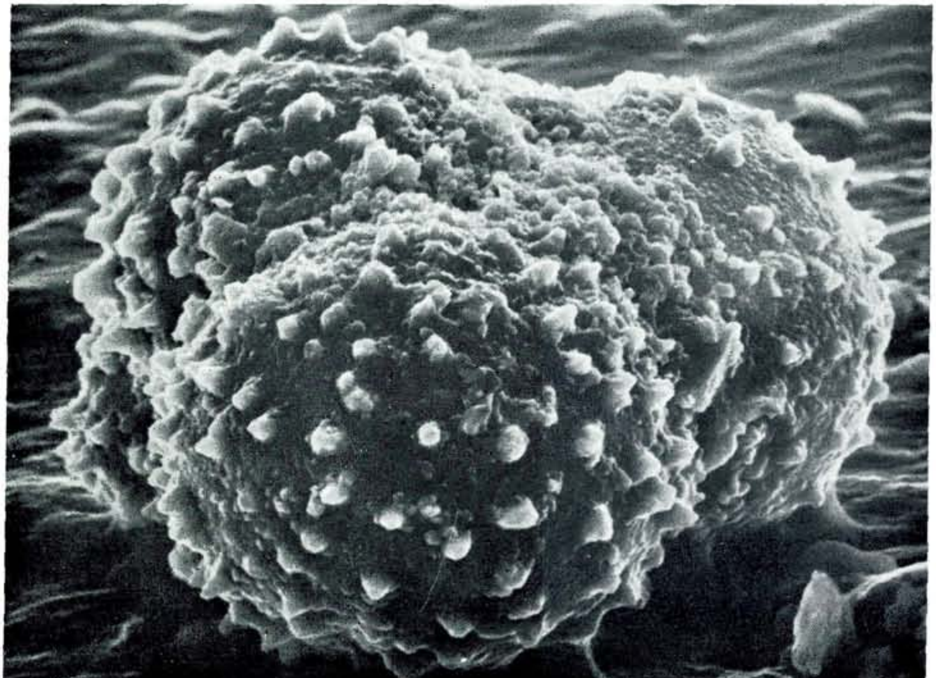
Fig. 1. *Globigerina bulloides* d'Orbigny. Shore sand, Rimini, Italy. Detail of surface showing reticulate structure. 1090 x.
Fig. 2. *Globigerinoides* sp. Recent, Siam Bay. Detail of surface showing reticulate structure with spine bases. 2300 x.

Plate 6

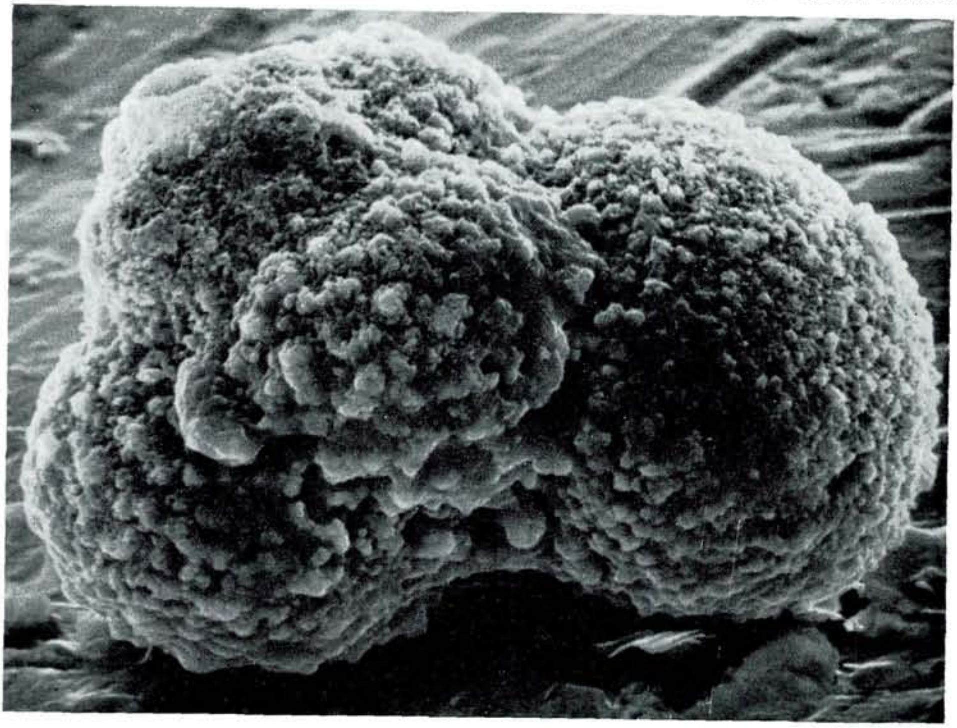
Figs 1 and 2. *Globoconusa kozlowskii* (Brotzen & Pozaryska). Montian, locality Pamietowo boring, Poland.
Fig. 1. Oblique spiral view of specimen with smooth final chamber. Note the blunt scattered spines. 504 x.
Fig. 2. Detail showing supplementary spiral aperture. 3410 x.



