Morphology and phylogeny of pseudorbitoid foraminifera from Jamaica and Curaçao, a revisional study

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In the present paper, certain morphological features and the ontogenetical development of members of the subfamily Pseudorbitoidinae Rutten, 1935 are discussed. A study of the evolution of *Pseudorbitoides* Douvillé, 1922 resulted in testing the concept of nepionic reduction in populations of this genus from Jamaica (Green Island- and Sunderland Inlier) and Curaçao (Cas Abao Limestone lenses). Within the *Pseudorbitoides*-lineage, *P. trechmanni pectinata* subsp. nov. is distinguished from *P. trechmanni trechmanni* Douvillé on account of different post-juvenile features.

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Summary

Due to the presence of extremely rich populations of pseudorbitoid foraminifera in samples from Jamaica – from the type locality of *Pseudorbitoides trechmanni* Douvillé, 1922 near Green Island, as well as a continuous section in the Sunderland Inlier – and Curaçao, an investigation was started which aimed at 1) obtaining additional information on the morphology of the test and moreover, the ontogenetical development, and 2) reconsidering some phylogenetical tendencies, with the emphasis on testing the hypothesis of nepionic reduction, in successive populations of pseudorbitoids.

The morphology of the test has been the subject of several studies by Brönnimann (1954-1958), who distinguished a number of forms by tracing differences in the structure of the equatorial layer. However, due to a different conception of the diagnostic value of certain characteristics in the post-juvenile (= 'cyclical') phase of the equatorial layer, the recognizability of several representatives – *Historbitoides, Rhabdorbitoides, Aktinorbitoides* – is now considered questionable.

By studying the relationships between the various arrangements of juvenile chambers, Mac Gillavry (1963) contributed to a logical interpretation of the build of the equatorial layer, particularly its post-juvenile phase which in contrast to Brönnimann's views was considered to consist of true equatorial chambers. The present author fully endorses Mac Gillavry's opinions. The equatorial layer in *Pseudorbitoides* now appears comparable to the layer of equatorial chambers in other orbitoids, such as *Orbitoides* and *Lepidorbitoides*.

In *Pseudorbitoides* the building up of lateral chambers supposedly starts together with the formation of the primary chambers. The bulk of the material examined, however, shows the development of a continuous equatorial layer with layers of lateral chambers on both sides of it, indicating a certain time lag between the formation of equatorial chambers and the introduction of lateral chambers. On the other hand, the occurrence of actinate forms, such as *Aktinorbitoides,* with interradii interrupting the equatorial layer, reveals that a time lag is not always present. In this case it is considered that 'juvenile' lateral chambers, as the result of a comparatively slow increase of the number of chambers during the growth of the juvenarium, have reached the juvenile periphery. Subsequently, 'focus-points' of interradii may have been created by blocking the formation of equatorial chambers, at one or more places. This conclusion is based on the common occurrence of actinate forms in populations of primitive uniserial individuals, while such forms rarely occur in highly advanced populations. It is considered that the probability of the development of actinate forms diminishes as the result of progressive nepionic acceleration, with the accompanying early attainment of equal growth of equatorial chambers in all radial directions.

In this study special attention has been paid to the juvenarium which apparently passes through successive phylogenetical stages. The number of primary chambers (Y) and the diameter (width) of the protoconch (P) may represent valuable parameters for the purpose of distinguishing these stages from one another. It should be mentioned that Y in megalospherical forms is less useful for the distinction of the highest phylogenetical levels as the mean value appears to become stationary in these levels. In order to be able to define even these levels, the parameter P was introduced, its mean value having been observed to increase more or less steadily in five successive samples, followed by a sudden decrease in three successively younger samples.

From the behaviour of P and Y in megalospherical forms, it is concluded that evolution of *Pseudorbitoides curacaoensis* Krijnen, 1967, via *P. chubbi* Brönnimann, 1958 and *P. israelskyi* Vaughan & Cole, 1932, to *P. trechmanni* – the latter form is now designated as *P. trechmanni trechmanni* – represents one single lineage, notwithstanding the fact that a sudden decrease of the P-value in advanced forms, together with the development of different post-juvenile features, at first glance might suggest the presence of two independent lineages, or a bifurcation of the original lineage in a final stage.

The author is inclined to believe that evolution of the juvenarium proceeds towards an equilibrium between Y and P: once this stage has been reached, a further decrease of Y or increase of P do not seem to take place any more, unless circumstances permit, i.e., the maintenance of the equilibrium may be controlled by ecological factors, with changes or differences in the environment resulting in a shift of P and/or Y – in the case of the *Pseudorbitoides*-lineage mainly of P – to another equilibrium.

It is concluded finally that ecological factors indeed may have played an important controlling rôle in the evolutionary process, not only because of a sudden decrease of the size of the protoconch but also because of other internal and external differences in the build of the test (different structure of the pseudorbitoid layer; possession of a pectinate flange). Consequently, the forms encountered in samples J 3700, J 3680, J 3686 and J 3688 have been grouped as a new subspecies, *P. trechmanni pectinata.*

P. trechmanni trechmanni Douvillé and *P. trechmanni pectinata* subsp. nov. represent the highest stage of evolution in the subfamily Pseudorbitoidinae known to occur in Jamaica (the even more advanced *P. rutteni* Brönnimann, 1955 was described from Cuba).

Chapter 1. Introduction

ACKNOWLEDGEMENTS

In early 1967 paleontological fieldwork was started in Jamaica which was financed by the 'Koninklijke/Shell Prijs' awarded to Professor H. J. Mac Gillavry, under whose general direction the project was completed. I am greatly indebted to Prof. Mac Gillavry for being offered the chance to partake in this project and subsequently to study the collected pseudorbitoid foraminifera under his kind guidance. Sincere thanks are also due to Mrs. H. J. Mac Gillavry whose stimulating presence and enthusiasm, despite the rather primitive circumstances prevailing on the field trips, made our stay in Jamaica an unforgettable experience. To Dr. H. van Dommelen, who joined the Jamaican project for the purpose of studying rudist faunas, I owe many thanks for pleasant cooperation, stimulating comments and fruitful discussions of results.

I have been most fortunate in receiving advice and assistance from Dr. E. Robinson, head of the Department of Geology, University of the West Indies, Kingston, who liberally offered the use of the latest field data, aerial photographs and several detailed maps, and moreover, arranged our transportation so that we were able to hire Mr. Singh's memorable Landrover. I am also indebted to Mr. H. R. Versey, director of the Geological Survey, for valuable advice and the loan of camping equipment. Mr. D. H. Wozab, director of the Groundwater Survey, generously offered to the party the use of Green Park House, near Falmouth, as an operational base. The hospitality extended by Dr. and Mrs. Robinson, Mr. and Mrs. Versey, and also Mr. and Mrs. 'Dingle' Smith and Mr. and Mrs. Macbeath is gratefully remembered.

I also wish to thank both Mr. L. J. Chubb and Mr. R. Wright, of Kingston, for putting at my disposal useful field data. Dr. P. J. Bermudez kindly made available a valuable collection of Cuban material for comparison. Mr. D. J. Beets, Amsterdam, collected the sample X 6002 mentioned in this paper, in Curaçao in 1961. Additional samples J 5128 and J 5129 from the same locality were collected by Mr. Van Dommelen and myself, thanks to a 'Z.W.O.' grant. The Puerto Rican material of sample P 326 mentioned in this paper was collected in 1968 by Prof. Mac Gillavry and Mr. D. J. Beets.

To Professor J. J. Hermes and his staff members Mr. B. Meinster and Mr. B. Kuhry, I owe many thanks for the determination of Jamaican planktonic foraminifera.

I am furthermore indebted to Professor C. W. Drooger for critically reading the manuscript. To several colleagues, Messrs. Ph. Hoedemaeker, D. J. Beets, P. H. De Buisonjé, D. van Harten and J. Werner, I am indebted for lively discussions on various paleontological and stratigraphical problems which contributed to no small extent to the completion of the present paper.

Furthermore, I wish to express my great obligations to Shelltankers N.V., particularly its director, Mr. D. Rodenburg, for the arrangement of transportation to and from Kingston, and no less to the crews of the tankers Viana, Norse King, Hastula, Helisoma, Olympic Snow and Oscar Gorthon for their companiable hospitality. For the care of transporting 4,000 kg of rock samples from Jamaica to Amsterdam, thanks are due to Shell Jamaica.

Acknowledgements are due to the Netherlands Organization for the Advancement of Pure Research ('Z.W.O.'), whose financial support enabled me to carry out this study, also, fieldwork in Curaçao, and moreover, to have these results published.

Finally, thanks are due to Mr. C. van der Jagt for his skilful preparation of the thin-sections, and to Messrs. Th. Frank and R. van Oosterom for their photographical work.

GENERAL SCOPE

Though many detailed studies on the pseudorbitoid foraminifera have been made – see Douvillé (1922), Vaughan & Cole (1932-1943), Cole (1944), Keijzer (1945), Cole & Bermudez (1947), Brönnimann (1954-1958), Glaessner (1960) and Mac Gillavry (1963) – there are still some gaps in our knowledge of the morphology, ontogeny and phylogeny, at least there have been no satisfactory answers to some quite important questions.

There can be little doubt that this caused by the lack of continuous sections containing pseudorbitoid foraminifera at successive levels, and by the generally limited number of specimens studied.

As the present study was not hampered by a shortage of material, some morphological and ontogenetical problems could be unravelled. From the interpretation of morphological units, the investigation moved on to an evaluation of the evolutionary pattern. As a result, several supposed phylogenetical tendencies were reconsidered, with the emphasis on the behaviour of the juvenarium in successive populations.

Much work has already been done – mainly by M. G. Rutten, P. Brönnimann and H. J. Mac Gillavry – in order to establish the following generally accepted taxonomic frame work:

Family Pseudorbitoididae Rutten, 1935
Subfamily Pseudorbitoidinae Rutten, 1935
  Genera: *Pseudorbitoides* Douvillé, 1922
    Sulcorbitoides Brönnimann, 1954
    Historbitoides Brönnimann, 1956
    Rhabdorbitoides Brönnimann, 1955
    (*Conorbitoides* Brönnimann, 1958)
Subfamily Vaughanininae Mac Gillavry, 1963
  Genera: *Vaughanina*, Palmer, 1934
    Aktinorbitoides Brönnimann, 1958
    Ctenorbitoides Brönnimann, 1958

It should be mentioned that for the present study only certain members of the subfamily Pseudorbitoidinae have been analysed. In order to show the general structure of interradii in both subfamilies, a few specimens of *Vaughanina cubensis* from Cuba have been figured as well.

MATERIAL; DESCRIPTION OF LOCALITIES

The Jamaican material discussed below derives mainly from a sequence of Upper Cretaceous sediments in the Sunderland Inlier (Parish of St. James). The sample location map (textfigure 1) covers the southern part of this inlier, in which the following stratigraphical units have been recognized (see Chubb, in: Zans et al., 1962), from top to bottom:

4. *Shepherds Hall Conglomerates and Tuffs,* totalling about 900 m in thickness and provisionally included in the Campanian.
3. *Barrettia Limestone,* about 8 m in thickness. Its age is Campanian, according to Chubb. The limestone, in association with some shales, overlies the Newman Hall Shale conformably.
2. *Newman Hall Shale,* grey shales with large calcareous concretions. The combined thickness of the Newman Hall and the underlying Sunderland Shale is probably some 1,500 m. Chubb mentioned the occurrence of *Globotruncana stuarti* and *Globotruncana lapparenti tricarinata* which would indicate an Upper Campanian age.
1. *Sunderland Shale,* brown-weathering and well-bedded, with *Inoceramus* in its lowermost part; also yielding *Globotruncana stuarti, Globotruncana fornicata* and *Globotruncana lapparenti lapparenti* indicating a Campanian age.

The beds generally dip 30 to 40 degrees S to SSE. The shaly Sunderland and Newman Hall formations coincide with a large topographical depression. The resistent *Barrettia* Limestone takes the shape of a cuesta, with an escarpment which runs E – W to ENE – WSW, immediately to the south of the bridge of Stapleton.

For statistical analysis, mainly samples containing ample amounts of free individuals were used. For this reason samples taken from the hard calcarenitic *Barrettia* Limestone with larger foraminifera were not included. Instead, extremely rich samples have been used which were taken from debris in the immediate vicinity – almost *in situ* – of the limestone outcrops. However, several random thin-sections of the calcarenites have also been made in order to gather as much information on the general structure of the foraminifera as possible.

The following samples have been investigated:

J 3978, Jamaica

Located in the Parish of Hanover, near Green Island and Haughton Hall, West Jamaica. This is the type locality of *Pseudorbitoides trechmanni* Douvillé, 1922, from which Brönnimann obtained additional material (Brönnimann, 1955a, text-figure 1a). At the time of our visit the greater part of the area was still covered by sugar-cane and did not show any reliable rock exposures, in fact only some loose blocks of *Barrettia* Limestone were found. However, clay soil in the immediate vicinity of the limestone blocks proved to contain an abundance of pseudorbitoid material. These samples may be regarded as being derived from an interval in the basal (?) portion of the *Barrettia* Limestone unit.

Accompanying fauna: *Sulcoperculina* (abundant), *Fallotia*?, benthonic smaller foraminifera, ostracods and fragments of rudists, other mollusks (?) and echinoderms.

J 3416, Jamaica

Located in the Parish of St. James, between Sunderland and Amity Hall in the Sunderland Inlier (see textfigure 1). This sample, taken from a sandy-silty level in the Sunderland Shale, turned out to be very important as it contained primitive pseudorbitoids as well as planktonic foraminifera valuable for dating (see results obtained by the University of Amsterdam Microplankton Section, page 10).

Accompanying fauna: *Sulcoperculina,* benthonic smaller foraminifera, fragments of echinoderms.

J 3419, Jamaica

Located in the Parish of St. James, about 100 to 150 meters E of Stapleton in the Sunderland Inlier (see textfigure 1). The sample was taken from the upper part of the Newman Hall Shale, which is exposed just below the calcarenites of the *Barrettia* Limestone. In this part of the Newman Hall Shale succession, large calcareous-shaly concretions (up to 20 or even 30 cm in size) seem to reflect a prelude to the fore-reef conditions of the overlying *Barrettia* Limestone. These concretions proved to contain pseudorbitoid foraminifera.

Accompanying fauna: *Sulcoperculina,* fragments of rudists.

J 3700, Jamaica

Located in the Parish of St. James, between Amity Hall and Kensington in the Sunderland Inlier (see textfigure 1). The sample was taken from a 10 cm thick marly bed, a few centimeters below the base of the *Barrettia* Limestone (see textfigure 2), yielding an abundance of pseudorbitoid foraminifera.

Accompanying fauna: *Sulcoperculina,* ostracods and fragments of radiolitid rudists.

J 3601 and J 3697, Jamaica

Both samples were taken from soils which derived from the upper part of the *Barrettia* Limestone unit mentioned above in the description of sample J 3700. The sample localities are in the Parish of St. James between Amity Hall, Kensington and Stapleton in the Sunderland Inlier (see textfigure 1), and are approximately 1 km apart.

Accompanying fauna: *Sulcoperculina* (abundant), benthonic smaller foraminifera, ostracods and fragments of rudists, echinoderms and algae.

J 3680, Jamaica

Located in the Parish of St. James near Stapleton in the Sunderland Inlier (see textfigure 1). The sample was taken from a thin fossiliferous layer in outcropping sandy-conglomeratic sediments approximately 10-20 meters stratigraphically above the top of the *Barrettia* Limestone unit (see description of sample J 3700) which is exposed in the immediate vicinity of the bridge of Stapleton. The sample yielded an astonishing number of pseudorbitoids.

Accompanying fauna: *Sulcoperculina* (few), and fragments of rudists and echinoderms.

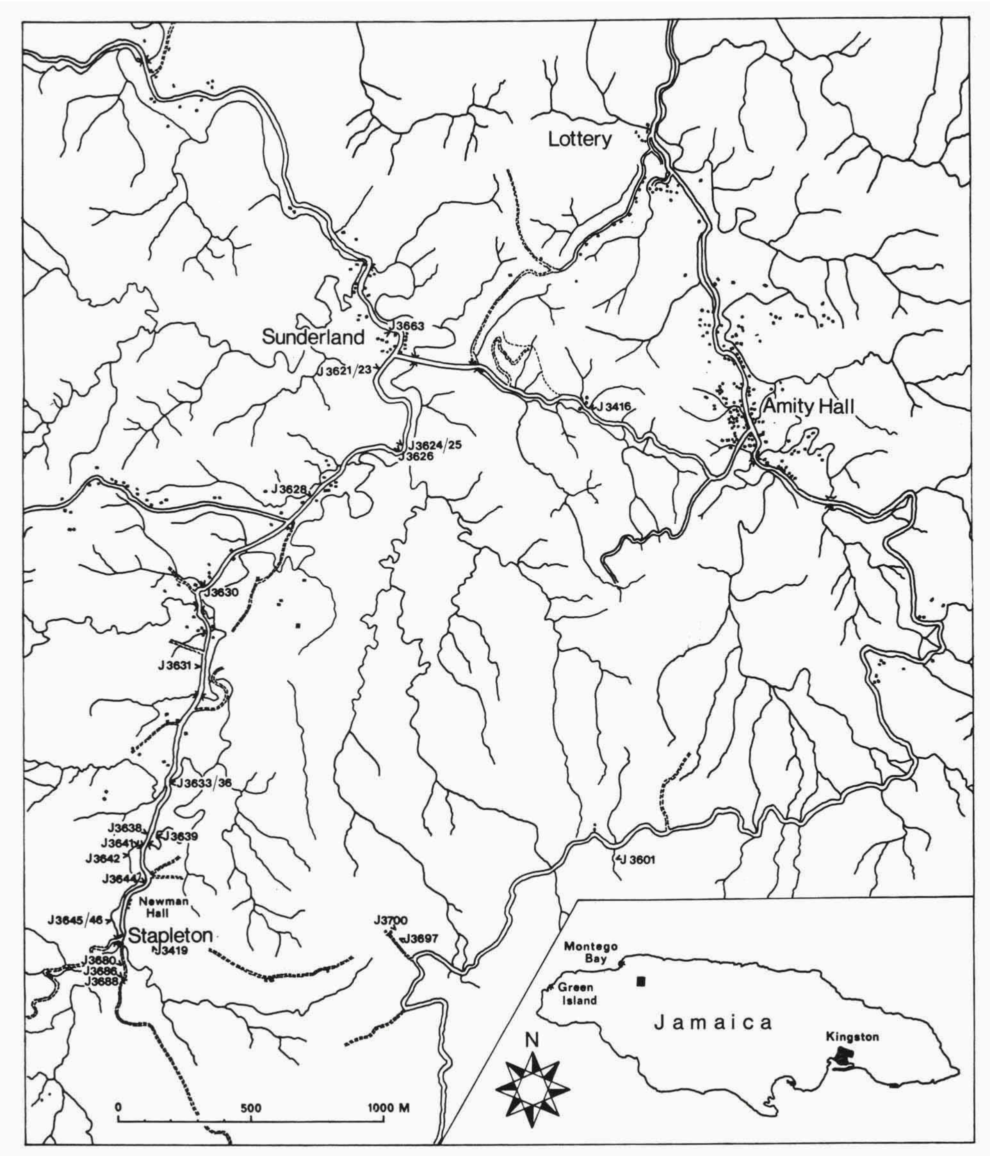


Fig. 1 – Map of the Sunderland/Stapleton area in the Parish of St. James.

J 3686, Jamaica

Located in the Parish of St. James near Stapleton in the Sunderland Inlier (see textfigure 1). This sample was taken from a marly level approximately 5 meters stratigraphically above sample J 3680, and yielding a satisfying number of pseudorbitoids.

Accompanying fauna: small forms of *Antillocaprina*?, rudist fragments and fragments of echinoderms.

J 3688, Jamaica

Located in the Parish of St. James near Stapleton in the Sunderland Inlier (see

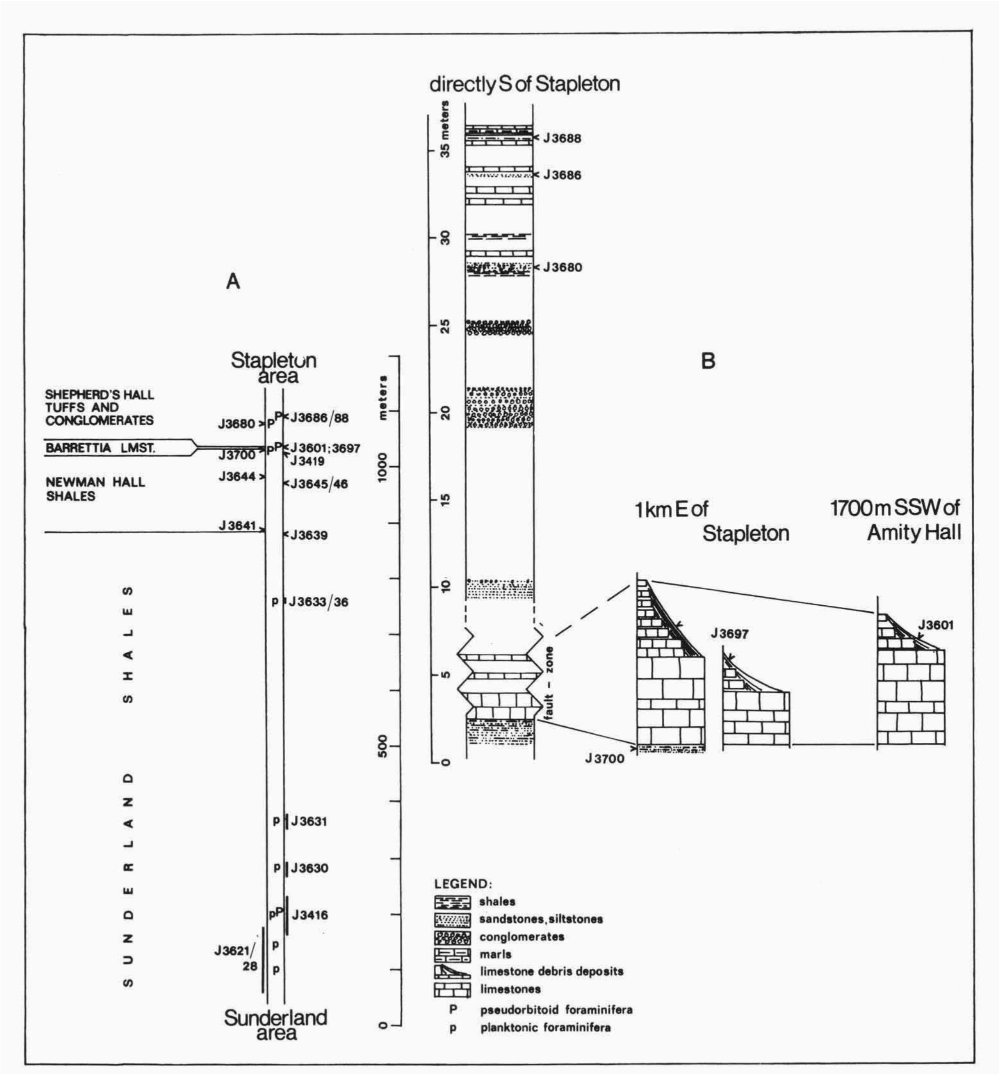


Fig. 2 – Part of the Upper Cretaceous sequence in the Sunderland Inlier (A) with detailed stratigraphical columns across the *Barrettia* Limestone and the overlying Shepherds Hall sediments in the Stapleton area (B).

textfigure 1). The sample was collected from a marly level about 2 meters stratigraphically above J 3686, and yielded many individuals of pseudorbitoid foraminifera.