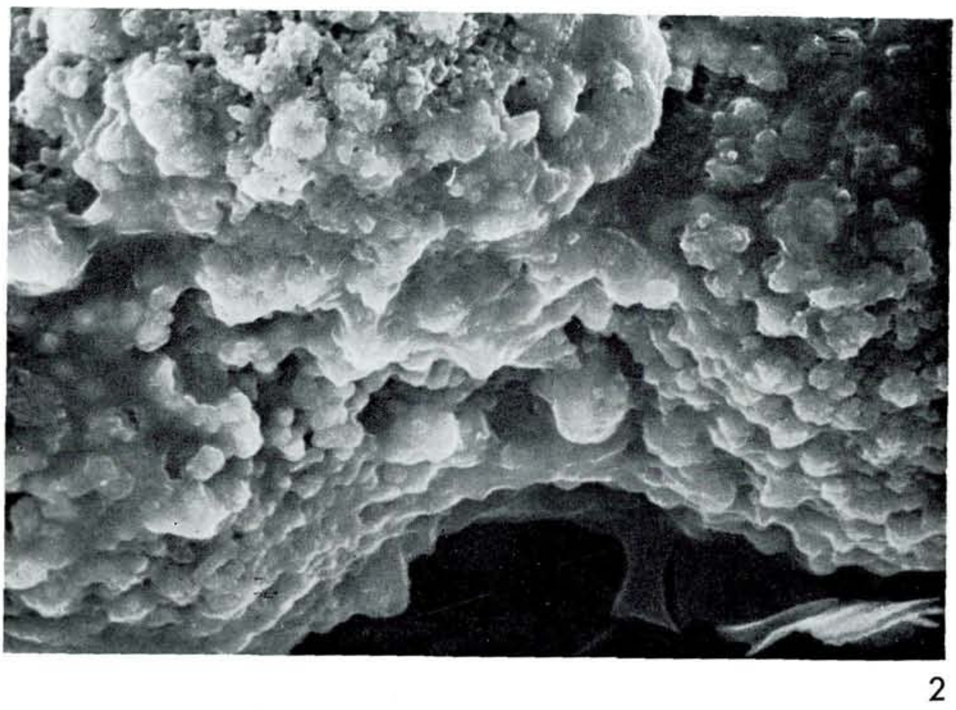
1



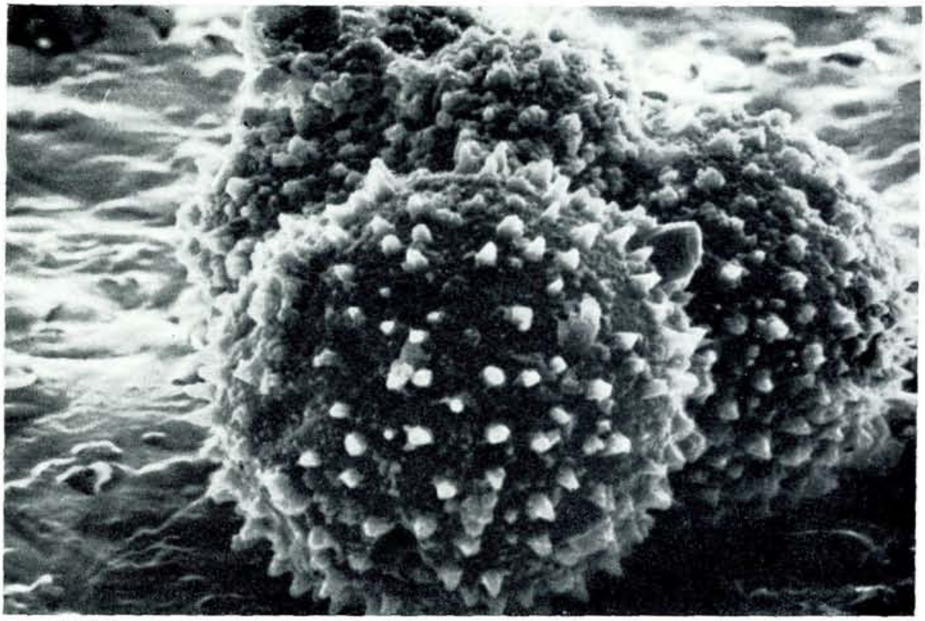
2