Accompanying fauna: *Sulcoperculina* (many), rudist fragments, algae, ostracods and fragments of echinoderms.

X 6002, J 5128, and J 5129, Curaçao

Location of these samples about 1,500 meters ESE of the country-house St. Jan in the central part of Curaçao, the type locality of *Pseudorbitoides curacaoensis* Krijnen, 1967.

Sample X 6002, taken by Mr. D. J. Beets, and the samples J 5128 and J 5129 collected by the author in exactly the same locality as X 6002, derive from the westernmost of two calcarenitic limestone lenses (Krijnen, 1967, textfigure 1), designated as Cas Abao Limestone lenses (see Beets, 1966). The pseudorbitoids from this locality have been described in a previous paper as *Pseudorbitoides curacaoensis, Sulcorbitoides pardoi* Brönnimann, 1954 and *Aktinorbitoides browni* Brönnimann, 1958 (see Krijnen, 1967).

However, the author now prefer a different interpretation of some of the diagnostic criteria proposed by Brönnimann, with the result that all the forms mentioned above are presently considered to be members of one population, i.e. of *P. curacaoensis.*

Accompanying fauna: *Sulcoperculina,* some badly preserved planktonic foraminifera, fragments of rudists, echinoderms, algae and possibly bryozoa.

J 9667, Cuba

Locality: P. J. Bermudez, Station no. 239 (= R. H. Palmer no. 1214), 1 km west of Central San Antonio, Madruga, Prov. Matanzas. Some individuals of *Vaughanina cubensis* Palmer, 1934 from this locality have been figured hereafter (Plate 27) for the purpose of showing the general build of the equatorial layer in members of the subfamilies Pseudorbitoidinae and Vaughanininae.

P 326, Puerto Rico

Located about 380 meters north of the most northerly point of Isla Guayacan, about 4.7 km WSW of the centre of Parguera, Parguera Quadrangle, South-West Puerto Rico (= locality N. Sohl no. 546). One specimen of *Pseudorbitoides* cf. *P. israelskyi* Vaughan & Cole, 1932 from this locality has been figured in order to show the peculiarities of the two aktinorbitoid interradii interrupting the equatorial layer (see page 25, and textfigure 8). Pseudorbitoid material from this locality was sampled by Prof. Mac Gillavry and Mr. Beets during the Virgin Islands Conference in 1968.

Results obtained by the University of Amsterdam Microplankton Section (Mr. B. Meinster and Mr. B. Kuhry):

J 3663: *Globotruncana elevata* (Brotzen)
Globotruncana fornicata Plummer
Globotruncana rosetta (Carsey)
Globotruncana linneiana (d'Orbigny)
Globotruncana falsostuarti Sigal
Hedbergella sp.
Globigerinelloides sp.

J 3416: *Globotruncana fornicata* Plummer
Globotruncana arca (Cushman)
Globotruncana elevata (Brotzen)
Globotruncana falsostuarti Sigal
Globotruncana coronata Bolli
Globotruncana bulloides Vogler
Globotruncana linneiana (d'Orbigny)
Globotruncana rosetta (Carsey)

J 3621: *Globotruncana elevata* (Brotzen)
Globotruncana fornicata Plummer
Globotruncana rosetta (Carsey)
Globotruncana linneiana (d'Orbigny)
Globotruncana coronata Bolli
Globotruncana falsostuarti Sigal

J 3622: *Globotruncana fornicata* Plummer
Globotruncana elevata (Brotzen)
Globotruncana rosetta (Carsey)

J 3623: *Globotruncana fornicata* Plummer
Globotruncana linneiana (d'Orbigny)
Globotruncana elevata (Brotzen)
Globotruncana rosetta (Carsey)
Globotruncana bulloides Vogler

J 3625: *Globotruncana* sp.

J 3626: *Globotruncana fornicata* Plummer
Globotruncana coronata Bolli
Globotruncana linneiana (d'Orbigny)
Globotruncana elevata (Brotzen)

J 3630: *Globotruncana coronata* Bolli
Globotruncana elevata (Brotzen)
Globotruncana fornicata Plummer

J 3631: *Globotruncana fornicata* Plummer
Globotruncana elevata (Brotzen)
Globotruncana falsostuarti Sigal
Globotruncana coronata Bolli
Globotruncana ventricosa White

J 3634: *Globotruncana elevata* (Brotzen)
Globotruncana coronata Bolli
Globotruncana fornicata Plummer
Globotruncana falsostuarti Sigal

J 3636: *Globotruncana coronata* Bolli

Note: all samples mentioned in this paper have been deposited in the Geological Institute, Amsterdam University.

SUCCESSION OF SAMPLES; AGE

Both the Sunderland Shale and overlying Newman Hall Shale contain occasional horizons with pseudorbitoid foraminifera, as is proved by samples J 3416, J 3419 and J 3700. The overlying *Barrettia* Limestone and the lowermost portion of the Shepherds Hall Conglomerates and Tuffs contain abundant populations: cf. samples J 3601, J 3697, J 3680, J 3686 and J 3688, in this order of succession (see also textfigure 2).

From the results of phylomorphogenetical studies of the juvenarium of pseudorbitoids it is concluded that sample X 6002, and also of course samples J 5128 and J 5129 from the same locality in Curaçao, are considered to be older than the Jamaican sample J 3416. Moreover, sample J 3978 from the type locality of *Pseudorbitoides trechmanni* (in this study designated as *P. trechmanni trechmanni*) is considered to be older than sample J 3700, but younger than sample J 3416.

The Sunderland column has been considered as Campanian by Chubb (1962). However, according to A. G. Coates, J. E. Hazel and J. F. Mellow (personal communication to Mac Gillavry) the discovery of *Globotruncana contusa* in the Newman Hall Shale indicates a Maastrichtian age for the upper part of the column (Newman Hall Shale, *Barrettia* Limestone and Shepherds Hall Conglomerates and Tuffs).

Samples J 3663, J 3416, J 3621, J 3622, J 3623, J 3626, J 3630, J 3631 and J 3634 (see textfigure 2) contain sufficient planktonic foraminifera to determine their age within comparatively narrow limits. According to the University of Amsterdam Microplankton Section the fauna of these samples indicates a Late Campanian to Early Maastrichtian age. The presence of moderately conical specimens of *Globotruncana fornicata* Plummer may indicate an Early Maastrichtian age, but the Microplankton Section does not consider this as conclusive because species indicative of either Campanian – such as *Globotruncana calcarata* Cushman – or Maastrichtian – such as, for example, *Globotruncanella havanensis* (Voorwijk) and *Globotruncana contusa* (Cushman) – are absent.

PREPARATION OF MATERIAL; EQUIPMENT

For this study, numerous horizontal or near-horizontal central sections of pseudorbitoids have been made for analysis of the juvenile chamber arrangement. Again, oriented vertical and tangential sections have been prepared for the purpose of morphological studies of the pseudorbitoid layer.

In order to maintain the random selection of material for statistical purposes, individuals were drawn from the total sample by lot.

Grinding was done under the microscope by means of the frosted side of a glass-slide (Van Morkhoven's method, 1958). For the examination of the thin-sections, a monocular Leitz SM-POL microscope (no. 549594) was used, in combination with a Zeiss micrometer eyepiece (no. 4190554). The required drawings were made by means of a modern projection prism, while maintaining the same enlargement in the various textfigures.

Chapter 2. Brief historical review

To date, the most valuable studies of pseudorbitoid foraminifera are Brönnimann's (1954-1958). His results form a considerable step towards understanding of the relationships between the members of this family. Brönnimann's detailed descriptions enabled Mac Gillavry (1963) to tackle the phylomorphogenetical problems from the angle of Tan's concept of nepionic acceleration (Tan, 1932). Mac Gillavry's conclusions and considerations, however, necessarily remained somewhat theoretical, due to the lack of sufficient material. Yet they seem to be consistent.

Brönnimann and Mac Gillavry came to somewhat contradictory interpretations of certain structural elements (equatorial layer, primary lateral chambers, juvenarium). Therefore, a discussion of some basic problems is needed. The following extracts of publications by these authors are given:

SUMMARY OF BRÖNNIMAN'S WORK

The value of Brönnimann's work lies particularly in its detailed descriptions of the complex build of the test, with emphasis on the structure of the radial elements constituting the pseudorbitoid layer. The following morphological units are distinguished in the descriptions of the various forms:

Equatorial layer:
1. Nepiont: protoconch, deuteroconch and peri-embryonic chambers.
2. A zone with arcuate undivided chambers around the nepiont (in microspherical forms of *P. trechmanni* and *P. rutteni* exclusively).
3. The pseudorbitoid layer, consisting of radial elements around the nepiont or the zone of arcuate undivided chambers. This pseudorbitoid layer is continuous, except in *Aktinorbitoides*. In this genus it appears to be restricted to the so-called radii which alternate with interradii (wedge-shaped interruptions in the median plane which consist of lateral chambers).

Lateral chambers:
4. The primary lateral chambers, which form a layer on either side of, and adjacent to, the pseudorbitoid layer.
5. The layers of normal lateral chambers on either side of the pseudorbitoid layer + primary lateral chambers.

The significance of the structure of the pseudorbitoid layer has been emphasized by Brönnimann as is shown by the following table for the determination of genera (Brönnimann, 1958):

Test lenticular:	
Outline actinate	*Aktinorbitoides* Brönnimann, 1958
Outline circular:	
Equatorial layer with annular walls ..	*Vaughanina* Palmer, 1934
Neanic stage with radial rods:	
Two sets of radial rods	*Sulcorbitoides* Brönnimann, 1954
More than two sets of radial rods	*Rhabdorbitoides* Brönnimann, 1955
Neanic stage with radial plates:	
Single set of radial plates, as a rule not interconnected laterally	*Pseudorbitoides* Douvillé, 1922
Single set of radial plates, irregularly interconnected laterally and with incipient radii and interradii	*Historbitoides* Brönnimann, 1956
Test conical:	
Apex pointed, neanic stage sulcoperculinoid	*Conorbitoides* Brönnimann, 1958
Apex comb-like, neanic stage vaughaninid	*Ctenorbitoides* Brönnimann, 1956

With regard to phylogenetical tendencies, Brönnimann distinguished:

1. A development in the construction of the radial elements:
(a) from two systems of radial rods (*Sulcoperculina* and *Sulcorbitoides*) to a complex layer of more than two sets of radial rods (*Rhabdorbitoides*).
(b) from the sulcorbitoid layer of radial rods via a combination of radial rods and

radial plates (*Pseudorbitoides*) and a system of single radial plates (*Pseudorbitoides*), to complex radial elements with irregular horizontal interconnections (*Historbitoides*).
(c) from short radial rods – as in *Sulcoperculina* – to a continuous layer consisting of two sets of radial plates separated from the layers of lateral chambers by a roof and a floor (*Vaughanina, Aktinorbitoides* and *Ctenorbitoides*).
2. A development in the nepionic chamber arrangement from uniserial (*Sulcorbitoides, Pseudorbitoides* (?) *chubbi, P israelskyi*), via biserial and triserial (*P. trechmanni*) to quadriserial (*P. trechmanni, P. rutteni, Rhabdorbitoides, Historbitoides*).
3. A development of arcuate equatorial chambers around the nepiont (in microspherical forms of *P. trechmanni* and *P. rutteni*).
4. A development of actinate forms in the *Vaughanina*-lineage (*Aktinorbitoides*), and of stellate forms in the *Pseudorbitoides*-lineage (*Historbitoides*).

Brönnimann considered mainly two phylogenetical lineages: the first represented

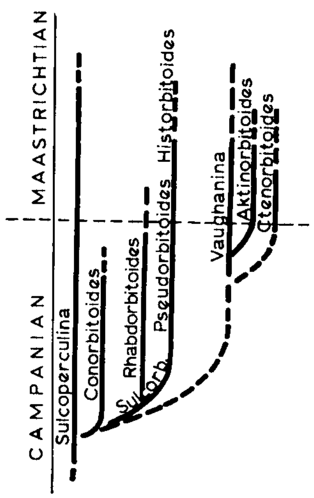


Fig. 3 – Evolution of the pseudorbitoid foraminifera as considered by P. Brönnimann.

by *Sulcorbitoides, Pseudorbitoides* and *Historbitoides*, with an offshoot from *Sulcorbitoides* to *Rhabdorbitoides;* the second represented by *Vaughanina* (and *Ctenorbitoides* ?) with an offshoot to *Aktinorbitoides* somewhere in this phylogenetical development (see textfigure 3).

SUMMARY OF MAC GILLAVRY'S INTERPRETATIONS

Primarily, Mac Gillavry stressed the resemblance of the juvenile equatorial chamber arrangement in the megalospherical forms of *Pseudorbitoides* (and related genera) to *Lepidorbitoides*. Therefore he was inclined to assume that, initially, the same type of phylomorphogenesis obtained in the evolutionary series of both the pseudorbitoids and lepidorbitoids, characterized by the introduction of a retrovert (= second) aperture in a uniserial spiral of uni-apertural chambers (Mac Gillavry, 1963). It was also supposed that the introduction of the retrovert aperture would behave in a deuterogenetical manner, and from this Mac Gillavry concluded that there is a logical development from a uniserial juvenarium, via a biserial and a triserial stage to the ultimate quadriserial juvenarium in forms in which the retrovert aperture shows a continuous shift down to the second chamber (deuteroconch).

The introduction of the retrovert aperture gives rise to the budding of biapertural primary chambers and of secondary chambers in the equatorial layer. The secondary chambers are arranged in spirals turning backwards (retrovert) or forwards, the first retrovert aperture usually giving rise to the formation of a retrovert spiral of secondary chambers, which delimits the primary chamber spiral. With the termination of the primary chamber spiral, the spiral arrangement of the equatorial chambers is considered to be abandoned. The next phase in the ontogenetical development is defined by the formation of cyclically arranged symmetrical secondary chambers up to the periphery.

In *Lepidorbitoides* for instance, no difficulties are encountered regarding this type of phylomorphogenesis. The equatorial layer in *Pseudorbitoides* and related genera, however, was considered as completely different by Brönnimann because of the presence of the radial elements in its cyclical phase. Suggesting the presence

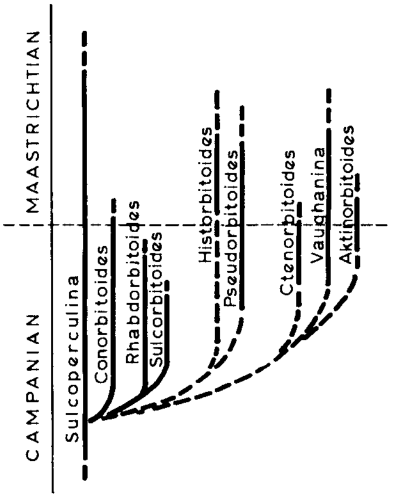


Fig. 4 – Evolution of the pseudorbitoid foraminifera as considered by H. J. Mac Gillavry.

of true secondary equatorial chambers in both megalospherical and microspherical forms (Brönnimann, 1955a, pl. 10, figs. 2, 4; textfigure 2 a-d; MacGillavry, 1963), Mac Gillavry advanced the hypothesis that the whole cyclical phase of the equatorial layer of *Pseudorbitoides* and allied genera is characterized by secondary chambers. Differences would be found in the construction of the cyclical secondary chambers, which have to be considered as being divided or traversed by the pseudorbitoid layer (it should be remembered that the juvenarium in microsperical forms of *P. trechmanni* and *P. rutteni* is surrounded by undivided arcuate secondary chambers). As a consequence, Mac Gillavry was inclined to regard each primary lateral chamber as defined by Brönnimann, as one half of a secondary equatorial chamber, hence, the layers of primary lateral chambers as the 'roof' and 'floor' part of the equatorial layer.

The presence of secondary chambers in megalospherical juvenaria and around the microspherical juvenarium is less surprising than the fact these chambers are not divided by the pseudorbitoid layer. Consequently the pseudorbitoid layer was considered to behave proterogenetically in its develcpment, that is, being 'pushed' outwards. Mac Gillavry even considered the possibility of a complete disappearance of this layer, ultimately resulting in the generation of *Orbitocyclina*-like homoeomorphs.

Mac Gillavry's table for the determination of genera, which follows Brönnimann's closely, is repeated below:

No lateral chambers present	*Sulcoperculina* Thalmann, 1939
Lateral chambers present .... fam.	Pseudorbitoididae Rutten, 1935
Sulcoperculinoid throughout	*Conorbitoides* Brönnimann, 1958
Sulcoperculinoid juvenarium:	
Equatorial chambers subdivided by pseudorbitoid layer of radial elements ...... subfam.	Pseudorbitoidinae Rutten, 1935
Radial rods:	
Two sets of radial rods	*Sulcorbitoides* Brönnimann, 1954
More than two sets of radial rods with complex interconnections	*Rhabdorbitoides* Brönnimann, 1955
Radial plates, nepionic stage reduced:	
Single set of radial plates, as a rule not interconnected laterally	*Pseudorbitoides* Douvillé, 1922
Single set of radial plates, irregularly interconnected laterally; incipient radii and interardii	*Historbitoides* Brönnimann, 1956
Equatorial chambers and chamber walls traversed by radial plates; later equatorial chambers concentrically elongated, with chamber walls perforated by radial stolons. Equatorial layer = pseudorbitoid layer, with roof and floor .... subfam.	Vaughanininae Mac Gillavry, 1963
Circular forms	*Vaughanina* Palmer, 1934
Conical forms, with comb-like adventitious equatorial layer	*Ctenorbitoides* Brönnimann, 1958
Actinate forms, with equatorial layer restricted to the radii	*Aktinorbitoides* Brönnimann, 1958

Mac Gillavry's interpretation of the evolution of the group, strongly based on Brönnimann's views, is illustrated by textfigure 4.

Chapter 3. Discussion of the morphology of the pseudorbitoidal test

Mac Gillavry's system in describing larger foraminifera, based on the ontogenetical introduction of a succession of new features in the equatorial layer (Mac Gillavry, 1963), resulted in a subdivision of the pseudorbitoidal test into the following morphological units which will be discussed in more detail in the following paragraphs:

1. the sulcoperculinoid uni-apertural phase, delimited by the ontogenetical appearance of the first retrovert aperture.
2. the juvenile phase or juvenarium, delimited by the ontogenetical appearance of the first symmetrical chamber terminating the primary chamber spiral (consisting of both juvenile equatorial chambers and juvenile lateral chambers).
3. the cyclical phase, initiated by the first symmetrical chamber terminating the primary chamber spiral (consisting of post-juvenile equatorial chambers and post-juvenile lateral chambers).

It is presently considered that the long radial elements which constitute the pseudorbitoid layer, protruded from the marginal walls of the equatorial chambers, and that the formation of the pseudorbitoid layer has been superimposed upon the equatorial chamber system. For a better understanding of the pseudorbitoid layer the development of the radial elements will be dealt with separately.

SULCOPERCULINOID PHASE; JUVENARIUM

Mac Gillavry (1963) regarded a nepionic stage as that part of the chamber development, which is delimited by the ontogenetical appearance of a new feature; the ontogenetical introduction of a succession of new features results in the delimitation of as many nepionic stages.

The ontogenetical introduction of the retrovert aperture which delimits the uni-apertural nepionic phase results in the termination of the primary spiral by a retrovert spiral of secondary chambers. The uni-apertural phase thus forms part of the juvenarium but does not coincide with it.

In the Pseudorbitoididae, the adjective 'sulcoperculinoid' can only be applied to the uni-apertural phase. In a former publication (Krijnen, 1967) the writer regarded the term 'sulcoperculinoid phase' as more or less synonymous with the terms juvenarium and primary chamber spiral. As the primary chamber spiral continues after the introduction of the retrovert aperture, the sulcoperculinoid phase is presently identified with the uni-apertural phase.

Phylogenetically, the introduction of the retrovert aperture behaves after the deuterogenetical manner, the number of sulcoperculinoid (uni-apertural) chambers gradually decreasing in the successive samples. According to Mac Gillavry the number of sulcoperculinoid chambers is to be taken as the most important evolutionary parameter. However, it can only be used in less advanced populations, up to the phylogenetical introduction of the second principal auxiliary chamber (for the nomenclature of juvenile chambers see textfigure 9). At this stage in the evolution the number of chambers in the sulcoperculinoid phase has become stationary (= 1) and further discrimination of evolutionary levels cannot be based on this parameter any more.

The pseudorbitoid test can be subdivided in a precyclical phase, with equatorial chambers arranged in spirals, followed by a cyclical phase. This is evident in advanced specimens in which one or two symmetrical chambers delimit the precyclical phase and initiate the cyclical phase. However, the subdivision, precyclical phase/cyclical phase, is less obvious in primitive members of the subfamily, with scarcely visible, cyclically arranged equatorial chambers. This is due to the presence of coarse radial elements starting in the precyclical phase (Plate 1, figs. 7-9; Plate 3).

The precyclical phase and the juvenarium are identical. It is defined as that portion of the chamber formation which is delimited by the ontogenetical appearance of either the first symmetrical chamber, or the first protoconchal symmetrical chamber (in quadriserial forms a distinction is made between the first protoconchal symmetrical chamber – on the protoconchal side – and the first deuteroconchal symmetrical chamber – on the deuteroconchal side). According to this definition of the precyclical phase or juvenarium, it includes (a) the primary chamber spiral – a continuous spiral of sulcoperculinoid uni-apertural chambers and bi-apertural spiral chambers, up to the ontogenetical introduction of the first symmetrical chamber – (b) a number of secondary chambers – issuing from the primary chambers, prior to the ontogenetical introduction of the first symmetrical chamber – and (c) the so-called juvenile lateral chambers (see page 24). As it is impossible to determine with certainty which secondary chambers are included in the juvenarium, my study was confined to the primary chamber spiral (see textfigure 5).

In primitive uniserial specimens, the initial undivided spiral chambers are considered as primary chambers. They are delimited by the formation of cyclically arranged chambers: the primary chamber spiral is cut off by radial elements protruding from an earlier primary chamber and dividing the first symmetrical chamber. By analogy, the primary chambers in advanced forms comprise: the protoconch, the deuteroconch, the first principal auxiliary chamber and the succeeding protoconchal spiral chambers up to the first (protoconchal) symmetrical chamber (textfigures 5 and 9).