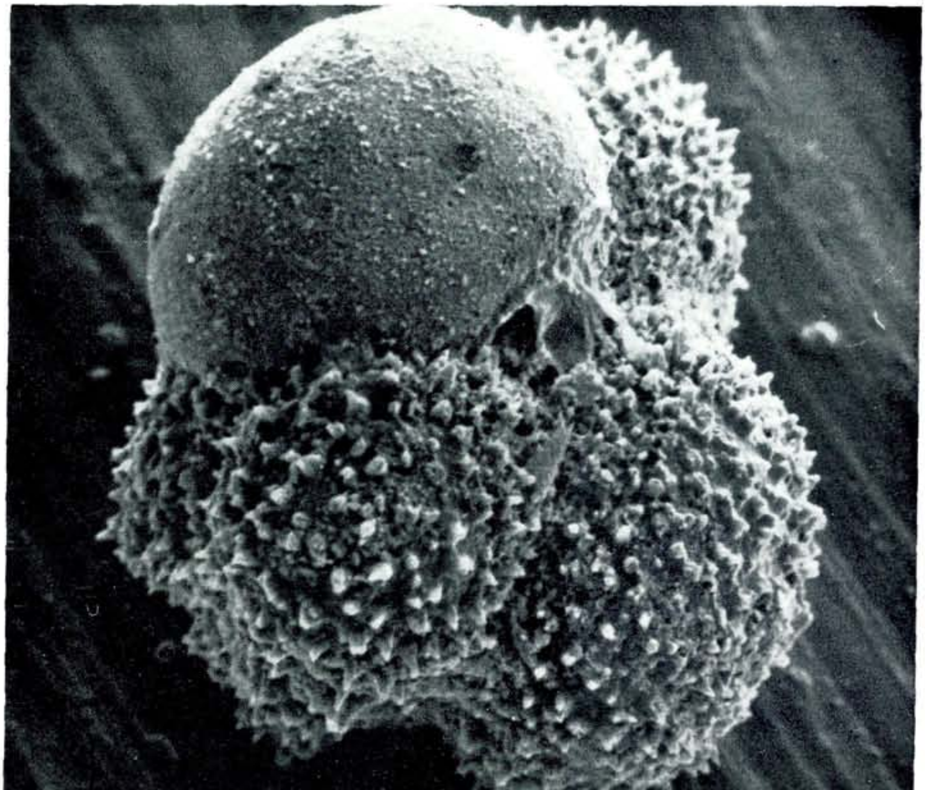
1



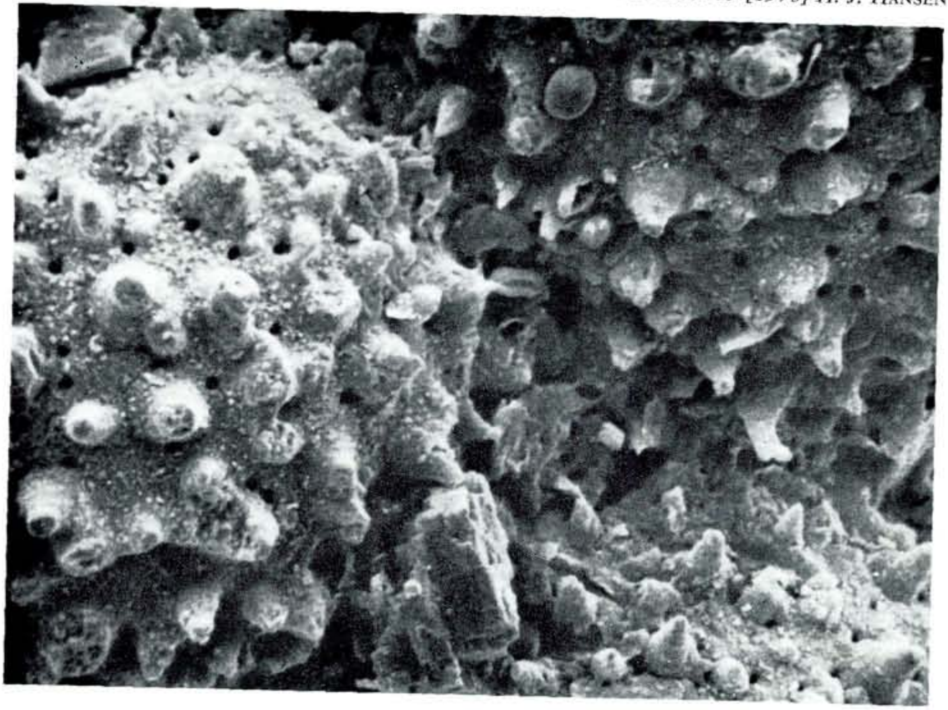
2



1