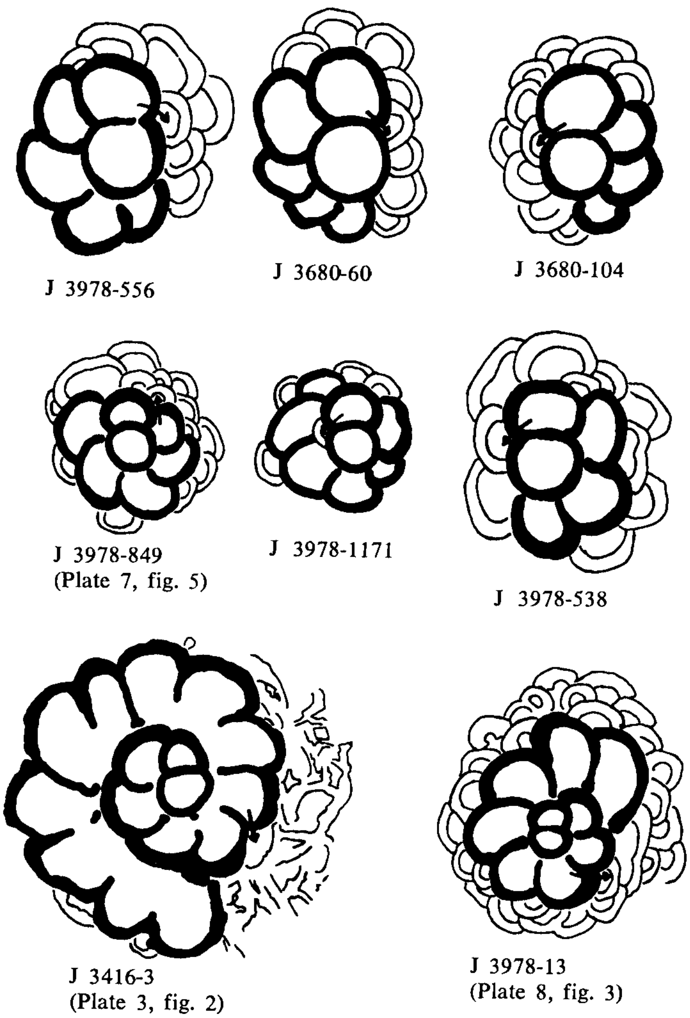


Fig. 5 – Initial chamber arrangements in various members of *Pseudorbitoides* Douvillé. The primary chamber spiral is drawn in black and the position of the first retrovert aperture indicated by an arrow.

It is concluded that the number of primary chambers (Y) can be used to distinguish evolutionary levels – even the highest – by gradually decreasing during phylogeny. Therefore the use of Y as an evolutionary parameter is preferred to employing the number of sulcoperculinoid uni-apertural chambers.

It should be noted that the phylogenetical delimitation of the juvenarium, and accordingly, the number of primary chambers, does not result from the introduction of the retrovert aperture exclusively. Considering that the formation of primary chambers in *Helicolepidina* persists up to the periphery due to a different rate of growth of the primary and secondary chambers (Mac Gillavry, 1963), the influence of the rate of retrovert growth of secondary chambers in pseudorbitoid foraminifera is not to be neglected. In some primitive pseudorbitoids the rate of retrovert growth of secondary chambers is less than that of the formation of primary chambers, while some of the earlier secondary chambers do not seem to have a retrovert aperture at all. These early secondary chambers are surrounded by the next whorl of the primary chamber spiral, so that, in this respect, the juvenarium resembles the helicolepidine type (Krijnen, 1967: textfig. 7; present textfigure 6). These indications of a helicolepidine arrangement disappear as evolution progresses. However, the retrovert growth of secondary chambers does not keep pace with the forward growth of the primary chambers – not even in the quadriserial forms found in the youngest samples investigated (see textfigure 5), or in the apparently stratigraphically even younger genus *Historbitoides* – and therefore results in asymmetry of the two protoconchal spirals.

Samples J 3601 and J 3697 however, though stratigraphically not the highest, are exceptional as most of their quadriserial specimens are symmetrical (Plate 16, figs. 1, 2, 4, 5; Plate 17, fig. 1).

For an analysis of the rôle played by the total number of primary chambers (Y) and the diameter (width) of the protoconch (P) and deuteroconch (D), in successive populations, see page 27.

POST-JUVENILE EQUATORIAL LAYER

Although in fact both Brönnimann and Mac Gillavry based their conclusions on virtually the same material, a different evaluation of the structural elements caused diversity of opinion on the ontogenetical development. Brönnimann strongly emphasized the characteristics of the pseudorbitoid layer, which he considered equivalent to the equatorial layer in other larger foraminifera. He gave excellent descriptions of the radial elements but failed to recognize the presence of equatorial chambers, except in the centre – with equatorial chambers undivided by radial elements – of microspherical forms of *P. trechmanni* and *P. rutteni.* He also seemed undecided as to the exact evolution pattern displayed.

Following Mac Gillavry, the present author assumes that the equatorial layer consists of both primary and secondary chambers, and that the pseudorbitoid layer should be interpreted as a structural element within the equatorial layer. This interpretation has the advantage of (1) adherence to the general principle underlying the development of the equatorial layer in orbitoids, the pseudorbitoids included, and (2) giving a clue to the understanding of the radial elements.

Mac Gillavry's point of view is endorsed by the present author's observations. If we suppose, as did Brönnimann, that the pseudorbitoid layer is an independent structure – in the system (1) pseudorbitoid layer = equatorial layer, and (2) layers of lateral chambers on either side of this equatorial layer – we might expect the growth of radial elements to be unaffected by the layers of lateral chambers – Brönnimann's primary lateral chambers – on either side of the equatorial layer. However, when studying the radial elements closely, the opposite is found to be true: it can be shown that radial elements grow outwards in a slightly winding manner – sometimes following a zig-zag course, though not very markedly so – in such a way that successive portions protrude more or less perpendicularly from the walls of preceding 'primary lateral chambers'. This is clearly visible in slightly eccentric horizontal sections which cut the primary lateral chambers as well as the radial elements (Plate 3, fig. 2 upper part; Plate 18, figs. 1-5; Plate 20, fig. 1; Plate 26, figs. 1, 2). The shape and arrangement of the primary lateral chambers again seem to endorse Mac Gillavry's view as these chambers show a marked resemblance to the equatorial chambers in other orbitoid foraminifera, for instance, *Lepidorbitoides*. Furthermore, shape and arrangement of the primary lateral chambers as seen in horizontal sections (Plate 7, figs. 3, 6; Plate 18, fig. 1) are different from the normal lateral chambers which are pronouncedly polygonal, whereas the former are distinctly arcuate to truncated arcuate. These differences undoubtedly originated from the budding of primary lateral chambers through one or more equatorial apertures, whereas addition of lateral chambers takes place through a fine pore-system, visible in all chamber walls.

It is my considered opinion that the growth of primary lateral chambers as defined by Brönnimann is of utmost importance for the development of the equatorial layer, whereas the pseudorbitoid layer is not. Furthermore, the development of primary lateral chambers may be considered equivalent to that of the equatorial chambers in other orbitoid foraminifera, so that every primary lateral chamber is thought to represent either the upper or lower 'half' of a true equatorial chamber. The growth of the equatorial layer can be explained by (1) periods of growth of the radial elements beyond the periphery of the equatorial layer, alternating with (2) periods of growth stagnation in which the radial elements are enveloped by subsequent equatorial chambers.

A high degree of cyclical development of equatorial chambers is reached in megalospherical forms found in samples J 3700, J 3680 and J 3688, so that, in a late ontogenetical phase, an equatorial layer is developed which might be thought to consist of annular chambers resembling those of *Vaughanina* in horizontal sections. This, however, is definitely not the case: instead, radial rows of truncated arcuate equatorial chambers appear to be separated by radial plates, the result being a pseudo-annular chamber arrangement. The presence of radial stolons in this structure of the equatorial layer is presumably connected with the radial growth pattern of the equatorial chambers (Plate 26, figs. 1, 2).

PSEUDORBITOID LAYER (LAYER OF RADIAL ELEMENTS)

On the basis of the shape and spatial arrangement of the radial elements, Brönnimann distinguished various genera (see page 13). However, the present author observed so much variation of the radial elements, that their value for classification is deemed questionable: the incipient radii (see page 26) and the irregular character of the plates in the pseudorbitoid layer of *Historbitoides* are not confined to this genus, but are also present in both primitive and more advanced forms of

Pseudorbitoides (*P. curacaoensis, P. chubbi,* and *P. trechmanni;* see Plate 1, figs. 1-5; Plate 4, fig. 5; Plate 19, fig. 9; Plate 20, figs. 2, 3). As presumably in *Historbitoides,* the incipient stellate character of the test in *Pseudorbitoides* may well have been caused by irregularities in the arrangement of the equatorial chambers in the cyclical phase: compare specimen 'S'J 3697-67, Plate 18, fig. 2, which is as good an example as any, showing an inward kink in the annular arrangement of its equatorial chambers (this phenomenon has often been observed in other individuals, though on a smaller scale). Consequently, the radial elements, which protrude more or less perpendicularly from the walls of the equatorial chambers (see page 19), are seen to converge, and in extreme cases to run into one another (Plate 18, figs. 1, 2, 4, 5), occasionally even resulting in a radius-like structure (Plate 20, figs. 1-3), as described from *Historbitoides.*

However, although rejecting the use of the radial elements for the separation of genera and species alike, the writer is very much aware of the general increase in complexity of the pseudorbitoid layer as described by Brönnimann.

The development of the pseudorbitoid layer may have been affected by ecological factors, as seem indicated by the examination of populations of *Pseudorbitoides trechmanni pectinata* subsp. nov., which were collected from levels just below and above the *Barrettia* Limestone in the neighbourhood of Stapleton (samples J 3700, J 3680, J 3686 and J 3688). The number of primary chambers in *P. trechmanni pectinata* does not differ significantly from that in *P. trechmanni trechmanni.* These subspecies can be distinguished from one another, however, by differences in the cyclical arrangement of the equatorial chambers, the construction of the pseudorbitoid layer and the size of the embryonic chambers. The radial plates in *P. trechmanni pectinata* are distinctly coarser than in *P. trechmanni trechmanni,* and have delicate interconnections. The distance between the plates is also clearly larger, as is testified by the number of plates per quadrant (30 in *P. trechmanni pectinata,* against approximately 60 in *P. trechmanni trechmanni;* see Plate 11; Plate 12; Plate 25, figs. 1-3) and by the fact that in *P. trechmanni pectinata* the radial plates do not traverse, but tend to border the equatorial chambers, separating radial rows of these (as seen in horizontal sections). The rows increase in number during ontogeny: an existing row of equatorial chambers bifurcates, while at each fork a new radial element is formed between the two rows of new chambers.

Differences in environmental conditions may well have been responsible for differences in the cyclical chamber arrangement, the construction of the pseudorbitoid layer, the size of the protoconch and deuteroconch and even the size of the microspherical tests. This opinion may be supported by the following considerations:

1. Successive populations of the *P. trechmanni* group show a reasonable phylogenetical development of the number of primary chambers.
2. *P. trechmanni trechmanni* seems to be restricted to typical fore-reef conditions (*Barrettia* Limestone); *P. trechmanni pectinata,* on the other hand, seems to be connected with shales, marls, sandstones and conglomerates.
3. Mixed populations of *P. trechmanni pectinata* and *P. trechmanni trechmanni* have not been encountered in a stratigraphical succession which shows sharp facies breaks.

Mac Gillavry suggested that the pseudorbitoid layer undergoes a proterogenetical effect. This was based on the occurrence of undivided equatorial chambers in the early part of the cyclical phase in microspherical forms of *P. trechmanni trechmanni* (Green Island, Jamaica) and *P. rutteni* (Cuba) (Mac Gillavry, 1963; see also page 15). There does indeed appear to be a gradual centrifugal shift of the pseudorbitoid layer (Plate 22). My views, however, hold the nepionic reduction responsible for this, which drives the precyclical phase back to an ever earlier ontogenetical stage and causes the formation of secondary chambers around the juvenarium, even before the ontogenetical introduction of the pseudorbitoid layer. This concerns both the microspherical and the megalospherical forms, in which cyclical arrangement of secondary chambers, occurring prior to the appearance of the pseudorbitoid layer, means a complication in the ontogeny which for comparative purposes must be eliminated. This can be done by counting the total number of budding stages preceding equatorial chambers with radial elements protruding from their marginal walls (instead of counting the total number of undivided secondary chambers).

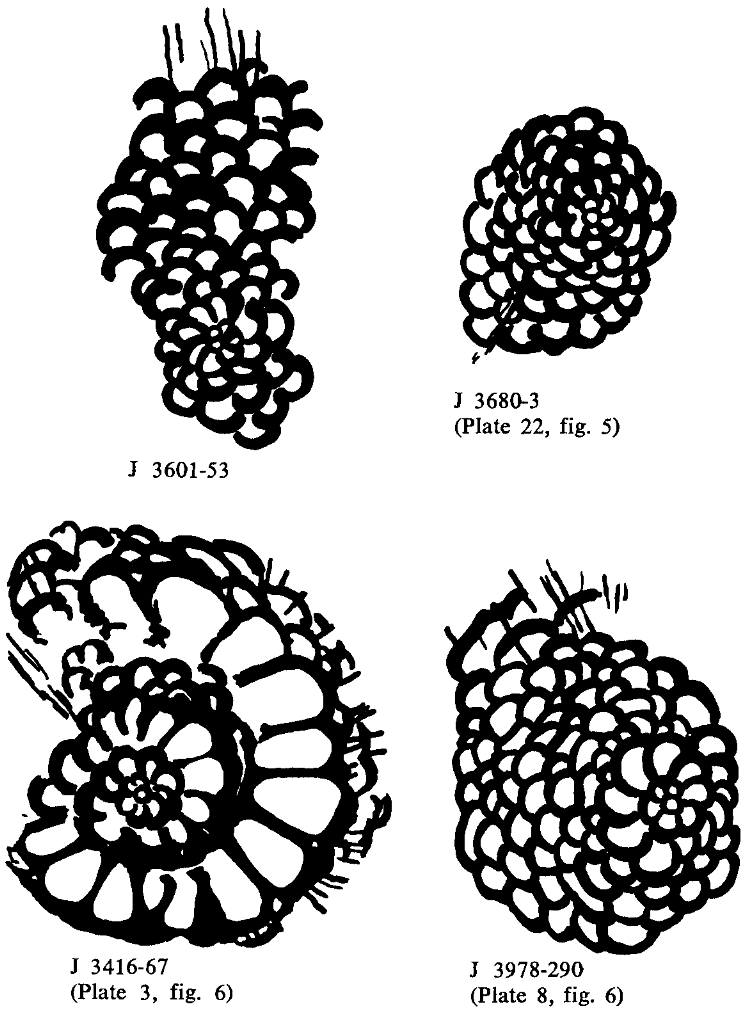


Fig. 6 – Central parts of horizontal sections of microspherical members of *Pseudorbitoides* Douvillé, showing the uniserial juvenarium, the zone of arcuate (undivided) equatorial chambers (with the exception of specimen no. J 3416-67) and the first radial elements.

The following table gives the counts of budding stages in specimens from a number of samples:

samples		number of budding stages prior to the appearance of radial elements	
		megalospherical forms	microspherical forms
J 3680	*(pectinata)*	8 - 10	18/19
J 3601, J 3697	*(trechmanni)*	4 - 5	18 - 31
J 3700	*(pectinata)*	8 - 15	
J 3978	*(trechmanni)*	4 - 6	19 - 30
J 3416	(cf. *chubbi)*	7 - 11	21
J 5129, X 6002	*(curacaoensis)*	8 - 17	

Obviously, there is no question of a gradually increasing number of budding stages, yet some slight acceleration of the nepionic reduction may have taken place, at least in the megalospherical forms. Slightly larger number of budding stages in *P. trechmanni pectinata* (samples J 3700 and J 3680) may be the result of special environmental conditions.

In microspherical forms the number of budding stages seems to be fairly constant, possibly as a result of the generally conservative nature of the microspherical generation (see textfigure 6).

As to the radial elements, these may originate from deposition of calcareous matter along protoplasm streamlets protruding through radial apertures in the equatorial chamber walls. At any rate, the radial elements are prone to growing more or less perpendicularly to the walls of the equatorial chambers (see page 19), and moreover, the presence of radial stolons in the equatorial chamber walls between the radial plates has been ascertained (Plate 20, fig. 4; Plate 26, figs. 1, 2). However, on the whole it is difficult to prove the presence of radial stolons, either because it is often impossible to decide whether we are dealing with stolons or spaces between radial elements, or because of a blurred microscopic image due to some recrystallization. One gets the impression, however, that radial stolons are present even when invisible, considering the generally radial arrangement of the equatorial chambers.

Initially a system of equatorial chambers appears to be present with interconnecting radial stolons. In a later phase of the ontogeny this pattern changes: as the equatorial layer thickens toward the periphery, the pseudorbitoid layer thickens too until at the outer edge the space between roof and floor of the equatorial chambers seems to be wholly taken up by the pseudorbitoid layer. In this ontogenetical phase the pseudorbitoid layer seems to consist of a large number of radial tubules which might have derived from the original stolons (Plate 20, figs. 2, 3).

Apart from these radial tubules, intramural lumina are present in the chamber walls as well as the radial elements (Plate 26, fig. 1).

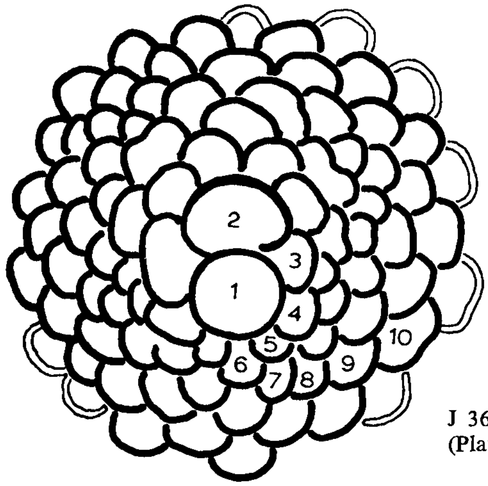
LATERAL CHAMBERS

Because the lateral chambers are overlapping like roofing-tiles and have a polygonal shape, they may have originated from the numerous pores in the equatorial and lateral chamber walls (Plate 20, figs. 4, 6), rather than from a few large apertures.

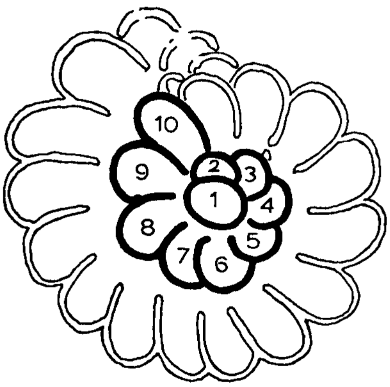
The presence of lateral chambers appears to be closely related to the orbitoid structure and is, in pseudorbitoids, characteristic for such forms as are supposed to be derived from *Sulcoperculina* (which has no lateral chambers).

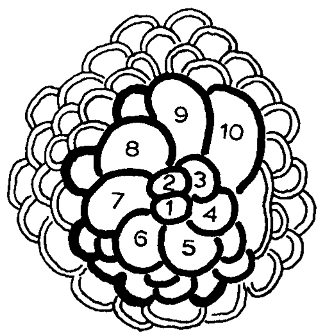
The question is whether there may be a correlation between the first ontogenetical appearances of lateral and secondary chambers. The answer may be in the affirmative, in which case we might assume that the first ontogenetical appearance of lateral chambers is also subjected to a deuterogenetical affect. This proces may proceed to the extent that lateral chambers may form simultaneously with primary chambers, that is, in the juvenile phase.

Generally speaking there may be a time-lag between the formation of equatorial chambers and lateral ones, resulting in an uninterrupted growth of the equatorial layer. However, since actinate forms occur commonly, we may be fairly certain that lateral chambers and juvenile equatorial chambers occur approximately



J 3601-214
(Plate 16, fig. 5)





J 3416-53

J 3978-13
(Plate 8, fig. 3)

Fig. 7 – Growth of the equatorial chambers after the first 10 buddings in 3 megalospherical specimens which are considered to represent 3 successive phylogenetical stages. In each specimen the chambers formed during these budding stages are drawn in black.

simultaneously and that they can impede one another's growth. When this happens, the result is either a deformation of equatorial chambers, or their replacement at the (juvenile) periphery by lateral chambers (= focus-points of aktinorbitoid interradii) so that no secondary equatorial chambers can be formed there.

As actinate forms occur mainly in primitive populations and because the focus-points of the interradii in all cases originate close to the juvenarium, we may assume that lateral chambers develop at an early stage in the juvenile phase and are furthermore responsible, to a large degree, for the occurrence of interradii. Consequently, the occurrence of interradii depends on the growth-rate of the juvenile equatorial layer. A slow growth of primary and secondary juvenile chamber spirals, as happens mainly in primitive forms with a persistent uniserial juvenarium, would favour the formation of aktinorbitoid interradii. In other words, a late ontogenetical beginning of cyclical formation of equatorial chambers provides conditions favouring the formation of aktinorbitoid interradii (see textfigure 7). In summing up, we may conclude that the formation of aktinorbitoid interradii should not be regarded as a new characteristic, but as a purely mechanical consequence of the build of the primitive uniserial juvenarium in which the formation of one or more equatorial chambers is evidently easily hampered by the formation of lateral chambers.

Once the development of an interradius has started, a corresponding interruption of the equatorial layer will generally persist throughout further growth. This, however, is not true in all cases, as may be gleaned from a photograph of a Puerto Rican pseudorbitoid (*Pseudorbitoides* cf. *P. israelskyi*, see page 10 and textfigure 8). In this specimen originally two aktinorbitoid interradii developed, one of which is enclosed by radial elements – and consequently, by equatorial chambers – in a later ontogenetical phase.

REMARKS

Some of Mac Gillavry's conclusions were based on a few pseudorbitoids collected 10.6 km west of Tuxtla Gutierrez, Chiapas, Mexico. As there are distinct rays with divergent growth of radial elements in at least one megalospherical specimen, he determined this material as *Historbitoides* sp. (Mac Gillavry, 1963: fig. 9; Plate 8, fig. 1).

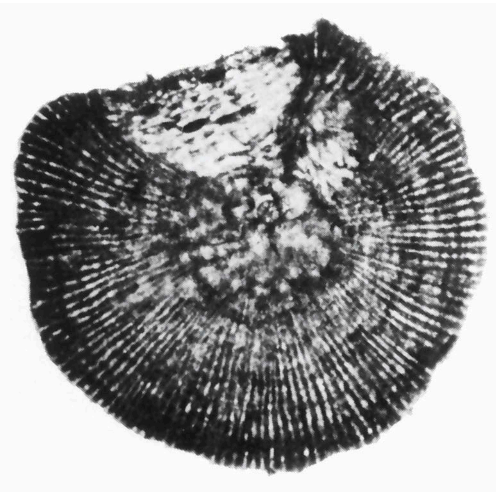


Fig. 8 – *Pseudorbitoides* cf. *P. israelskyi* Vaughan & Cole from Puerto Rico (locality N. Sohl 546; specimen no. P 326-36). The equatorial layer is seen to be interrupted by two aktinorbitoid interradii of which the right one is completely enclosed by the radial elements soon after its appearance.

Mac Gillavry drew attention to the fact that the pointed inner ends of the rays start at the partition between two secondary chambers. However, some of these chambers, particularly the ones approaching a triangular shape, actually may well be interradial lateral chambers, as is suggested by a comparison between the Mexican material and Jamaican specimens from sample J 3416 (Plate 3, figs. 1, 5). Consequently, it cannot be argued that these chambers denote a proterogenetical centrifugal shift of the radial elements, as suggested by Mac Gillavry (1963, p. 172).

Reverting to the Mexican material, the writer cannot agree with Mac Gillavry's above-mentioned identification of rays observed in a horizontal section of a megalospherical specimen, with the radii in *Historbitoides*. In the first place one should realize that Brönnimann's differentiating between incipient radii and interradii – in the equatorial layer of type material of *Historbitoides kozaryi* – was based on peripheral vertical sections, and such sections have not been made from the Mexican material available to Mac Gillavry, who therefore did not have at his disposal the only sections showing the swelling of the equatorial layer and the arrangement of radial plates around the axis of a radius. Secondly, the writer is convinced that the formation of a radius (incipient radius according to Brönnimann) results from a convergent, and definitely not divergent, growth of the radial elements towards the periphery (see page 20). This opinion is based on detailed observations on the growth of the radial elements shown in peripheral sections of Jamaican pseudorbitoids, in which an historbitoid arrangement of radial plates around a radial axis is occasionally visible. That this arrangement converges towards the periphery of the test, is shown by horizontal sections (Plate 20, figs. 1-3).

It seems improbable, therefore, that the Mexican specimens mentioned above should have an historbitoid stellate equatorial layer, as stated by Mac Gillavry. Actually, this layer appears to be actinate, resembling the Puerto Rican specimen of *Pseudorbitoides* cf. *P. israelskyi* rather closely (see textfigure 8). The writer therefore prefers regarding the Mexican pseudorbitoids as members of *Pseudorbitoides*. Moreover, the uniserial arrangement of the primary chambers, their number – about 7 in the megalospherical form, and 18 in the microspherical one – and the diameter of the megalospherical protoconch (50 micron), refer the Mexican specimens to either *P. israelskyi* or *P. trechmanni.*

REVISED DEFINITIONS OF MORPHOLOGICAL CHARACTERISTICS

Embryo – First (protoconch) and second chamber (deuteroconch).
Equatorial layer – Layer consisting of one subspherical chamber (protoconch) and the additional arcuate to truncated arcuate chambers, intercommunicating by means of one or two apertures and/or radial stolons, the whole situated in a median plane of the test.
Peri-embryonic chambers – Equatorial chambers immediately surrounding the embryo.
Primary chamber spiral – Spiral of equatorial chambers consisting of the protoconch, deuteroconch, principal auxiliary chamber and the corresponding protoconchal spiral of asymmetrical chambers up to the first symmetrical chamber. If two protoconchal spirals are present – for instance in quadriserial juvenaria – the one which contains the larger principal auxiliary chamber is designated as the primary chamber spiral; if the principal auxiliary chambers are equal in size, this designation is reserved for the spiral containing the larger number of asymmetrical chambers.

Primary chambers – The chambers which constitute the primary chamber spiral.
Juvenarium – Arrangement of equatorial and lateral chambers which have been formed prior to the budding of the first symmetrical chamber (which terminates the primary chamber spiral).
Post-juvenile phase – Comprising all the chambers which have grown since the budding of the first symmetrical chamber which terminates the primary chamber spiral.
Retrovert aperture – Distal aperture in the wall of a spiral chamber (opposite the proximal aperture).
Secondary chambers – All equatorial chambers with the exception of the primary chambers.
Budding stage – Period in which one equatorial chamber is formed (in the cyclical phase a budding stage may equally well refer to the period in which several equatorial chambers develop simultaneously).
Pseudorbitoid layer – Layer of radial elements, developed within the equatorial layer. When introduced, this layer divides each subsequent equatorial chamber in a top and bottom 'half'.
Radial elements – Secondary calcareous deposits, presumably developed along protoplasm streamlets protruding from radial stolons in the equatorial chamber walls during the life of the foraminifera.
Aktinorbitoid radius – Sector in the equatorial plane of actinate tests, to which the equatorial chambers are confined.
Aktinorbitoid interradius – Sector in the equatorial plane of actinate tests, which is composed exclusively of lateral chambers.
Actinate – Structure of the equatorial layer which is characterized by the presence of one or more aktinorbitoid interradii (this structure is not confined to the vaughaninid genus *Aktinorbitoides,* but occurs in the entire family Pseudorbitoididae).
Historbitoid radius – Radial swelling of the equatorial layer in which radial plates are arranged around the axis of the radial swelling.
Pectinate – Comb-like appearance of the outer margin of the test, resulting from a slight protrusion of the radial elements beyond the peripheral equatorial chambers.

Chapter 4. Phylomorphogenesis

This study aimed at testing the hypothesis of nepionic reduction in *Pseudorbitoides* with the aid of ample material, collected in stratigraphical order. The results leave no doubt about the existence of nepionic reduction in evolution. The phylogenetical introduction of retrovert apertures and its nepionic acceleration explain (1) the gradual reduction of the number of primary chambers, and (2) the change from uniserial to quadriserial juvenaria. The diameter (width) of the protoconch has also been analysed numerically. During evolution of megalosperical forms it tends to increase. Finally, the maximum diameter and thickness of the test were measured, in order to evaluate their diagnostic significance, if any.

NUMBER OF PRIMARY CHAMBERS (Y)

On the whole the number of primary chambers could be ascertained quite conveniently. In most cases the primary chamber spiral is easily recognizable, particularly in specimens in which the first principal auxiliary chamber is distinctly larger than the second (see textfigure 9). In a few advanced specimens from samples J 3601 and J 3697, with symmetrical quadriserial juvenaria, the principal auxiliary chambers are approximately of a size and the protoconchal spirals equally long; in these cases the designation of the primary chamber spiral is rather arbitrary, though immaterial to the analysis. The total number of primary chambers was counted by starting with proto- and deuteroconch, and following the spiral of asymmetrical primary chambers up to the first symmetrical chamber (see textfigure 9).

As based on the number of chamber spirals in the juvenarium, the juvenile chamber arrangements are designated as:

Uniserial – The retrovert aperture has not reached the third primary chamber.
Biserial I – The retrovert aperture has reached the third primary chamber; only one principal auxiliary chamber present.
Biserial II – The retrovert aperture has reached the second primary chamber or deuteroconch; two principal auxiliary chambers present; chamber spirals issuing from the second principal auxiliary chamber absent.
Triserial – The retrovert aperture has reached the deuteroconch; two chamber spirals issue from the first principal auxiliary chamber, one – either a protoconchal or a deuteroconchal spiral – from the second principal auxiliary chamber.
Quadriserial – The retrovert aperture is present in the deuteroconch; two principal auxiliary chambers present, from each of which a pair of chamber spirals issues forth.

The biserial II and triserial chamber arrangements are not essentially different from the quadriserial type.

The different types of juvenaria presumably represent an evolutionary series in the order given. The shift of the number of primary chambers is illustrated in textfigure 10 (for counting results see textfigure 11 and Tables 1-9). The sample succession from left to right, i.e., moving up in the time-scale is represented on the horizontal axis, bearing in mind, however, that the stratigraphical position of sample X 6002 (J 5129, Cas Abao, Curaçao) and sample J 3978 (Green Island, Jamaica) has been interpolated on the basis of the degree of nepionic reduction shown by their pseudorbitoid content.

The reduction of the number of primary chambers is confirmed by both the megalospherical and the microspherical populations. The juvenile chamber arrangement of the microspherical forms has not passed beyond the uniserial stage, in agreement with the conservative nature of the microspherical generation. The chamber arrangement of the megalospherical forms, on the other hand, evolves from a uniserial juvenile pattern, via successive intermediate stages (biserial, triserial), to the final quadriserial stage.

In some exceptional individuals even adauxiliary chambers have been found (specimen no. J 3697-339, see textfigure 9; specimen no. J 3978-545, see Plate 6, fig. 1; and (?) specimen no. J 3688-267, not figured).

The number of primary chambers of the megalospherical generation becomes stationary in the last 5 samples (J 3601, J 3697, J 3680, J 3686 and J 3688), with Y averaging about 5.

The shift of Y is also well illustrated by textfigure 11, in which the distribution of Y in the various samples is represented by histograms: see also Tables 10, 15a and 16. Table 15b gives the probabilities of exceedance, resulting from testing the coincidence of the variational spread between the various populations by means of Wilcoxon's two-sample-test, differences being considered as reliable at the 1% level of significance.

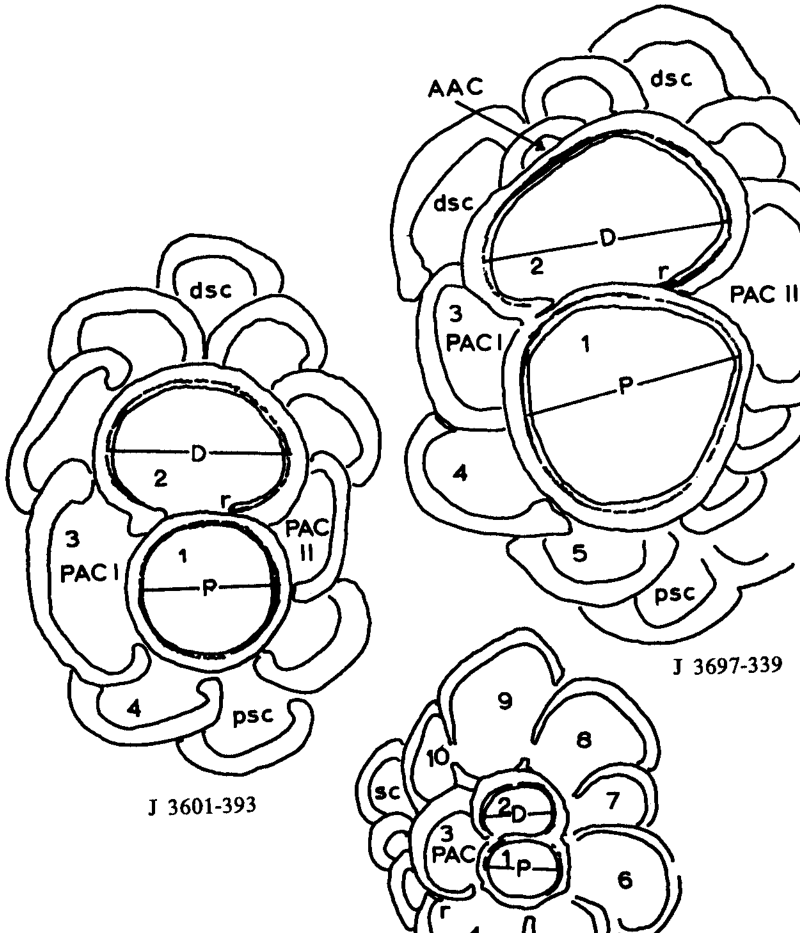
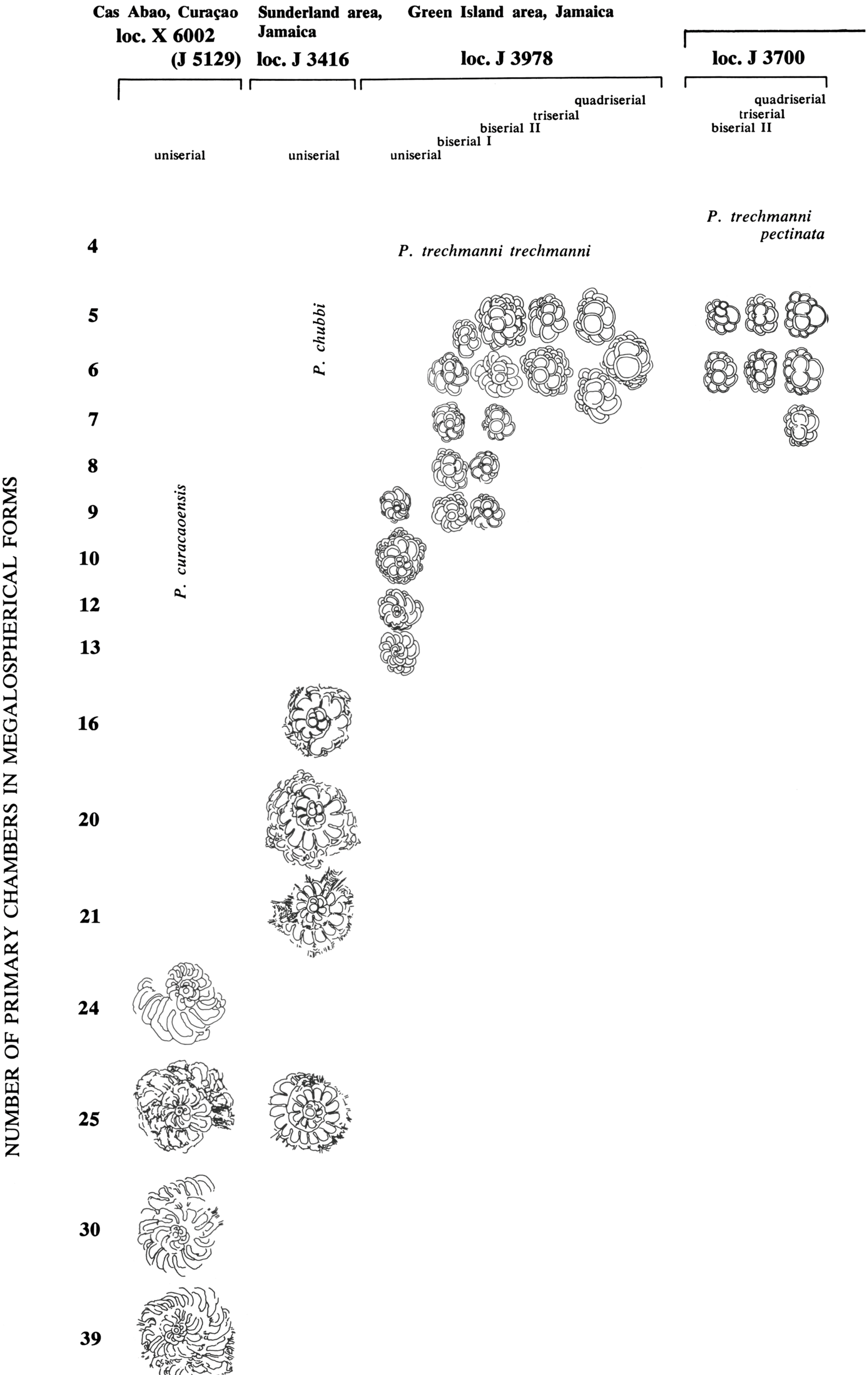
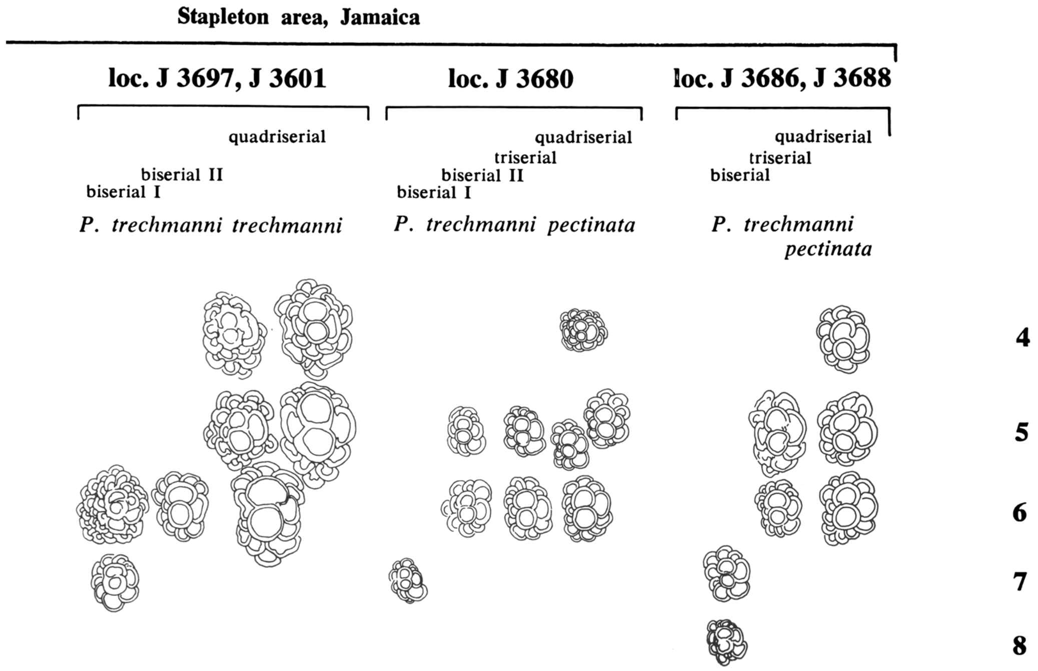


Fig. 9 – Various types of chambers in one uniserial and two quadriserial megalospherical juvenaria. Moreover, it is shown how P and D were measured, and the number of primary chambers (Y) counted (*P* = diameter of the protoconch; *D* = diameter of the deuteroconch; *PAC* = principal auxiliary chamber = 3rd primary chamber; *PAC I* = first principal auxiliary chamber; *PAC II* = second principal auxiliary chamber; *AAC* = adauxiliary chamber; *sc* = first 'symmetrical' secondary chamber; *psc* = first protoconchal 'symmetrical' secondary chamber; *dsc* = first deuteroconchal 'symmetrical' secondary chamber; *1, 2, 3, 4, 5, 6, 7, 8, 9, 10* = primary chambers; *r* = first retrovert aperture).


Cas Abao, Curaçao
loc. X 6002
(J 5129)
Sunderland area, Jamaica
loc. J 3416
Green Island area, Jamaica
loc. J 3978
loc. J 3700
uniserial
uniserial
uniserial
biserial I
biserial II
triserial
quadriserial
biserial II
triserial
quadriserial
P. trechmanni pectinata
P. trechmanni trechmanni
P. chubbi
P. curacaoensis
NUMBER OF PRIMARY CHAMBERS IN MEGALOSPHERICAL FORMS
4
5
6
7
8
9
10
12
13
16
20
21
24
25
30
39



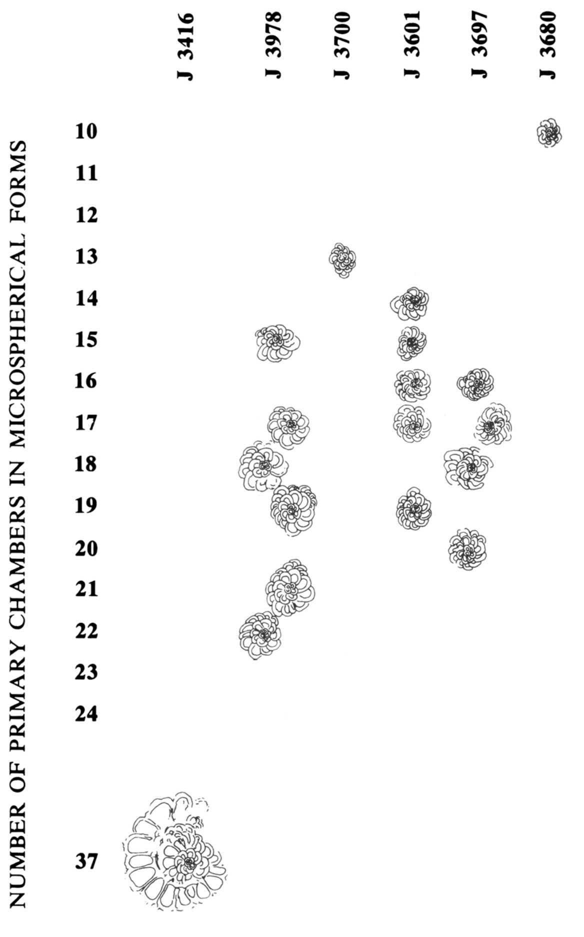
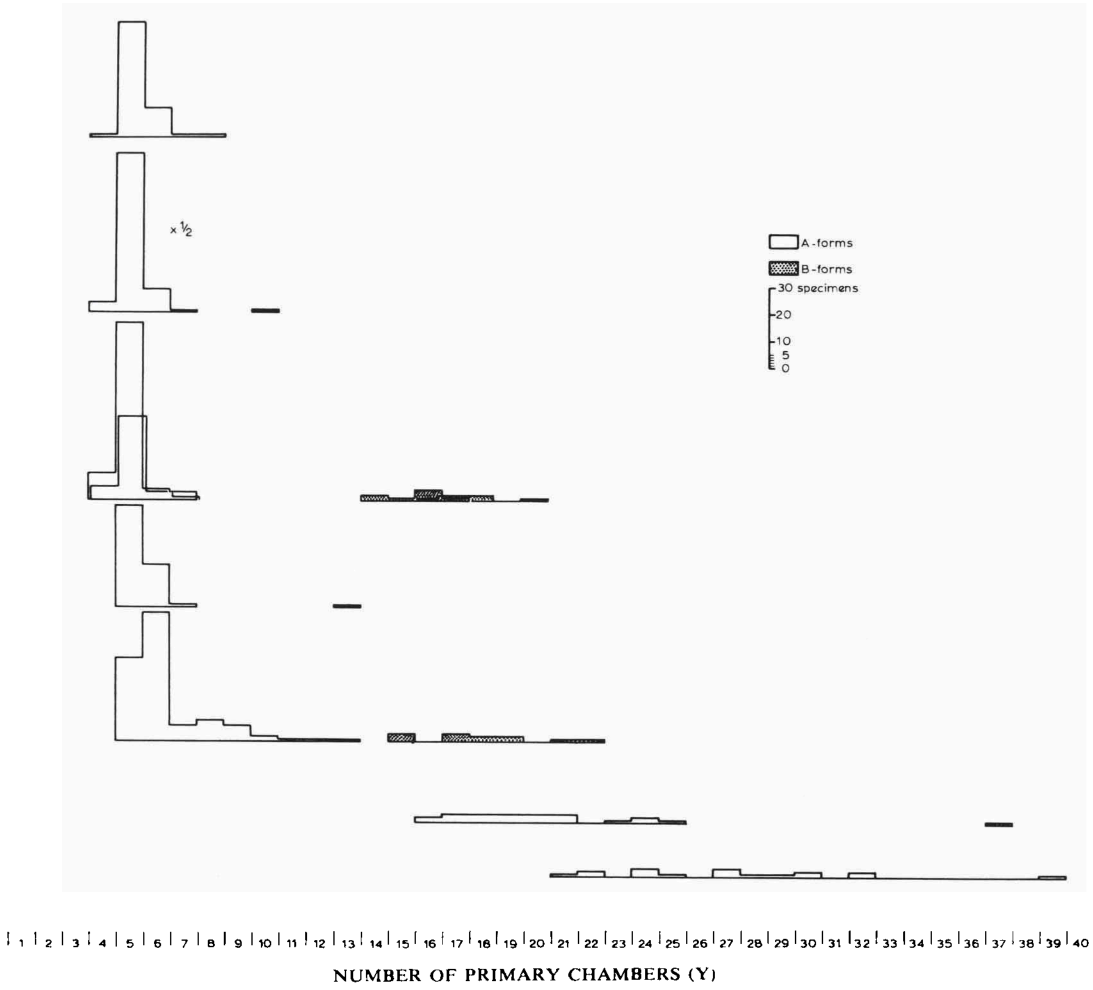


Fig. 10 – Various types of juvenaria of *Pseudorbitoides* Douvillé, 1922, arranged according 1) to the number of primary chambers, and 2) to the number of peri-embryonic spirals, in the successive samples.