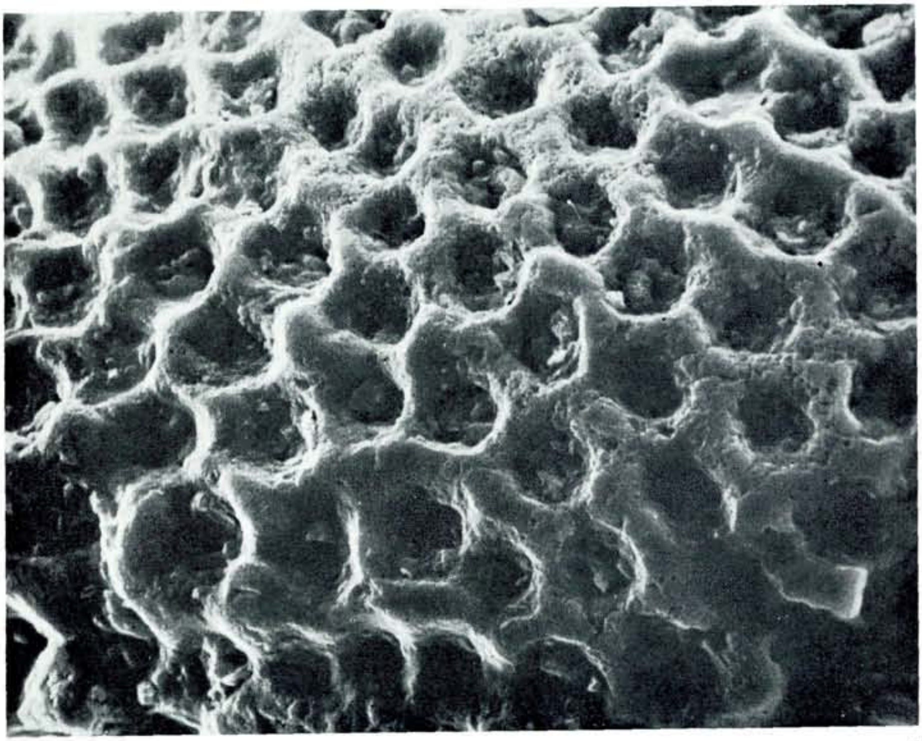


2

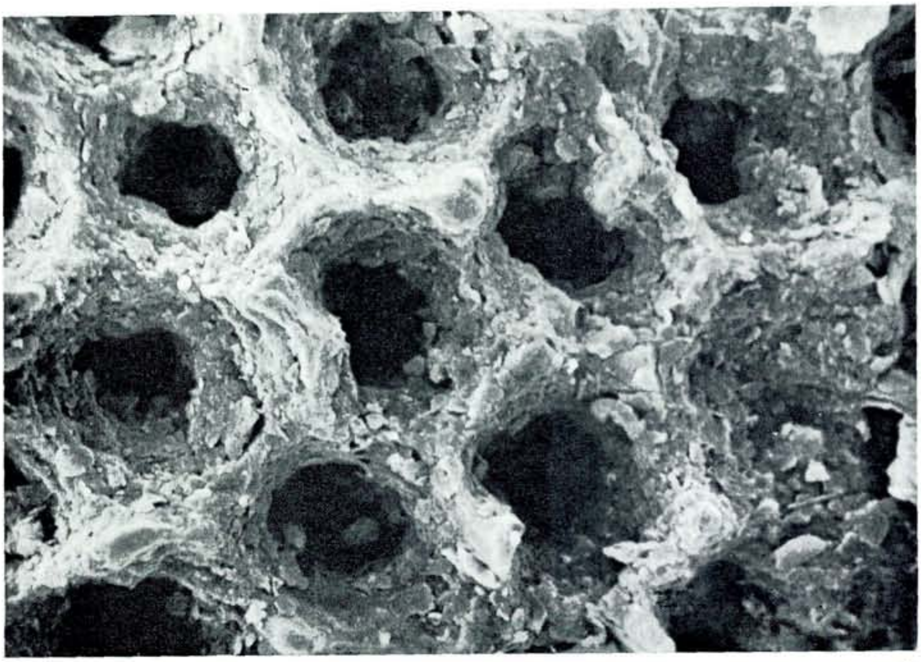


1