Samples	B-forms $\bar{Y}$	B-forms n	A-forms $\bar{Y}$	A-forms n
J 3688			5.26	57
P. trechmanni pectinata (Stapleton area)				
J 3680	10.00	1	5.08	143
P. trechmanni pectinata (Stapleton area)				
J 3697	17.67	6	4.94	80
J 3601	15.50	8	5.12	43
P. trechmanni trechmanni (Stapleton area)				
J 3700	13.00	1	5.33	55
P. trechmanni pectinata (Stapleton area)				
J 3978	17.75	12	6.34	104
P. trechmanni trechmanni (Green Island)				
J 3416	37.00	1	19.67	21
P. cf. *P.* (?) *chubbi* (Sunderland area)				
X 6002 } J 5129 }			27.24	17
P. curacaoensis (Cas Abao, Curaçao)				



DIAMETER (WIDTH) OF THE PROTOCONCH (P) AND DEUTEROCONCH (D)

It is concluded from the foregoing observations that the stratigraphical value of parameter Y diminishes in the highest phylogenetical levels. Therefore, the second parameter, the size of the protoconch (P), has also been analysed, as there were indications of its general increase in successive samples, at least in the megalospherical generation. The distribution of P is again illustrated by means of stratigraphically arranged histograms: see textfigure 12.

The diagram shows a general increase in diameter (width) of the protoconch in megalospherical forms taken from samples X 6002, J 5129, J 3416, J 3978, J 3697 and J 3601. However, specimens taken from samples J 3700, J 3680, J 3686 and J 3688 do not show this general increase of P. Their P-values are distinctly smaller than those of samples J 3697 and J 3601, yet they display a similarly advanced arrangement of the juvenile chambers, and consequently, the small P-values are regarded as the result of different environmental conditions.

In the microspherical forms no increase of P has been observed (see also textfigure 12). This might be explained as follows: the gametes, and the zygotes resulting from the fusion of gametes (with the size of the microspherical protoconch depending upon the size of the zygote), apparently did not show any significant variation in size, neither in one and the same generation, nor in time, at least not in a comparatively small taxon as the family Pseudorbitoididae.

In addition to textfigure 12, the shift of P is also illustrated by Tables 11, 17a and 18, in which the mean value and the dispersion of P in the various samples are given, as well as the distribution of P-values. Table 17b gives the probabilities of exceedance arrived at in the same way as in the case of Table 15b. Again, differences are considered as reliable at the 1% level of significance.

The width (D) of the deuteroconch in megalospherical specimens shows a phylogenetical development similar to that of the protoconch (P). In textfigure 13 the P- and D-values are plotted. In addition, the slope ($K = \frac{S_Y}{S_X}$) of the reduced major axis, and the intercept ($b = \bar{y} - \bar{x}.K$) have been computed for each sample (Table 14a), except for sample X 6002. There is (1) no significant difference between the K-values of the various samples (using $z = \frac{K_1 - K_2}{\sqrt{S^2_{K1} - S^2_{K2}}}$ according to Miller & Kahn (1962), see Table 16b), (2) no reason to reject linearity (see Table 13), and (3) no reason to reject the hypothesis $b = 0$ (see Table 14a). Therefore we may assume an isogonic relationship between D and P.

DIAMETER AND THICKNESS OF THE TEST

Since plotting the thickness and the ratio diameter/thickness seemed to suggest that some forms might be restricted to certain areas, Brönnimann (1954-1958) and Seiglie & Ayala-Castañares (1963) regarded the shape of the pseudorbitoidal test as being of some diagnostic importance. In order to check this point, the present writer analysed the shape of the test numerically by using the variables Th (thickness in mm) and Dm (diameter in mm). The ratio diameter/thickness was

Fig. 11 – Histograms showing the distribution of the number of primary chambers (Y) in the successive samples.

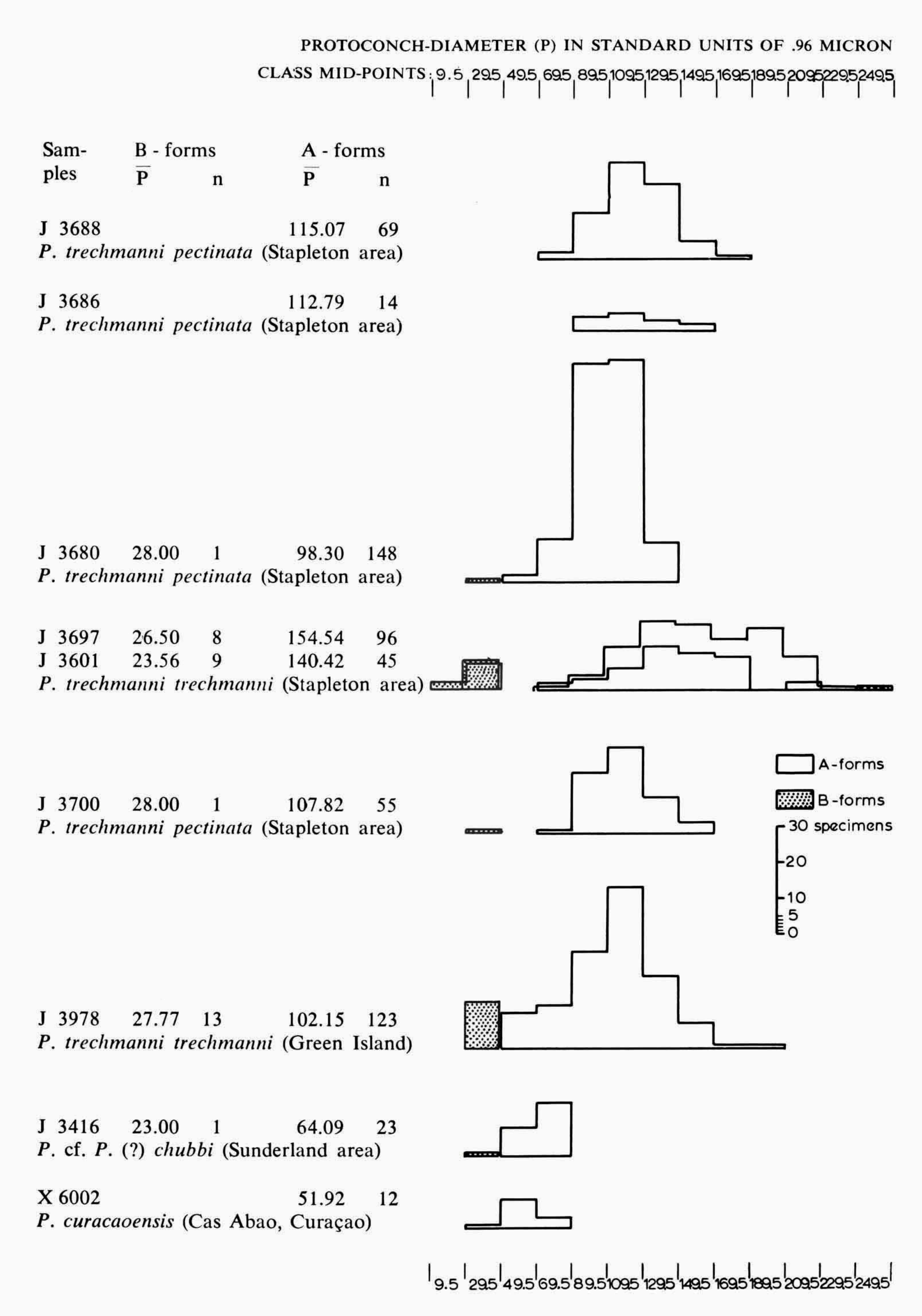


Fig. 12 – Histograms showing the distribution of the protoconch-diameter (P) in the successive samples.

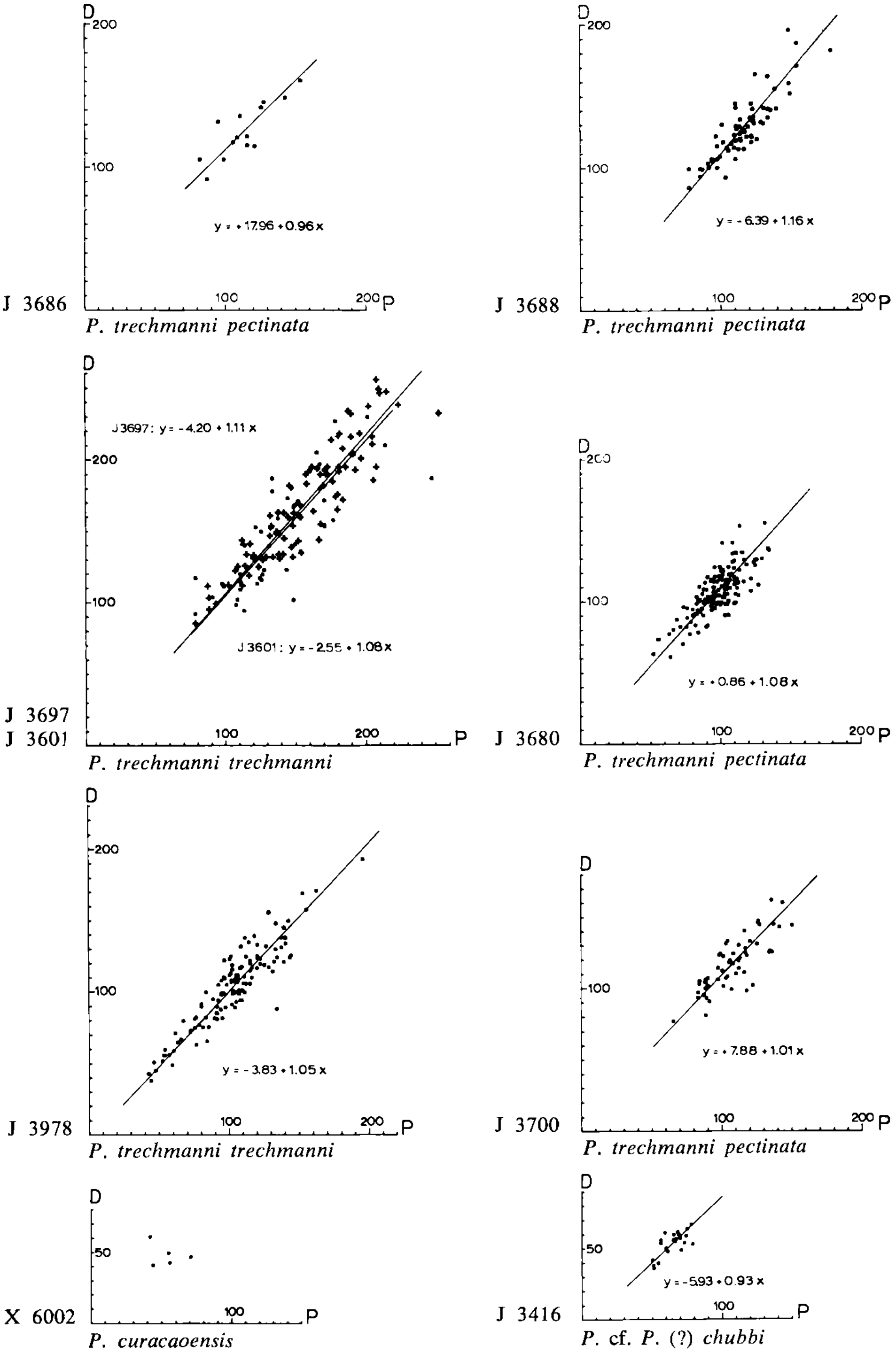


Fig. 13 – Scatter diagrams showing the relationship between the diameter of the deuteroconch (D) and the protoconch (P) of megalospherical forms in the various samples, with the computed slope and intercept of the reduced major axis for each sample.

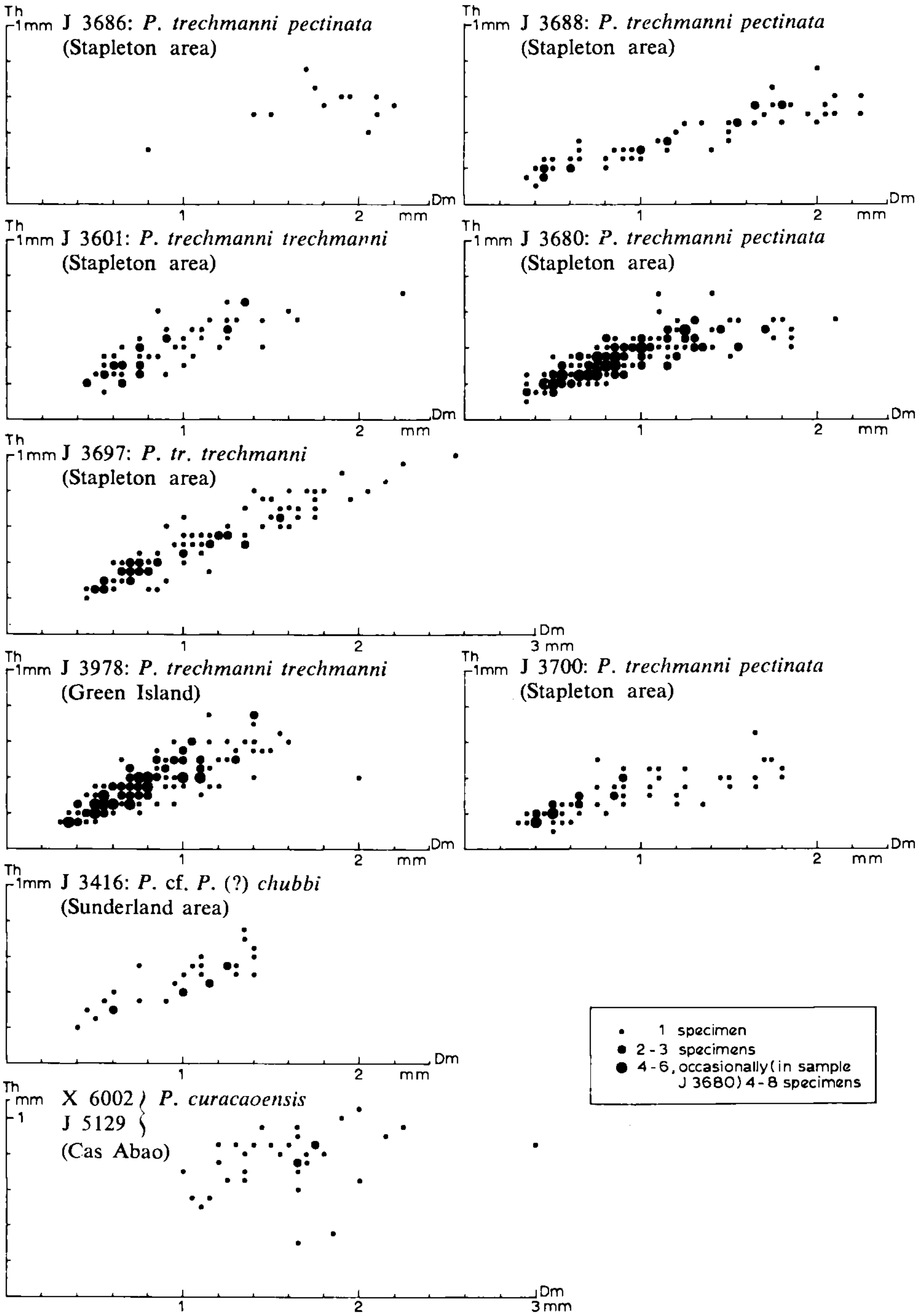


Fig. 14 – Scatter diagrams showing the relationship between the thickness (Th) and the maximum diameter (Dm) of the test of megalospherical forms in the various samples.

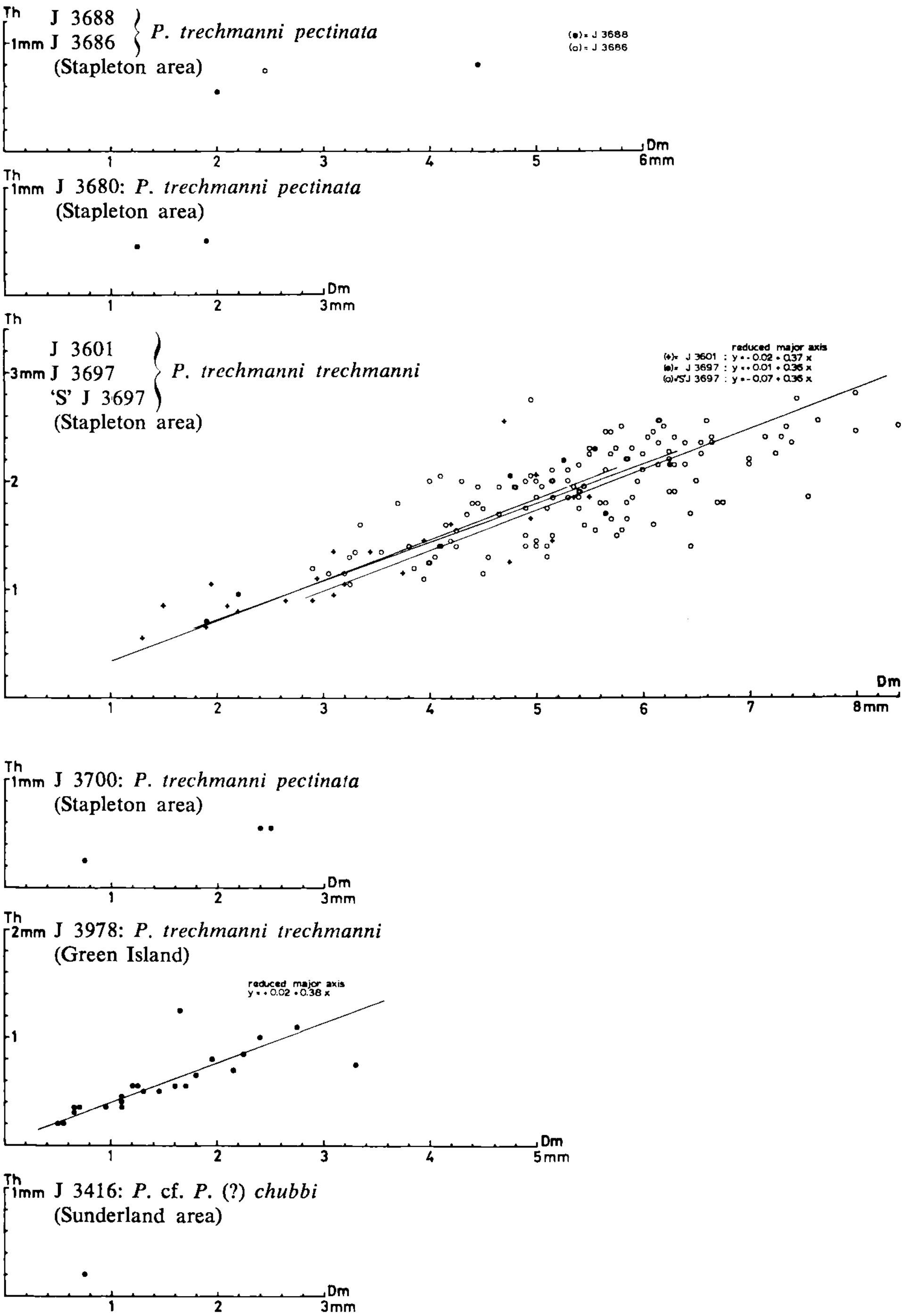


Fig. 15 – Scatter diagrams showing the relationship between thickness (Th) and maximum diameter (Dm) of the test of microspherical forms in the various samples, with the computed slope and intercept of the reduced major axis for samples J 3978, J 3601, J 3697 and 'S' J 3697. Samples 'S' J 3697 contains a quantity of selected specimens.

not used for the reason that if plots of Dm/Th and Th would be useful in classsification, a similar result would be obtained by restricting the analysis to the direct relation between Dm and Th (see textfigures 14 and 15). In this case, the slope of the regression lines is indicative of the degree of lenticularity of the test (it should be noted, however, that in samples J 3978, J 3601, J 3697 and 'S'J 3697, the linearity of regression and the value of intercept $b = 0$ (reduced major axis) are mere assumptions, due to the skewness of the distributions). Textfigure 15 shows that there is little reason to suspect any difference in the microspherical forms as far as can be judged from samples J 3978, J 3601, J 3697 and 'S'J 3697. There may be a slight difference between some of the megalospherical populations: specimens from samples J 3700, J 3680, J 3688 and (?) J 3686 in general may have a somewhat flatter test compared with specimens from samples X 6002, J 3416, J 3978, J 3697 and J 3601.

As has been pointed out before (see pages 28-33), the megalospherical individuals in samples J 3700, J 3680, (?) J 3686 and J 3688 are characterized by an advanced arrangement of juvenile chambers, combined with a comparatively small protoconch, which latter fact may have contributed to the depressed lenticular shape of the test. The presence of a prominent peripheral flange in these specimens may be responsible to some extent for the observed relation between Dm and Th, too.

In the microspherical generation exclusively, an increase in size appears to have taken place, at least up to samples J 3697 and J 3601, after which a decrease may have occurred.

REMARKS AND CONCLUSIONS

From the foregoing paragraphs, it is concluded that parameter Y, in combination with parameter P, seems to be reasonably adequate for stratigraphical purposes. The question is, however, to what extent these parameters are associated. In order to examine their relation, the material was subdivided according to the number of primary chambers. For each class of Y_i thus obtained, the logarithmic average of the corresponding protoconch-diameter $\overline{\log P_{Y_i}}$ was plotted against Y_i. This was done separately for each sample as well as each generation. This procedure has the advantage of reducing the number of points, and results in an approximately linear relation within each sample (see textfigure 16).

It appears that in the microspherical forms, Y has gradually diminished during evolution, while P remained approximately constant. The continual reduction of Y is evident from the diagram though samples J 3416, J 3700 and J 3680 contributed but single observations to the total.

In the case of megalospherical forms, the plotting results in a somewhat more complicated pattern. As we have seen before, both Y and P are changing in the course of the evolution. As a result of the reduction of Y and the general increase of P, one would expect a steady rise of the concentrations of points from right to left in the diagram. This is indeed found to be true for the plottings of Y_i and $\overline{\log P_{Y_i}}$ in samples J 3416 and J 3978, in which the leftward rise of the points in each sample follows the straight line of communication between the 'centre' of the megalospherical population and the 'centre' of the accompanying microspherical one, rather than the line of communication between the successive megalospherical populations. This at least would seem to be the case in samples J 3416 and J 3978,

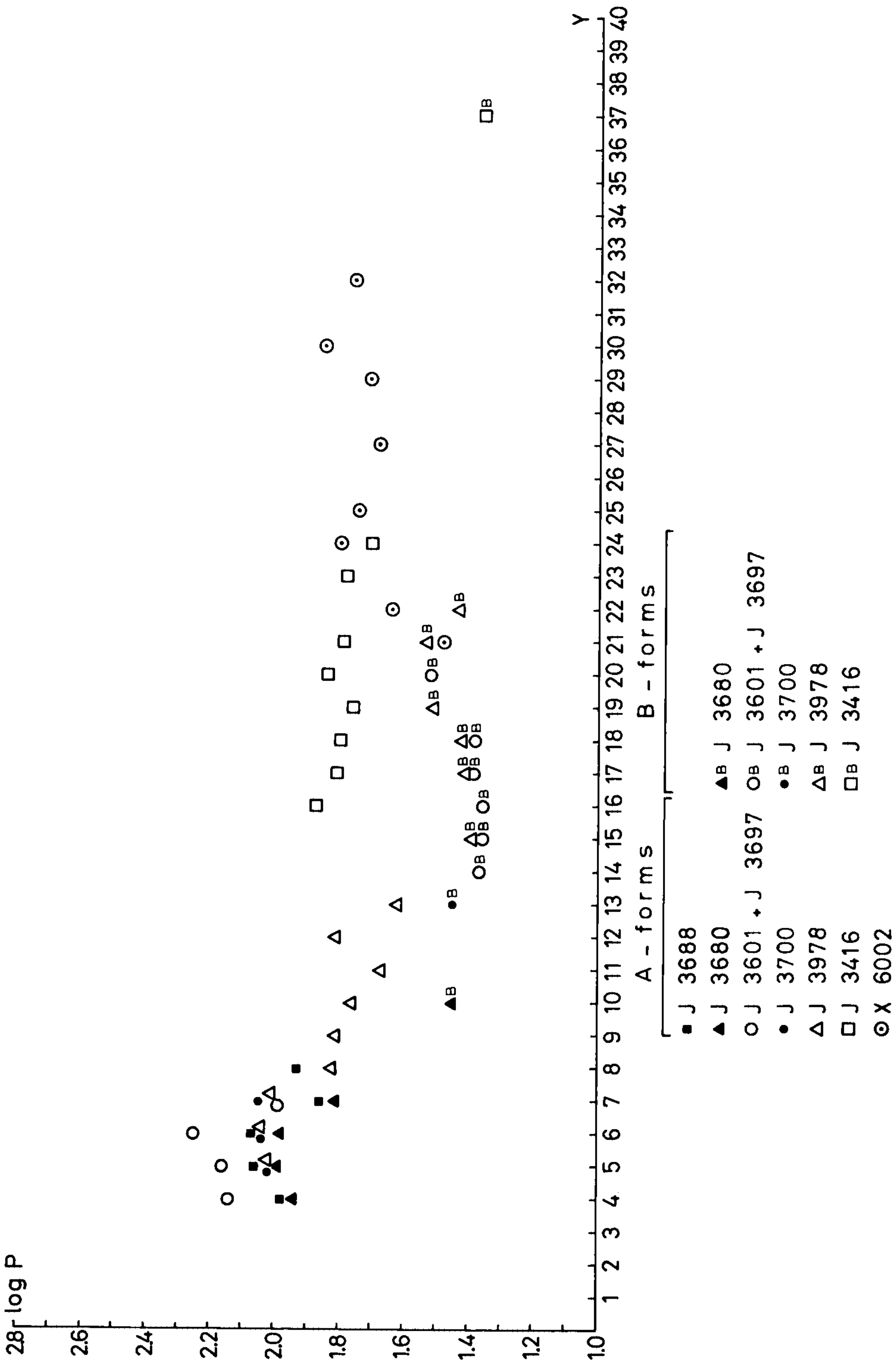


Fig. 16 – Scatter diagram showing the relationship between log P and Y. Each point represents the plotting of the logarithmic average of the protoconch-diameter of all specimens having a certain number of primary chambers ($X = \overline{\log P_{Y_i}}$) and the number of primary chambers ($Y = Y_i$).

but cannot be tested statistically because of the skewness of the distributions. In spite of this handicap the present writer believes that such a relationship between Y_i and $\overline{\log P_{Y_i}}$ may well exist in all samples examined. If true, this would mean that the increase of P and decrease of Y in megalospherical forms depend upon the stage of reduction of Y in microspherical forms.

With regard to the diagram in textfigure 16, computation of the slope of the regression line is hampered by the eccentric distributions, but what is more important, by difficulties encountered in the stratigraphically higher samples. In these levels, the smallest Y-values seem to be connected with comparatively small P-values. This cannot be verified statistically but it is thought that in quadriserial juvenaria a small size of the protoconch causes a decrease in the number of primary chambers. This is concluded from the slightly downward position of the points with the lowest Y-values of all populations with quadriserial individuals. This feature may be associated with the introduction of the second protoconchal spiral in quadriserial specimens, and consequently, with the development of the retrovert aperture in the deuteroconch. As far as can presently be judged, the introduction of the retrovert aperture in the deuteroconch caused a further decrease in the number of primary chambers to a minimum of four. If, for the sake of argument, we do not restrict our reasoning to one protoconchal spiral in quadriserial forms, but consider the total number of peri-protoconchal chambers, we may assume that evolution proceeds to a stage in which the diameter of the protoconch becomes a controlling factor.

The assumption that the diameter of the microspherical test may be associated with the diameter of the protoconch in megalospherical forms, is based upon the behaviour of both variables in successive populations.

Chapter 5. Systematical part

TAXONOMY

In 1967 the writer described the fauna of the Cas Abao Limestone lenses, Curaçao (Krijnen, 1967) in which different pseudorbitoidal forms were distinguished. From the present study it is concluded that the fauna actually comprises no more than one species, viz. *Pseudorbitoides curacaoensis* Krijnen, 1967. The plate-like nature of the radial elements and the extraordinarily primitive juvenarium still set *P. curacaoensis* apart as a characteristic species. However, the determinations of *Sulcorbitoides pardoi* Brönnimann, 1954 and *Aktinorbitoides browni* Brönnimann, 1958 have to be withdrawn. These species were thought to be present among the accompanying fauna of *P. curacaoensis* because of certain characteristics rated as diagnostic: the trochoid nature of the primary chamber spiral in *Sulcorbitoides* and the presence of interradii interrupting the equatorial layer, in *Aktinorbitoides*.

The material collected from Jamaica afterwards, has considerably reduced the diagnostic value of the characteristics mentioned because trochoid primary chamber spirals, as well as aktinorbitoid interradii, are also found in forms belonging to *Pseudorbitoides*. The diagnosis of this genus has to be emended accordingly. This applies also to *P. curacaoensis*, for the same reasons.

Specimens from sample J 3416 in the Sunderland Inlier resemble *P.* (?)

chubbi Brönnimann, 1958 closely. Plate-like radial elements are undoubtedly present (Plate 4, fig. 5), referring the specimens to *Pseudorbitoides* Douvillé, 1922. The number of primary chambers, however, is slightly larger than in Brönnimann's *P.* (?) *chubbi,* but this hardly justifies setting the material apart as a new species.

In sample J 3978 from the type locality of *P. trechmanni* Douvillé, 1922, some uniserial megalospherical individuals – with 13 to 9 primary chambers – were encountered, apart from biserial, triserial and quadriserial forms. The uniserial forms resemble *P. israelskyi* Vaughan & Cole, 1932 closely, yet they are presently incorporated in the *P. trechmanni* population as variants. I feel fully justified in doing so, as the megalospherical forms of *P. trechmanni* – designated below as *P. trechmanni trechmanni* – appear to be characterized by (1) a juvenile chamber arrangement ranging either from uniserial to quadriserial, or biserial to quadriserial, (2) the diameter of the protoconch ranging from 40 to 243 micron (see Tables 5 and 17a), and, moreover, (3) the delicacy of the radial elements of which there are about 60 per quadrant of the equatorial layer. These characteristics are also shown by specimens from samples J 3697 and J 3601 from the Sunderland Inlier, which have accordingly been determinated as *P. trechmanni trechmanni* as well. However, they are considered to represent a slightly more advanced evolutionary stage than *P. trechmanni trechmanni* from Green Island.

Megalospherical forms from samples J 3700, J 3680, J 3686 and J 3688 differ sharply from those of *P. trechmanni trechmanni* in samples J 3978, J 3697 and J 3601, not so much with respect to the phylogenetical stage reached in the reduction of the number of primary chambers (juvenile chamber arrangement ranging from biserial to quadriserial), as in: (1) the diameter of the protoconch, which is significantly smaller than in *P. trechmanni trechmanni* from the Stapleton area, (2) the rather coarse radial elements (about 30 per quadrant), and (3) the distinctly pectinate flange. As an ecological factor is thought to be responsible, differentiation on subspecies level seems reasonable. The name *P. trechmanni pectinata* subsp. nov. is therefore proposed for these forms from samples J 3700, J 3680, J 3686 and J 3688.

DESCRIPTIONS

Family PSEUDORBITOIDIDAE Rutten, 1935
Subfamily PSEUDORBITOIDINAE Rutten, 1935

Genus *Pseudorbitoides* Douvillé, 1922

Genoholotype *P. trechmanni* Douvillé, 1922

Diagnosis – Members of *Pseudorbitoides* are characterized by the presence of a pseudorbitoid layer which sooner or later ontogenetically divides the equatorial chambers. In this respect they differ from *Vaughanina* Palmer, 1934, *Aktinorbitoides* Brönnimann, 1958 and *Ctenorbitoides* Brönnimann, 1958, in all of which the equatorial chambers are actually traversed by the pseudorbitoid layer. In addition, *Pseudorbitoides* lacks the permanent median gap in the post-juvenile equatorial layer that is present in the three other genera.

The presence of historbitoid and rhabdorbitoid features in the pseudorbitoid layer of *Pseudorbitoides,* perhaps makes the differentiation from *Historbitoides* Brönnimann, 1956 and *Rhabdorbitoides* Brönnimann, 1955, somewhat doubtful.

However, this problem actually could not be solved because of insufficient information on the population characteristics of the latter genera.

Pseudorbitoides, by its larger post-juvenile phase may differ from *Sulcorbitoides* Brönnimann, 1954. In this case, too, a differentiation between these groups cannot be given conclusively since a reliable overall picture of the population characteristics of *Sulcorbitoides* is lacking.

Emended definition – Test lenticular, circular to sub-circular in outline, and papillate. Structure orbitoidal, the lateral chamber layers completely covering the equatorial layer, or nearly so. Dimorphism already present in an early phylogenetical stage. The microspherical forms, particularly the smaller ones, occasionally have rather heavy pillars in the umbonal region. The sub-circular outline is occasionally interrupted by smooth inward curvations corresponding with aktinorbitoid interradii (mainly in primitive uniserial forms). The equatorial layer is composed of true equatorial chambers: its central portion of juvenile primary and secondary chambers, the surrounding portion of cyclically arranged secondary chambers. These latter chambers are arcuate to truncated arcuate in shape, their arrangement following an orbitoidal pattern. In the more primitive uniserial members, even the first secondary chambers appear to be divided by radial elements, but this is not the case in the more advanced representatives. In even only moderately advanced microspherical specimens (Green Island), up to and including the most advanced megalo- and microspherical forms (from the Sunderland Inlier), formation of undivided secondary chambers seems to have taken place prior to the appearance of radial elements. In this manner, a zone of undivided arcuate equatorial chambers is formed, partly belonging to the juvenarium and partly to the post-juvenile phase. Once introduced ontogenetically, the pseudorbitoid layer divides all subsequent secondary chambers.

The pseudorbitoid layer appears to consist of several types of radial elements which radiate from the central portion of the equatorial layer to the periphery, and depart nearly perpendicularly from successive chamber walls (therefore, they do not follow a straight course). Originally, in ontogeny as well as phylogeny, the arrangement of the radial elements is rather simple: made up of two alternating systems of rods. In phylogenetical development, their structure becomes rapidly more complex, as is shown by the formation of plates and rods in several populations. The microspherical forms in particular are prone to produce complex structures of the pseudorbitoid layer in which rambling radial plates, irregularly interconnected, occasionally lead up to the formation of historbitoid-like incipient radii. It is assumed that radial stolons, piercing the walls of the equatorial chambers between the radial elements, are present in all species. The radial elements themselves appear to contain minute intramural lumina.

The cyclical pattern of the equatorial chambers, as in most orbitoids, consists of a more or less regular arrangement of radial rows of somewhat truncated arcuate equatorial chambers. A perfect regularity, however, is rarely realized, also by the radial elements, for their position depends strongly upon the degree of regularity displayed by the equatorial chambers.

The juvenile stage of the equatorial layer consists of: a phylogenetically decreasing number of sulcoperculinoid primary chambers without any retrovert apertures (finally, in advanced megalospherical forms, only one such chamber is present), followed by primary chambers with a retrovert aperture, and finally, secondary chambers belonging to the juvenile phase. With regard to nepionic reduction, the megalospherical juvenarium passes from a uniserial stage, via a biserial and triserial one to a quadriserial stage; this development depends basically on the phylogenetical shift of the retrovert aperture towards the deuteroconch. Nepionic reduction occurs also in the microspherical forms, but does not pass beyond the uniserial stage.

Lateral chambers, appearing at an early stage of the ontogenetical development, form regular layers on both sides of the equatorial layer. Polygonal in shape, they are bordered by several small pillars which cause the papillate appearance of the test. Occasionally, somewhat heavier additional pillars are present in microspherical specimens. Ontogenetically, the formation of pillars makes a rather early start. Beginning from the central interior portion of the test the pillars traverse the layers of lateral chambers, reaching the surface in the umbonal region.

In quite a number of specimens (up to 30% of all individuals in sample J 3416, rarely in the stratigraphically higher samples from Green Island and the Sunderland Inlier), aktinorbitoid interradii have developed, i.e. wedge-shaped interruptions of the equatorial layer. The focus-points of these interradii are invariably situated immediately around the juvenarium. In the more advanced populations, occasional aberrant forms as described and figured by Glaessner (1960, Plate 6, fig. 7) occur, with a branched median layer arranged in three planes.

The following subdivision of the subfamily Pseudorbitoidinae is still rather provisional because it is presently not possible to give accurate data on population characteristics such as the diameter of the protoconch and the number of primary chambers, of some of the genera and species. It depends largely upon the nature of the juvenarium to which the highest diagnostic value has been assigned, since it appears to be unaffected by changing environmental conditions.

Provisional subdivision of the subfamily Pseudorbitoidinae, based on the arrangement of juvenile chambers in megalospherical forms:

Uniserial:
Sulcorbitoides pardoi Brönnimann, 1954 (= ? *Pseudorbitoides pardoi* (Brönnimann, 1954))
Pseudorbitoides curacaoensis Krijnen, 1967 (= ? *Pseudorbitoides pardoi* (Brönnimann, 1954))
Pseudorbitoides chubbi Brönnimann, 1958 (= *Pseudorbitoides* (?) *chubbi* Brönnimann, 1958)

Uniserial/biserial:
Pseudorbitoides israelskyi Vaughan & Cole, 1932

Uniserial/biserial/triserial/quadriserial:
Pseudorbitoides trechmanni trechmanni Douvillé, 1922
Pseudorbitoides trechmanni pectinata subsp. nov.

Quadriserial:
Pseudorbitoides rutteni rutteni Brönnimann, 1955
Historbitoides kozaryi Brönnimann, 1956 (= ? *Pseudorbitoides rutteni kozaryi* (Brönnimann, 1956))
Rhabdorbitoides hedbergi Brönnimann, 1955 (= ? *Pseudorbitoides rutteni hedbergi* (Brönnimann, 1955))

Pseudorbitoides curacaoensis Krijnen, 1967
Textfigs. 10-14, 16; Plate 1; Tables 1, 10, 11, 15a, 15b, 18a, 18b.

1967 *Pseudorbitoides curacaoensis* sp. nov. – Krijnen, p. 146, pls. 1-3, textfigs. 2-7.
1967 *Aktinorbitoides browni* Brönnimann. – Krijnen, p. 156, pl. 5, figs. 3, 4; pl. 6, figs. 2-5 (not Brönnimann, 1958).
1967 *Sulcorbitoides pardoi* Brönnimann. – Krijnen, p. 155, pl. 4, figs. 3-7; pl. 5, fig. 2; pl. 6, fig. 1 (not Brönnimann, 1954).

Material – Several random sections and some free individuals, all obtained from samples X 6002, J 5128 and J 5129.

Locality – Cas Abao Limestone lenses, about 1,500 meters ESE of country house St. Jan, Curaçao (type locality of the species).

Diagnosis – *P. curacaoensis* differs from all other members of *Pseudorbitoides* by its larger number of primary chambers.

Emended description – Test lenticular, circular to sub-circular in outline, occasionally with one (or more?) deep inward curvation interrupting the (sub-) circular outline. Diameter of test ranging from .85 to 3.00 mm, its thickness from .30 to 1.05 mm. Lateral chambers polygonal, completely covering the equatorial layer, or nearly so. The periphery is slightly pectinate due to a slight protrusion of the radial elements beyond the periphery. The test is covered with numerous small papillae but in the umbonal region strong pillars may be present.

The equatorial layer can be divided in a juvenarium, followed by a cyclical orbitoidal phase. The juvenarium is invariably uniserial, consisting of: a subspherical protoconch, its diameter ranging from 29 to 68 micron; an arcuate deuteroconch, its diameter varying from 39 to 59 micron; 19 to 37 post-embryonic primary chambers arranged in some 2½ whorls (the total number, Y, of the primary chambers – protoconch and deuteroconch included – varies from 21 to 39); and finally a small number of juvenile secondary chambers. The total number of these latter chambers cannot be determined accurately, but at its maximum is thought to equal the number of bi-apertural primary chambers. The first retrovert aperture is assumed to be situated in the 8th to 18th primary chamber, depending upon the length of the primary chamber spiral, so that the number of bi-apertural primary chambers may vary from (21-8=) 13 to (39-18=) 21. The primary chamber spiral occasionally tends to widen in its final stage. It would appear that this feature, as in *Vaughanina jordanae* Brönnimann, 1958, results from the development of juvenile secondary chambers in the opening between the end of the primary chamber spiral and earlier primary spiral chambers. The first juvenile secondary chamber or chambers do not immediately start the formation of counter-spirals, but instead, seem to give rise to spirals curving forward exclusively, which are partly covered by the last whorl of the primary chamber spiral.

No microspherical forms have been encountered.

Radial elements – 2 to 3 traversing each equatorial chamber, as is seen in horizontal sections – are developed at an early stage, sometimes even in the first secondary chambers. The pseudorbitoid layer is therefore considered to start with the development of the retrovert aperture, without any indication of the presence of an intermediate zone of arcuate undivided secondary chambers.

The equatorial layer is occasionally interrupted by one or more interradii

(Plate 1, fig. 8). The structure of the radial elements is not limited to one particular system. Referring to Brönnimann's classification of the structural patterns of the pseudorbitoid layer, several types could be recognized with certainty:

1. Two systems of radial rods, as in *Sulcorbitoides* (Plate 1, fig. 2).
2. A single system of fairly regular radial plates (Plate 1, fig. 1).
3. One system of radial plates with irregular horizontal interconnections, as in *Historbitoides* (Plate 1, figs. 4, 5).
4. 'Incipient radii' as in *Historbitoides,* indicating the presence of stellate tests (Plate 1, fig. 5).

Pseudorbitoides cf. *P.* (?) *chubbi* Brönnimann, 1958
Textfigs. 5-7, 10-16; Plates 2-4; Tables 2, 10, 11, 13-18.

Material – Several free individuals, obtained from sample J 3416.

Locality – Sunderland Shale, about 800 meters ESE of Sunderland, close to the road from Sunderland to Amity Hall, Parish of St. James, Jamaica (see text-figure 1).

Description – Test lenticular, circular to sub-circular, often actinate in outline (Plate 2), its diameter ranging from .40 to 1.40 mm, its thickness from .20 to .75 mm.

The equatorial layer is nearly completely covered on both sides by polygonal lateral chambers which are arranged in regular layers. The surface of the test is papillate, due to the presence of small pillars. Radial elements, whenever slightly protruding beyond the marginal face, are occasionally visible on the exterior (Plate 2, figs. 3, 4, 6, 7).

In the megalospherical forms as well as in a single microspherical one encountered, the equatorial layer consists of true chambers throughout. It can be divided into a juvenarium, followed by a cyclical phase.

The megalospherical juvenarium is invariably uniserial, consisting of: a subspherical protoconch, its diameter ranging from 48 to 76 micron; an arcuate deuteroconch, its diameter varying from 35 to 64 micron; 14 to 23 post-embryonic primary chambers arranged in 1½ to nearly 2 whorls (the total number, Y, of the primary chambers, protoconch and deuteroconch included, varies from 16 to 25); and finally a small number of juvenile secondary chambers. The first retrovert aperture is assumed to be situated in the 6th to 11th primary chamber, depending upon the length of the primary chamber spiral. The number of bi-apertural primary chambers and, accordingly, the maximum number of juvenile secondary chambers, may therefore range from (16 – 6 =) 10 to (25 – 11 =) 14.

As in *P. curacaoensis,* the primary chamber spiral occasionally tends to widen and in this case too, the first juvenile secondary chamber or chambers do not immediately produce counterspirals, but conversely, seem to cause the formation of spirals curving forwards, and partly covered by the last portion of the primary chamber spiral.

The microspherical specimen mentioned above has a small protoconch (diameter: 22 micron) and a primary chamber spiral consisting of 37 chambers (Plate 3, fig. 6). It is apparently an immature individual, as only a small part of the cyclical phase has developed, consequently its test is small in comparison with the bulk of the megalospherical forms.

The cyclical phase of the megalospherical forms is comparatively large and shows a cyclical arrangement of arcuate to truncated arcuate secondary chambers divided by the pseudorbitoid layer (its radial elements depart from the last whorl of primary chambers, traversing the subsequent secondary chambers rather than bordering them). In most case it is difficult to observe secondary chambers, either in horizontal sections or particularly in vertical ones in which the picture is complicated by comparatively coarse radial elements.

Cross-sections of the pseudorbitoid layer in several specimens show the sulcorbitoid type of rods, the pseudorbitoid type of radial plates, as well as the historbitoid-like incipient radii and plate-like radial elements, irregularly interconnected by horizontal bars (Plate 4, fig. 5). Interradii are often present, occasionally even up to about nine. From central cross-sections of such an interradius, it appears that the interradii are entirely composed of lateral chambers (Plate 4, fig. 6). These interradial lateral chambers are easily recognizable in horizontal sections, because – in contrast to the concentrical arrangement of the secondary chambers – they are tiered in more or less regular curves, concave towards the periphery (Plate 3, figs. 2,5).

Note – The total number of primary chambers slightly exceeds that in *P.* (?) *chubbi* Brönnimann. For this reason, and as insufficient data on the population characteristics of *P.* (?) *chubbi* could be assembled, the specimens from locality J 3416 are designated as *Pseudorbitoides* cf. *P.* (?) *chubbi.*

Pseudorbitoides trechmanni trechmanni Douvillé, 1922
Textfigs. 5-7, 10-16; Plates 5-9, 14-20; Tables 3, 5, 6, 10-18.

1922 *Pseudorbitoides Trechmanni* nov. gen., nov. sp. – Douvillé, p. 204, fig. 1.
1955 *Pseudorbitoides trechmanni* Douvillé. — Brönnimann, p. 58, pls. 9, 10, textfigs. 1, 2-7.

Material – Abundant free specimens of megalospherical forms and a fair number of microspherical ones from samples J 3978, J 3601, and J 3697. From specimens in sample J 3419 only a few random sections are available: some of megalospherical forms and one of a microspherical individual.

Localities

J 3978:Basal portion of the *Barrettia* Limestone, near Haughton Hall and Green Island, Jamaica (= type locality).
J 3601: Top part of the *Barrettia* Limestone, close to the road between Amity Hall and Kensington, about 1,800 meters E of Newman Hall, Jamaica (see textfigure 1).
J 3697: Top part of the *Barrettia* Limestone, close to the road between Amity Hall and Kensington, about 1,000 meters E of Stapleton, Jamaica (see textfigure 1).
J 3419: Top part of the Newman Hall Shale, near the bridge of Stapleton, Jamaica (see textfigure 1).