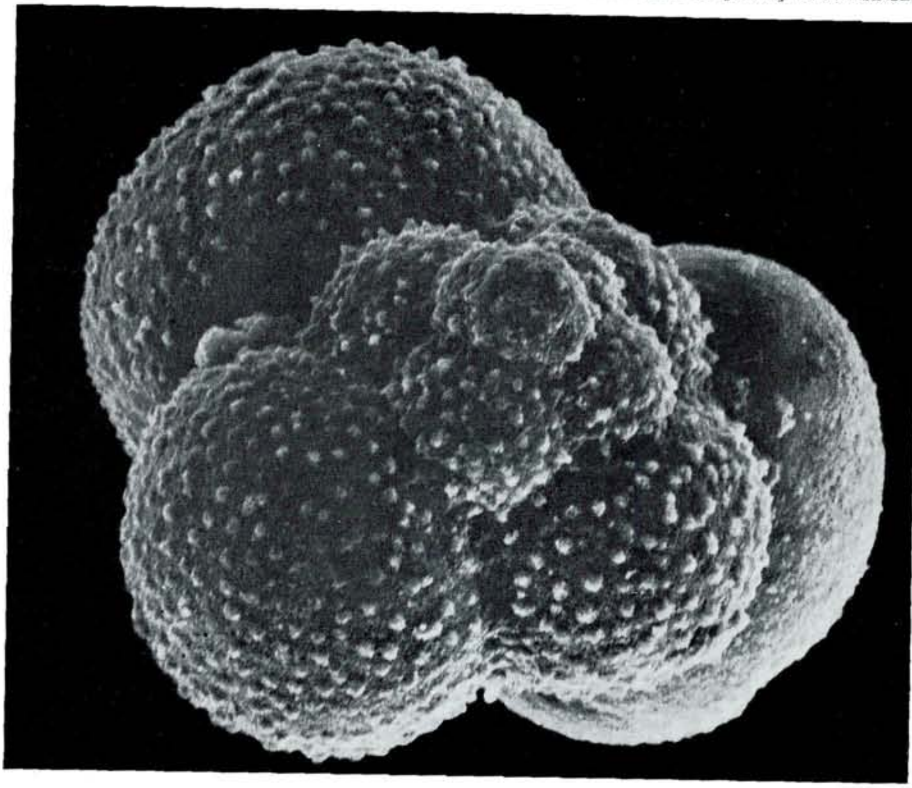
2



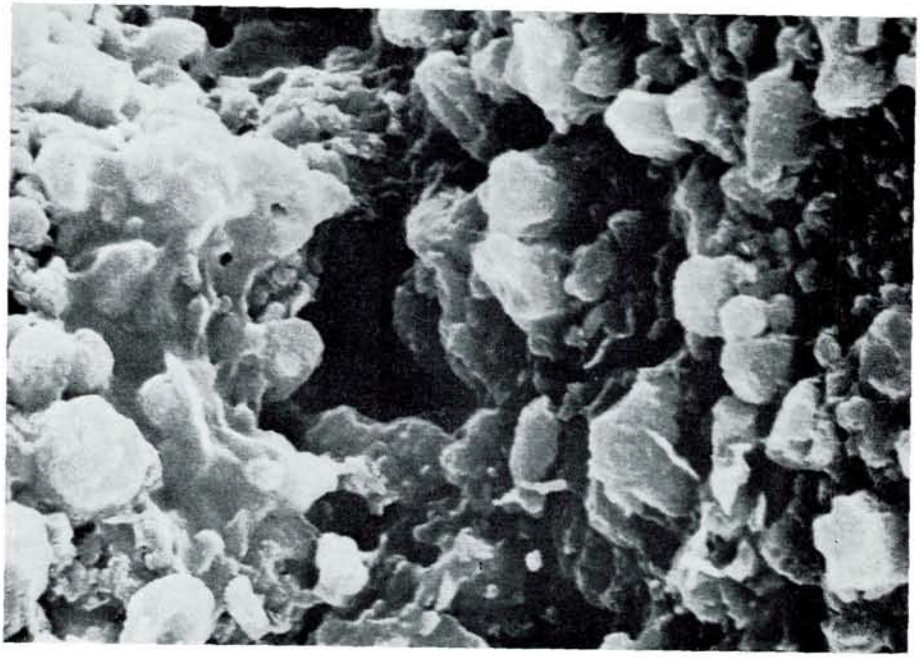
1



2



1



2