Description of the megalospherical form – Test lenticular, circular to sub-circular in outline, its surface generally papillate. The (sub-) circular outline is in rare cases interrupted by a deep smooth inward curvation corresponding with an interradius. Maximum diameter (Dm) and thickness (Th) of the test (in mm) are:

Samples	Dm	Th
J 3978	.30 - 2.00	.15 - .75
J 3601	.45 - 2.25	.15 - .70
J 3697	.45 - 2.55	.20 - 1.00

(for data listed per individual see Tables 3, 5, 6).

The megalospherical form is characterized by large embryonic chambers (proto- and deuteroconch) surrounding by one to four spirals of peri-embryonic chambers.

The size of both the protoconch (P) and deuteroconch (D) varies considerably, as is seen in the following summary (measurements in microns):

Samples	P	D
J 3978	40 - 187	36 - 164
J 3601	75 - 237	88 - 221
J 3697	75 - 243	82 - 246

(for data listed per individual see Tables 3, 5, 6).

The primary chamber spiral is usually well defined (textfigure 9). In the uniserial, biserial and triserial forms its chambers are in most cases slightly larger than the other peri-embryonic chambers.

The number of primary chambers (Y) in the different samples varies as follows:

Samples	Y
J 3978	13 - 5
J 3601	7 - 4
J 3697	7 - 4

(for data listed per individual see Tables 3, 5, 6).

In each sample one may consider P inversely proportional to Y. However, it is remarkable that, contrary to expectation, the forms with four primary chambers in samples J 3601 and J 3697 do not posses the largest protoconchs.

Protoconch and deuteroconch are devoid of a sulcus. That this is so may safely be concluded from studying a fair number of central vertical sections, in which the protoconch invariably shows a globular shape. Absence of a sulcus in the wall of the deuteroconch is concluded from the fact that the surrounding deuteroconchal peri-embryonic chambers, like the protoconchal ones, are never seen to be divided by radial elements. In contrast to the embryonic chambers, the peri-embryonic ones do posses sulci and it is concluded that the pseudorbitoid layer initiated from these sulci. However, radial elements are seen to start from the peri-embryonic chambers in only a few specimens. These elements are assumed to be effaced in most of the specimens by a slight recrystallization.

The cyclically arranged equatorial chambers are arcuate to truncated arcuate and easily distinguishable from the lateral chambers. Occasionally, small radial apertures are visible in the arcuate walls. These openings are regarded as stolons which might have created a radial channel system between the radial elements. In horizontal sections each equatorial chamber is seen to contain 3-4 radial elements (about 60 per quadrant).

Description of the microspherical form – Test lenticular, circular to sub-circular in outline with a slightly thickened outer margin. The surface of the test is usually completely covered with polygonal lateral chambers. The test is commonly papillate but in specimens from sample J 3978 heavier pillars are also present in the umbonal region (Plate 5, figs. 1-6; Plate 14, figs. 1-8). Small vertical striations on the marginal face of extremely well preserved specimens indicate the presence of radial elements (Plate 14, figs. 2,7). Occasionally small notches and inward curvations are visible, interrupting the (sub-) circular outline. As frequently visible in horizontal sections, they are due to irregularities in the concentrical arrangement of the equatorial chambers in the cyclical phase.

Full-grown specimens are large in comparison with the megalospherical forms. The maximum diameter (Dm) and thickness (Th), in mm, vary as shown below:

Samples	Dm	Th
J 3978	.50 - 3.60	.20 - 1.25
J 3601	1.30 - 5.50	.55 - 2.55
J 3697	1.90 - 7.35	.70 - 2.50

(for data listed per individual see Tables 3, 5, 6).

The microspherical form has a uniserial juvenarium with small embryonic chambers (proto-and deuteroconch), and a small primary chamber spiral (Plate 18, fig. 6). The diameter of the protoconch (P), in microns, varies as follows:

Samples	P
J 3978	19 - 36
J 3601	17 - 29
J 3697	20 - 32

(for data listed per individual see Tables 3, 5, 6).

The number of primary chambers (Y) was counted by starting from the protoconch and following the primary chamber spiral up to the first symmetrical chamber. The data on Y are:

Samples	Y
J 3978	22 - 15
J 3601	17 - 14
J 3697	20 - 16

(for data listed per individual see Tables 3, 5, 6).

The juvenile stage is considered to be terminated by the appearance of the first symmetrical chamber (which in fact is a secondary chamber). Formation of the symmetrical chamber starts cyclical development of the equatorial layer.

The juvenile chambers – primary chambers plus juvenile secondary ones – seem to be devoid of a sulcus.

The secondary chambers of the post-juvenile phase, which immediately surround the juvenarium, also lack a sulcus in the marginal face of the chamber walls. Moreover, these chambers are not divided by the pseudorbitoid layer. The undivided secondary chambers occupy a distinct zone, formed prior to the ontogenetical appearance of the radial elements within the cyclical phase. However, once introduced ontogenetically, the pseudorbitoid layer divides all the subsequent secondary chambers into two 'halves'.

The structure of the first radial elements is rather simple, as is seen in tangential sections. It is conceivable that first of all, two systems of rod-like elements are formed (Brönnimann, 1955a), which structural type of the pseudorbitoid layer subsequently changes over into a single system of radial plates. These plates are clearly visible in a tangential section close to the centre of the test (Plate 20, fig. 4). This section also reveals the presence of radial stolons between the radial plates. On the other hand, a vertical section near the outer margin of the test shows a much more complicated picture (Plate 20, figs. 2, 3, 6). At this point in the ontogenetical development, the pseudorbitoid layer appears to consist of numerous bifurcating and anastomosing, irregularly interconnecting tubules which are regarded as analogous to the radial stolons developed in the walls of the secondary chambers between the radial plates, in an earlier stage of the ontogeny (Plate 20, fig. 4).

At several points in the development of the equatorial layer, the concentrical arrangement of the chambers is found to be disturbed. This can be seen when following concentrical rows of chambers with equal budding stage numbers. Rarely is a perfect circle detected. Instead, one is almost invariably dealing with rows of chambers with occasional inward kinks presumably resulting from disharmonic growth.

Cyclically arranged secondary chambers and radial elements are often visible in one and the same horizontal section. From such sections it was noticed that kinks in the rows of chambers with equal budding stage numbers, subsequently caused the radial elements to converge in the same parts of the equatorial layer (Plate 18, figs. 1, 2, 5). The peculiar bunches of radial elements which occasionally radiate from some of the equatorial chambers – as can be seen in some of the vertical sections (Plate 9, fig. 6b) – are assumed to be conditioned by the same convergence.

Pseudorbitoides trechmanni pectinata subsp. nov.
Textfigs. 1, 2, 5, 6, 10-16; Plates 10-13, 21-26; Tables 4, 7-18.

Material – Abundant free specimens (mainly megalospherical forms, and rarely microspherical ones), obtained from samples J 3700, J 3680, J 3686 and J 3688.

Localities (see textfigure 1)
J 3700: Top part of the Newman Hall Shale, close to the road between Amity Hall and Kensington, about 1,000 meters E of Stapleton, Jamaica.
J 3680, J 3686, J 3688: In the Shepherds Hall Conglomerates and Tuffs, about 100 meters S of the bridge of Stapleton, Jamaica.

Diagnosis – *P. trechmanni pectinata* subsp. nov. resembles *P. trechmanni trechmanni* with respect to the arrangement of the juvenile chambers, but differs sharply from it (1) by having a smaller megalospherical protoconch and deuteroconch, (2) by the position of the radial plates – passing between the radial rows of equatorial chambers instead of traversing these, as can be seen in horizontal sections – and (3) by the presence of a distinct pectinate flange.

P. trechmanni pectinata subsp. nov. differs from *P. rutteni* in having a biserial to quadriserial arrangement of its megalospherical juvenile chambers, whereas the juvenarium of *P. rutteni* is considered to be exclusively quadriserial (Brönnimann, 1955a).

The megalospherical specimen no. J 3680-61 (Plate 21, figs. 3 and 3a, and Plate 22, fig. 2) is the holotype of *P. trechmanni pectinata* subsp. nov.

Description of the megalospherical form – Test lenticular, circular to sub-circular in outline, its surface generally papillate. A well defined flange is present, poorly covered by lateral chambers, or not all. The fact that the radial elements protrude slightly from the lateral surface of the flange, and even beyond its periphery, emphasizes its comb-like appearance (Plates 10, 21, 24), to which the name *pectinata* alludes, in accordance with Brönnimann's descriptive term. Interradii are rarely developed (Plate 10, fig. 1; Plate 11, fig. 2).

The maximum diameter (Dm) and thickness (Th) of the test (in mm) are:

Samples	Dm	Th
J 3700	.30 - 1.80	.15 - .65
J 3680	.35 - 2.10	.15 - .70
J 3686	.80 - 2.20	.30 - .75
J 3688	.35 - 2.25	.10 - .75

(for data listed per individual see Tables 4, 7, 8, 9).

The equatorial layer can be subdivided into two phases, the central juvenile phase, followed by the cyclical one. The juvenile phase comprises a subspherical protoconch and an arcuate deuteroconch, surrounded by 2 to 4 spirals of peri-embryonic chambers.

The diameter (in microns) of the protoconch (P) and the deuteroconch (D) are:

Samples	P	D
J 3700	62 - 144	74 - 155
J 3680	50 - 130	59 - 149
J 3686	78 - 147	88 - 155
J 3688	74 - 148	83 - 188

(for data listed per individual see Tables 4, 7, 8, 9).

The primary chamber spiral comprises the proto- and deuteroconch, the first principal auxiliary chamber and the corresponding spiral of asymmetrical chambers up to the first symmetrical (secondary) chamber. The number of primary chambers (Y) varies as follows:

Samples	Y
J 3700	7 - 5
J 3680	7 - 4
J 3686	6 - 5
J 3688	8 - 4

(for data listed per individual see Tables 4, 7, 8, 9).

The cyclical phase of the equatorial layer shows cyclically arranged arcuate to truncated arcuate secondary chambers, starting with a narrow zone of chambers which are not divided by the pseudorbitoid layer (Plates 12, 22; Plate 23, figs. 1, 2; Plate 25). After the ontogenetical appearance of the pseudorbitoid layer in the cyclical phase, all subsequent equatorial chambers are seen to be divided into two 'halves'.

The pseudorbitoid layer of this form characteristically shows radial plates which do not traverse the secondary chambers, but tend to border these (cf. horizontal sections). The arrangement of the equatorial chambers in *P. trechmanni pectinata* differs in this respect from the normal orbitoid-like arrangement, by the formation of distinct radial rows. It can be seen, moreover, that equatorial chambers with the same budding stage number tend to form annular rows.

The secondary chambers, which first enclose the radial elements, are situated more or less between the radial plates in a later ontogenetical phase. Radial stolons in the secondary chamber wall are probably present on either side of the radial plates (Plate 26, fig. 1; Plate 13, fig. 5). The number of these stolons presumably increases during the ontogenetical development, so that finally each secondary chamber wall is provided with a pair vertical rows of radial stolons (Plate 13, fig. 6).

The lateral chambers are arranged in regular layers on both sides of the equatorial layer.

Peripheral vertical sections (Plate 13, fig. 6; Plate 23, fig. 6) show very low lateral chambers, slightly curved inwards and situated between lateral extensions of the radial plates.

Description of the microspherical form – In external view the microspherical forms are hardly distinguishable from the megalospherical ones. The test is lenticular in shape and circular to sub-circular in outline. Specimens possessing aktinorbitoid interradii were never observed. The surface of the test is papillate, and strong pillars may be present (Plate 23, fig. 4).

The maximum diameter (Dm) and thickness (Th) of the test (in mm) are:

Samples	Dm	Th	
J 3700	.75 - 2.50	.25 - .55	(5 specimens)
J 3680	1.25 - 1.90	.45 - .50	(3 specimens)
J 3686	2.45	.75	(1 specimen)
J 3688	2.00 - 4.45	.55 - .80	(2 specimens)

(for data listed per individual see Tables 4, 7, 8, 9).

The equatorial layer shows a uniserial arrangement of the juvenarium, followed by a cyclical orbitoid-like pattern.

Because of slight recrystallization, it is not easy to observe the primary spirals in their entirety. The size of the protoconch could be measured but twice (in one specimen from sample J 3700 and another from sample J 3680), its diameter in both cases being 27 micron. The number of primary chambers of the same specimens are 13 (J 3700) and 10 (J 3680). The cyclical phase, up to the introduction of equatorial chambers, from whose marginal walls the radial elements issue forth, consists of arcuate secondary chambers which are apparently not divided by the pseudorbitoid layer. This first part of the cyclical phase is definitely wider than its equivalent in the megalospherical forms. In horizontal sections, the undivided arcuate equatorial chambers are usually well defined, communicating by means of basal apertures (Plate 11, figs. 5, 6; Plate 5). In a later ontogenetical phase, the radial plates tend to separate radial rows of equatorial chambers (as they do in the megalospherical forms). These plates are slightly coarser than in the megalospherical forms, and seem to be interconnected by very delicate horizontal bars, as may be seen rather vaguely in some peripheral vertical sections: Plate 23, fig. 6; Plate 26, figs. 4, 6.

Radial stolons are visible on either side of the radial plates (Plate 26, fig. 1). Judging from the presence of translucent lines, intramural lumina may be present within the radial plates (Plate 26, fig. 1).

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Appendix 1

TABLES 1-18

Explanation of the symbols:

Dm = diameter of test in mm
Th = thickness of test in mm
P = protoconchal diameter (width) in standard-units of .90 micron
D = deuteroconchal diameter (width) in standard-units of .96 micron
Y = number of primary chambers (protoconch and deuteroconch included in counting)
p_2 = number of chambers, constituting the protoconchal spiral which issues from the second principal auxiliary chamber, up to the first symmetrical chamber on the protoconchal side (protoconch, deuteroconch and second principal auxiliary chamber included in counting)
d_1 = number of chambers constituting the deuteroconchal spiral which issues from the first principal auxiliary chamber, up to the first symmetrical chamber on the deuteroconchal side (protoconch, deuteroconch and first principal auxiliary chamber included in counting)
d_2 = number of chambers, constituting the deuteroconchal spiral which issues from the second principal auxiliary chamber, up to the first symmetrical chamber on the deuteroconchal side (protoconch, deuteroconch and second principal auxiliary chamber included in counting)

TABLE 1. SAMPLES X 6002 AND J 5129 (CAS ABAO LIMESTONE, CURAÇAO)

Horizontal sections:

spec. no.	Dm(mm)	Th(mm)	P	D	Y
			(in units of .96 micron)		
J 5129-1	1.65	.60			30
— 3	3.00	.85			
— 5	1.40				
— 7	1.80				
— 9	2.15	.90			

For measurements and counts on individuals from sample X 6002 see Krijnen (1967).

TABLE 2. SAMPLE J 3416 (SUNDERLAND INLIER, JAMAICA)

Microspheric forms:

spec. no.	Dm(mm)	Th(mm)	P	D	Y
			(in units of .96 micron)		
67	.75	.20	23	17	37

Megalospheric forms:

spec. no.	Dm(mm)	Th(mm)	P	D	Y
			(in units of .96 micron)		
1	1.30	.55			
2	1.30	.50			
3	1.35	.70	74	59	16
4	1.25	.55	56	54	18
5	1.35	.75			
6	1.40	.50	51	36	24?
7	1.15	.45	68	62	
8	1.40	.60	59	61	20
12	1.00	.50			
13	1.25	.55			
15	1.40	.65	79	53	20
22	1.15	.45			
33	1.05	.55	65	60	19
36	1.10	.60	75	64	16
38	1.10	.55	67	57	17
41	.95	.45	51	38	21
43	1.00	.40	70	57	18
46	1.00	.40	61	48	
49	.90	.35	65	56	18
53	.75	.55	78	67	25
55	1.10	.50	73	54	17
64			50	42	24?
66	.75	.35	56	54	19
75	.60	.40	71	49	20?
78	.60	.30	69	60	21
79	.60	.30	66	55	21
82	.55	.35	56	56	17
83	.40	.20			
84	.45	.30			
90	.50	.25	54	40	19?
92			60	50	23

TABLE 3. SAMPLE J 3978 (GREEN ISLAND INLIER, JAMAICA)

Microspheric forms:

spec. no.	Dm(mm)	Th(mm)	P (in units of .96 micron)	Y
18	1.80	.65		
38	1.15	.55		
44	1.10?	.45	22	15
62	1.70	.55?	28	
141	1.20?	.55		
149	2.40	1.00	25	18?
160	.65?	.30		
164	1.45	.50	27	22
168	2.15	.70	31	17
171	1.60	.55		
256	3.30	.75?	34	21
260	.95	.35	28	17
264	3.60			
290	1.95?	.80	28	19
293			20	17
303	1.10?	.40	28	18
319	1.65?	1.25	29	15
378	2.25	.85	24	15
379	1.30	.50	37	19
396	1.10	.35		
461	2.75	1.10		
814	.65?	.35		
939	.70?	.35		
1114	.55	.20		
1162	.50	.20		

Megalospheric forms:

spec. no.	Dm(mm)	Th(mm)	P (in units of .96 micron)	D	p_1 (Y)	p_2	d_1	d_2
10	1.25	.50	108	132	7	3	6	3
13	.70	.25	59	49	10	–	–	–
24	.75	.20	67	80				
33	1.00	.55	103	100				
39	.65	.35	100	112	5	4	6	3
80	1.10	.45	118	139				
82	1.30	.55	105	107	7	–	6	–
86	1.10	.40	94	99	5	3	4	4
91	.55	.30	115	115	6	4	5	4
93	1.10	.50	128	156	7	3	5	4
97	1.50	.55	61	71				
99	2.00	.40	101	107	6	3	5	3
103	.95	.50	96	122	6	3	5	3
111	.85	.55	80	90	6	3	5	3
130	1.40	.55						
133	.95	.60	101	125				
148			142	150				
184	1.60	.60	91	85				
202	1.20	.50	106	112				
207	1.40	.75	78	77	6	–	6	–
212	1.15	.60						
218	.80	.30	195	193				
228	1.45	.55						
251	.90	.45	102	119	5	3	5	3

to be continued

spec. no.	Dm(mm)	Th(mm)	P	D	p_1	p_2	d_1	d_2
			(in units of .96 micron)		(Y)			
277	1.30	.50	137	138	6	4	5	4
278	1.10	.40	72	73	5	3	4	4
286	1.40	.40	104	89	6	3	6	3
307	1.15	.35						
314	1.40	.75	60	57				
315	1.55	.65	162	171				
325	1.50							
329	1.00	.35						
333	1.35	.60						
337	1.20	.35	96	99	5	3		
344	.95	.40	101	108	5	3	6	3
349	.85	.40	144	125	6	3	6	4
358	.80	.30	42	43	13	–	–	–
366	1.15	.75						
370	1.00	.50	76	82				
376	1.40	.70	102	99	6	4	5	4
395	.90	.40						
402	1.05	.60	111	100				
418	1.10	.30						
443	1.10	.45	94	108	6	3	4	3
449	1.05	.60						
451	.95	.50	100	123	5	4	6	4
455	1.00	.40	111	138	5	3	5	4
479	1.40	.60	84	66	8	–		
485	1.30	.50	91	81	6	3	5	4
495	1.25	.60	75	81	9	–	4	–
498	1.15	.45	120	125	6	4		
501	1.10	.40	44	38	8	–	4	–
514	1.10	.50	46	51	8	–	4	–
516	1.00	.40						
518	.85	.50	101	113	5	3	5	4
524	1.10	.40						
531	.90	.35	76	63	9	–	4	–
533	1.00	.40	88	95	5	3	5	3
536	.95	.25						
538	.85	.40	112	125	5	3	5	3
539	.90	.50	102	101	8	–	5	–
540	1.00	.40						
544	1.00	.55						
545	.90	.45	154	158	5	4	4 (3, 3)	4
552	.85	.25	92	105	6	3	6	3
556	.80	.35	122	123	6	4	5	3
564	.85	.40	114	135	5	3	4	4
587	.80	.35	128	117	6	3	5	3
592	.80	.35	94	98	6	3	5	4
595	.75	.30	107	101	5	3	5	3
610	.80	.40	47	45	11	–	–	–
616	1.00	.50						
620	.95	.35	109	118	6	3	5	3
655	.80	.30	126	132	6	3	6	3
665	.75	.35	54	60	9	–	–	–
669	.80	.40	83	100	6	3	6	3
674	.85	.45						
693	.85	.50	102	99	6	3		
694	.80	.35						
711	.75	.35	101	108	5			
712	.80	.40	125	119	5	3	5	3

to be continued

spec. no.	Dm(mm)	Th(mm)	P	D	p_1	p_2	d_1	d_2
			(in units of .96 micron)		(Y)			
713	.75	.35	115	122	5	3	5	3
720	.75	.40						
726	.80	.40	112	106				
727	.80	.35	102	91	5	3		
736	.70	.25	122	120	6	4		
737	.80	.40	94	88	5	3	5	3
739	.70	.30						
740	.75	.30	111	111	5	3	6	3
746	.75	.25						
753	.75	.40	131	114	5	4	?6	3
758	.75	.40						
774	.70	.25	80	91	5	3	5	3
786	.75							
795	.70	.35	85	76	6	3	5	4
798	.70	.35	133	148	6	3	5	4
801	.70	.45	120	124	6	3		
802	.75	.40	134	124	6	3		3
823	.45	.30						
833	.70	.40	107	99	6	3	5	4
836	.70	.30	120	117	6	3	6	4
842	.70	.45	139	145	6	4	6	4
849	.70	.25	72	72	7	–	5	–
851	.65	.25	115	106	6	4	5	3
855	.70	.40						
857	.65	.35	91	90	6	3	5	5
880	.70	.40						
883	.70	.25	108	117	5	3	5	4
887	.65	.30						
903	.55	.35						
910	.75	.40	95	82				
943	.55	.30	120	133	5	3	5	4
947	.65	.30	137	131	6	4	5	3
949	.55	.25						
950	.60	.25						
953	.60	.35	139	121	6	3	5	4
962	.60	.25	132	121	6	3	5	3
966	.65	.50						
976	.60	.25						
989	.60	.25	105	112	5	3	5	3
996	.60	.35	134	88	6	3	5	3
998	.55	.30						
1004	.60	.20	109	101	7	3	6	3
1017	.75?	.40						
1025		.40						
1036	.55	.25	109	94	5	3	5	3
1040	.55	.30	116	117	6	4	5?	4?
1045	.55	.25	143	124	6	4	5	3
1050	.50	.20	91	85	6	3	5	4
1062	.50	.20	106	110	5	3	5	4
1083	.50	.35	52	52	8	–	4	–
1102	.55	.20	116	110				
1104	.55	.25	97	89	6	3	5	4
1108	.55	.30	53	56	9	–	–	–
1110	.50	.20	105	93	5	3	5?	4
1112	.50	.25						
1119	.55	.25						

to be continued

spec. no.	Dm(mm)	Th(mm)	P (in units of .96 micron)	D	p_1 (Y)	p_2	d_1	d_2
1161	.45	.20	98	105	6	3	5	3
1164	.50	.25	94	99	6	3		
1165	.50	.20	152	169	6	5	6	5
1166	.55	.20						
1171	.45	.20	83	82	8	3	4	3
1174	.50	.25	104	108				
1176	.35	.15	63	65	8	–	4	–
1180	.50	.25						
1189	.50	.30	108	94	6	3	4	3
1192	.50	.20	104	100	5	3	5	3
1194	.50	.15	57	56	10	–	–	–
1197	.45	.20						
1209	.45	.15	92	94	6			
1210	.50	.25	104	109	6	3	5	4
1220	.40	.15	115	120	5	4		
1229	.40	.15	102	116	5	3	4	4
1260	.30	.15	89	82	6	3	5	4
1266	.40	.15						
1269	.35	.15						
1270	.40	.25	75	75	8	–	4	–
1276	.40	.20	65	67	12	–	–	–
1278	.35	.20						
1283	.35	.15	110	106				
1286	.35	.15						
1297	.50	.20	81	76	9	3	5	3
1307	.40	.25	54	56	9	–	–	–
1315			133	130	6	3	5	3
1321			96	110	6	3		
1327			140	134	6	3		
1332			140	138	6	4	6	4

TABLE 4. SAMPLE J 3700 (SUNDERLAND INLIER, JAMAICA)

Microspheric forms:

spec. no.	Dm(mm)	Th(mm)	P (in units of .96 micron)	D	Y
3	2.50	.55?			
8	2.40	.55	28		13
67	1.55				
180		.40			
326	.75	.25			

Megalospheric forms:

spec. no.	Dm(mm)	Th(mm)	P (in units of .96 micron)	D	p_1 (Y)	p_2	d_1	d_2
28	1.75	.50	116	140	5	5	6	5
33	1.80	.40	89	93	5	4	5	4
53	1.80	.45	108	117	5	4	5	4
58	1.70	.50						
61	1.65	.35	106	119	5	4	6	4
82	1.65	.65	90	101	5	4	5	4
97	1.20	.25	143	160	5	4	5	4
102	1.65	.40						

to be continued

spec. no.	Dm(mm)	Th(mm)	P (in units of .96 micron)	D (in units of .96 micron)	p_1 (Y)	p_2	d_1	p_2
107	1.50	.40	65	77	5	3	5	4
114	1.35	.25	117	125	6	3	6	3
121	1.45	.40	141	143	6	4	5	3?
162	1.25	.35	103	107	5	4	5	4
168	1.25	.45	125	131	5	6	6	5
174	1.10	.40	84	103	6	4	5	4
206	1.10	.45	112	119	5	4	5	4
215	1.05	.35	137	145	5	4	5	4
218	1.05	.45	116	111	5	4	5	4
231	1.25	.30	83	93	6	5	5	4
238	.90	.40	117	128	6	3	5	4
242	.90	.30	108	124	5	4	5	4
250	1.05	.30	90	107	5	3	5	4
272	.85	.30	134	125	6	5	5	4
288	.90	.25	136	125	5	5	5	4
299	.90	.45	118	123	5	4	3	6
301	.90	.35	103	131	5	4	5	4
331	.75	.35	135	162	5	5	6	4
333	.85	.35	107	99	5	4	5	5
341	.90	.40	134	125	6	4	5	5
359	.85	.30	113	121	5	4	5	4
382	.80	.20						
389	.75	.50	150	144	6	4		
391	.75	.25	118	98	5	4	5	4
403	.65	.25	100	112	6	3	5	4
406	.65	.25	127	144	5	4	5	4
417	.65	.30						
422		.40	126	147	6	5	5	4
427	.65	.20	88	100	5	4	5	4
436	.60	.15						
462	.65	.25	110	110	6	5	5	4
473	.55	.20	88	81	5	4	5	4
483	.65	.30	88	104	6	4	6	3
495	.60	.25	104	133	5	4	5	4
502	.55	.15						
521	.50	.20						
529	.55	.25						
561	.50	.25	122	102	5	3	5	3
588	.50	.20	105	118	5	4	5	3
592	.50	.25	101	101	6	4	6	4
611	.50	.25	112	130	7	4	5	4
628	.50	.20	99	124	5	4	5	5
637	.50	.20	87	95	5	5	5	4
654	.50	.15						
657	.50	.20	120	133	5	5	5	5
665	.45	.20	98	123	5	4	6	5
674	.50	.10						
686	.40	.15	112	114	5	4	5	4
693	.40	.20	88	106	5	4	6	4
701	.40	.15	83	97	5	3	5	4
711	.35	.15	97	106	6	3	5	4
717	.40	.15	84	105	5	4	5	4
735	.40	.20	104	108	5	4	5	4
770	.35	.20	100	112	5	4	5	4
785	.30	.15	101	122	5	4	5	4
788	.40	.15	97	114	6	4	6	4
812	1.50	.35	91	91	6	3	5	4

TABLE 5. SAMPLE J 3601 (SUNDERLAND INLIER, JAMAICA)

Microspheric forms:

spec. no.	Dm(mm)	Th(mm)	P	D	Y
			(in units of .96 micron)		
36	5.35	1.85			
38	5.50	1.85			
40	4.95	1.65	18	17	14
41	5.15	1.45			
42	5.00	2.05			
44	4.70	2.55	18	20	16
53	4.75	1.25	24	21	16
63	3.75	1.15			
68	3.95	1.45	26	18	17
74	4.20	1.60			
83	3.10	1.35			
85	3.20	1.05			
90	3.10?	.95			
98	3.45	1.35			
103	2.90	.90	30	36	14
104	2.65	.90			
108	2.75?	1.10	23	20	15
116	2.20	.80			
127		1.25			
132	1.95?	1.05	26	22	16
133	2.10	.85			
141	1.90	.65			
159	1.50?	.85	21	14	16
195	1.30	.55	26	27	

Megalospheric forms:

spec. no.	Dm(mm)	Th(mm)	P	D	p_1	p_2	d_1	d_2
			(in units of .96 micron)		(Y)			
18	1.00	.45	143	123	5	5	5	5
29	1.25	.50						
119	2.25	.70	148	102	6	4	5	4
153	1.65	.55	214	210	5	5	5	5
169	1.60	.60						
170	1.35	.65	90	104	4	4	5	4
175	1.45	.55	133	178	5	5	6	5
184	1.25	.50						
187	1.25	.55	78	92	5	4	4	4
190	1.45	.40	126	120	5	5	4	4
192		.60	107	98	5	5	5	4
193	1.20	.40						
202	1.30?	.55	165	205	5	5	5	5
205	1.25	.65	151	171				
214	1.25	.45	144	173	5	5	5	5
215	1.35	.65	201	230	5	5	4	4
217	1.15	.55						
232	1.00	.30						
233	1.05	.50	149	186	5	4	5	5
247	1.25	.50	170	154	5	5	5	4
256	1.10	.50	148	159	5	5	5	5
264	1.10	.45						
269	1.05	.35						
278	.95	.40	178	227	6	5	5	5

to be continued

spec. no.	Dm(mm)	Th(mm)	P (in units of .96 micron)	D	p_1 (Y)	p_2	d_1	d_2
296	.85	.60	149	141	5	5	5	5
305	1.00	.40						
324	.75	.40	170	155	5	5	5	5
327	.90	.50	176	158	5	5	6	5
329	.90	.25	78	117	7	–	5	–
330			247	187				
335	.90	.45	125	116	5	5	5	5
339	.90	.45	113	140	5	5	5	5
343	.80	.35						
346			98	111	5	5	5	4
368			170	193	5	5	5	5
372	.75	.25	110	109	5	5	6	5
373	.75	.45						
376	.85	.35	150	169	5	5	5	5
378	.75	.25						
379	.75	.35						
386	.75	.30	127	123	5	4	4	4
393	.75	.30	121	153	4	4	5	5
399	.65	.30	122	113	5	5	5	4
407	.65	.30						
410	.65	.20	125	150	5	5	5	4
412	.60	.35	108	102	7	–	6?	–
414	.60	.30	148	167	6?	3	7	3
424	.75	.40	133	187	5	5	6	5
432	.65	.25	97	113	4	4	5	5
436	.55	.35						
439	.55	.25	110	120	5	4	5	5
441	.60	.25						
442	.65	.40	137	159	5	4	5	4
451	.60	.30	131	140	5	4	4	4
477	.65	.20						
482	.55	.15	113	94	7	–	6	–
488	.55		167	197	5	5?	5	5
489	.45	.20	167	180	4	4		
490	.55	.25						
492	.45	.20	170	172?	5	5		
494	.75	.25	153	136	5	5	5	5
504	.50	.25	135	149	4	4	5	4
506	.55	.30						
516	.55		124	117	6?	4?	5?	5?

TABLE 6a. SAMPLE J 3697 (SUNDERLAND INLIER, JAMAICA)

Microspheric forms:

spec. no.	Dm(mm)	Th(mm)	P (in units of .96 micron)	Y
4	6.25	2.15		
5	5.55	2.30		
10	5.65	1.70		
12	4.75	2.05		
13	5.25	2.20		
21		1.70		
28				
50	2.20	.95	27	
51		.95	31	
62	1.90	.70		

10% drawn from a select sample ("S"J 3697) of microspheric forms (see Table 6b):

1	7.35	2.50		
5	7.15	2.40		
19	7.25	2.25		
23	4.35	1.70	27	18
29	5.40	1.90		
60	5.70	1.65	27	16
67	4.55	1.30	26	17
71	4.55		28	
73	5.15	2.00		
81			21	17
100	4.50	1.75	28	
119	3.25	1.05	33	20
126	5.45	1.95	22	18
128	4.95	2.75		

Megalospheric forms:

spec. no.	Dm(mm)	Th(mm)	P	D	p_1 (Y)	p_2	d_1	d_2
			(in units of .96 micron)					
2	2.25	.95	205	216	5	5	5	5
34	2.55	1.00	182	218	5	4	5	5
55	2.05	.80	138	163	5	5	5	5
65	1.95	.75	208	195	5	6	6?	6?
73	1.80	.80	163	164	5	5	5	4
96	2.15	.85	206	186	5	5	5	5
104	1.65	.70	196	218				
107	1.70	.80	184	172	5?	5?		
111	1.75	.80	211	246	5	5	5	5
127	1.60	.80	253	232				
129	1.75	.70	190	232	5?	5?	5?	5?
136	1.60	.70	203	237	5	5	5	5
142	1.50	.75	191	205	4	4	5	5
145	1.75	.75	190	216	5	5	5	5
151	1.55	.65	224	238	5	4		
152	1.60	.60	146	182	5	4		
168	1.75	.65	145	160	5	5	5	5
188	1.45	.75	78	85	7	–	7	–
190	1.45	.60	167	144	5	5	5	5
193	1.55	.60	120	133	4	4	4	4
217	1.50	.65	125	149	5	5		
221	1.55	.65	129	132	5	6	5	5
241	1.65	.65	109	125				
249	1.35	.50	133	154	5	5	5	5
268	1.35	.55	112	112	5	5	5	5
270	1.55	.70	158	190				
277	1.40	.80	141	134			5	5
279	1.20	.55	179	174	5	5	5	5
281	1.35	.50	148	154	4	5	5	5
283	1.35	.70	132	147	5	5	5	5
285	1.20	.55	191	204	6	5	5	5
302	1.25	.55	148	132				
324	1.25	.60	180	176	5	5	4	5
328	1.15	.35	138	134	5	5	5	5
339	1.20	.55	188	234	5	5	4 (4, 3)	3
349	1.25	.55	181	192	5	5	5	5
367	1.10	.45	181	195	4	4	5	5
391	1.15	.50	127	130	5	5	5	5
399	1.15	.50	177	185	5	5	5?	4?

to be continued

spec. no.	Dm(mm)	Th(mm)	P (in units of .96 micron)	D (in units of .96 micron)	p_1 (Y)	p_2	d_1	d_2
400	1.15	.50	184	208	5	5	5	4
427	1.05	.55	205	211	5	5	4	4
439	1.10	.50	142	145	4	4	5	5
453	1.10	.55	158	183	5?	5?	5	5
466	1.00	.55	132	161	5	5	5	4
474	1.00	.50	149	163	5	5	5	5
480	1.05	.50	154	135	5	5	5	5
488	1.00	.45	186	195	5	5	5	5
513	1.00	.65	208	256	5	5	6	6
519	1.00	.40	87	111	5	3	5	3
522	1.00	.45	168	155	5	5		
531	.95	.50	173	195	5	5	5?	5?
536	1.15	.55	154	160				
544	1.90	.90	88	103	5	4	4	4
568	1.00	.45	142	163	5	5	5	5
578	.90	.30	166	194	4	4	5	5
597	.85	.40	107	122	5	5	5	5
608	.80	.35	174	190	5	5	5	5
616	.85	.45	147	181			5	5
629	.90	.60	102	112				
642	.85	.40	162	195	5	5	5	5
646	.80	.40	134	132	5	5		
658	.75	.45	216	247	6	6	5	5
666	.80	.35	181	216	5	5	5	5
670	.80	.25	149	167	5	5	5	5
678	.75	.40	193	193	5	5	5	5
682	.70	.40	118	141				
684	.75	.40	170	182	5	5	5	5
709	.75	.35	160	192	4	4	5	5
712	.75	.35	88	95	5	4	5	4
717	.80	.35	114	126				
722	.70	.40	153	169				
730	.75	.35	120	131	5	5		
738	.70	.35	197	201	5	5	5	5
745	.70	.30	180	165	5	5	4	4
746	.65	.30	113	141	5?	4?	5	5
761	.85	.25	153	161	5	5	5	5
773	.65	.35	147	139	5	5		
785	.70	.30	124	125	5	5	5	5
791			172	190				
793	.70		115	134				
797	.65	.40	168	190				
807	.65	.35	117	119				
819	.60	.40	123	153	5	5	5	5
821	.60	.30	176	214	5	5	5	5
828	.60	.25	152	143	5?	5?	5?	5?
833	.70	.35	110	116	5	5	5	5
853	.55	.25	122	131	5	5	5?	5?
854	.55	.25	139	131	5?	5?	5	5
860			139	148	5	5	5	5
875	.55	.25	110	114	4	4	5	5
877	.55	.30	137	150	5	5	5?	5?
885	.50	.25	112	144	4	4	5	5
889	.50	.25	133	153	5	5	5	5
904	.55	.30	133	156	4	4	5	4
916	.45	.20	93	99	5	5	4	5
919	.45	.25	210	249	6	6		

TABLE 6b. SAMPLE "S"J 3697 (A SELECT SAMPLE OF MICROSPHERIC FORMS, COLLECTED AT LOCALITY J 3697)

spec. no.	Dm(mm)	Th(mm)	spec. no.	Dm(mm)	Th(mm)
1	7.35	2.50	56	5.15	2.00
2	5.65	2.10	57	4.15	1.60
3	7.55	1.85	58	4.30	2.00
4	8.00	2.45	59	4.90	1.40
5	7.15	2.40	60	5.70	1.65
6	5.65	2.45	61	7.00	
7	6.75	1.80	62	5.10?	1.30
8	5.75	2.30	63	5.85	1.65
9	5.75	1.50	64		1.80
10	7.00	2.20	65	4.00	1.25
11	5.50	2.30	66	5.40	1.90
12	6.65	2.40	67	4.55	1.30
13	6.15	2.35	68	4.45	1.80
14	5.80	2.50	69	4.45	1.95
15	6.60	2.55	70	6.05	2.40
16	6.15	2.15	71	4.55	
17	6.10	2.45	72	5.05	
18	8.40	2.50	73	5.15?	2.00
19	7.25	2.25	74	5.45	1.60
20	5.00	2.00	75	5.85	2.20
21	6.20	2.50	76	6.25	1.90
22	6.55	2.25	77	5.55	1.55
23	4.35	1.70	78	5.70	2.45
24	8.00	2.80	79	5.65?	1.80
25	6.55?	2.35	80	3.35?	1.60
26	4.65	1.70	81	fragment	
27	5.70	2.25	82	6.45	1.70
28	6.70	1.80	83	5.90	1.85
29	5.40	1.90	84	4.65?	1.95
30	6.30	1.90	85	5.05	1.95
31	6.65?	2.35	86	7.30	2.40
32	6.10	1.60	87	6.50	2.00
33	3.30	1.35	88	5.10	1.75
34	6.00?	2.25	89	5.30?	1.85
35	6.30	2.15	90	5.00	1.40
36	5.40	2.15	91	5.40	1.85
37	4.90	2.00	92	3.80	1.40
38	7.00	2.15	93	6.25	2.25
39	7.45	2.75	94	5.15	1.50
40	6.25	2.20	95	4.80	1.95
41	6.30	2.40	96	3.95	1.10
42	7.65	2.55	97	4.40	1.80
43	6.00?	2.10	98	5.10	1.40
44	5.85	1.80	99	4.90	1.75
45	5.80	1.55	100	4.50	1.75
46	5.95	2.00	101	6.45	1.40
47	5.15	1.85	102	4.20	1.45
48	7.40	2.35	103	4.50	1.15
49	4.80	1.95	104	6.40	2.35
50	5.30?	2.10	105	5.60	1.80
51	6.40	2.15	106	4.10	2.05
52	6.15	2.55?	107	4.25	1.40
53	4.90	1.50	108	6.35	
54	6.15	2.55	109	5.85	2.20
55	5.40	1.75	110	3.05?	1.15

to be continued

spec. no.	Dm(mm)	Th(mm)	spec. no.	Dm(mm)	Th(mm)
111	2.90	1.20	125	4.10	1.40
112	4.95	2.05	126	5.45	1.95
113	5.35	1.95	127	3.25	1.30
114	4.00	1.25	128	4.95	2.75
115	3.20	1.15	129	4.00	2.00
116		1.95	130	4.05	1.30
117	5.50	2.25	131	4.10	1.40
118	5.15	2.10	132	4.25	1.55
119	3.25	1.05	133	5.90	2.30?
120	5.00	1.85	134	1.25	.50
121	3.85	1.20	135	1.05?	.50
122	3.70	1.80	137	.75	.50
123	3.55	1.35	142	.90	.50
124	5.00	1.45			

TABLE 7. SAMPLE J 3680 (SUNDERLAND INLIER, JAMAICA)

Microspheric forms:

spec. no.	Dm(mm)	Th(mm)	P (in units of .96 micron)	Y
3			28	10
24	1.90	.50		
269?	1.45			
384?	1.25	.45		

Megalospheric forms:

spec. no.	Dm(mm)	Th(mm)	P (in units of .96 micron)	D	p_1 (Y)	p_2	d_1	d_2
19	2.10	.55	90	82				
32	1.75	.55	102	109	5	4		
38	1.85	.50	93	102	5	4	5	4
48	1.85	.40	55	73	4	4	5	4
60	1.85	.45	125	129	6	6	5	4
69	1.80	.55	84	94	5	3	5	4
83	1.70	.50	76	95	5	4	4	5
104	1.70	.50	85	110	5	5	5	5
115	1.50	.55	85	100	5	5	5	5
136	1.55	.55	101	122	5	4	5	4
138	1.55	.40	107	115	5	4	5	4
151	1.45	.50	99	108	5	4	5	4
165	1.75	.45	96	124	5	4	5	5
177	1.50	.35	85	100	5	4	5	4
183	1.35	.40						
192	1.40	.50	91	117	5	3	5	4
213	1.45	.50	111	134	5	4	5	4
241	1.30	.55	109	141	5	4	6	5
250	1.25	.50	78	77	6	3	5	3
260	1.40	.40	95	114	5	4	6	4
266	1.30	.40						
274	1.35	.40	113	104	5	4	6	3
280	1.25	.45	94	97	5	3	6	4
306	1.40	.70	110	128	6	3	4	6

to be continued

spec. no.	Dm(mm)	Th(mm)	P (in units of .96 micron)	D	p_1 (Y)	p_2	d_1	d_2
321	1.55	.40						
338	1.30	.45	99	99	4	4	6	3
341	1.30	.40	91	83	5	4	4	4
347	1.25	.40						
358	1.15	.35	71	82	5	4	5	4
364	1.15	.45	93	114	5	4	5	4
372	1.25	.45						
380	1.25	.50	106	119	5	4	5	4
392	1.25	.50						
395	1.25	.50	119	126	5	4	6	4
406	1.15	.45						
412	1.20	.40	87	95	5	4	5	4
417	1.15	.30						
424	1.30	.45	130	130	6	4	5	4
434	1.20	.50						
469	1.05	.40	106	90	5	4	5	4
473	1.20	.55						
487	1.15	.40						
494		.45	94	103	5	4	5	4
505	1.00	.45	100	116	6	3	5	5
510	1.15	.50	73	70	4	4	4	4
527	1.00	.45	99	118	5	4		
531	1.15	.30	103	103	5	4	5	4
538	1.20	.35	85	93	6	4	5	4
546	1.10	.40	98	114	5	4	5	4
555	1.15	.50	99	104	5	5	5	4
564	.80	.20	110	112	5	4	5	4
594	1.20	.35	101	99	5	4	5	4
608	.75	.25	96	117	5	4	5	4
614	1.05	.35	84	78	5	3	4	4
636	.95	.30	104	114	5	4	5	4
647	.90	.25	102	121	5	4	6	5
651	.90	.30	64	61	7	–	5	–
655	.75	.30	103	90	5	4	5	4
658	.80	.30	91	100	6	4	6	4
673	1.05	.45	95	110	5	4	5	5
675	1.00	.40	95	106	5	4	5	5
688	1.30	.55						
711	1.10?	.60	97	98	5	4	5	4
719			94	100	5	4	5	4
730	1.30	.40	82	91	5	3	5	3
732	.95	.40	69	87	5	4	5	4
746	1.05	.40						
778	1.00	.45	98	104	5	4	5	4
788	1.00	.40	76	88	5	3	4	4
805	1.00	.40						
814	1.10?	.70	107	109	5	4	5	4
820	.95	.40						
836	.90	.25	93	100	5	4	5	4
839	1.00	.35	96	103	5	5	5	4
857	1.10	.45						
865	1.00	.30	127	111	5	4	5	4
877	1.00	.40	110	114	5	4	6	5
883	.85	.30	109	128	5	4	5	4
892	.90	.35	88	90	5	4	5	4
919	.90	.40						

to be continued

spec. no.	Dm(mm)	Th(mm)	P (in units of .96 micron)	D (in units of .96 micron)	p_1 (Y)	p_2	d_1	d_2
932	1.00	.35	66	80	5	3	6	3
936	.95	.45	111	134	5	4	6	4
940	1.00	.35	89	113	4	4	5	3
955	.80	.30						
963	.85	.35	73	96	5	3	5	4
964	.85	.25	84	101	5	3	5	3
975	.90	.40	101	122	5	4	5	4
991	.85	.35	135	136	5	4	5	4
1016	.85	.35	79	85	5	4	5	4
1025	.80	.45	94	99	5	4	5	4
1035	.85	.45						
1049	1.05		87	105	5	3	5	4
1063	.85	.25	104	110				
1069	.80	.25	110	123	5	4	5	4
1076	.85	.30	95	99	5	4		
1084	.75	.35	105	115	5	4	5	4
1093	.80	.40						
1104		.35	105	110	5	4	5	4
1118	.80	.45						
1132	1.00	.30						
1141		.40						
1146	.90	.25	103	106	5	4	5	4
1158			134	137	5?	4?	5	4
1176	.85	.40						
1200	.80	.30						
1221	.90	.40	122	116				
1223	.85	.30	88	100	6	3	5	4
1229	.85	.40	114	122	6	3	6?	4?
1244	1.00	.40						
1259	.85	.30	95	107	5	4	5	4
1279	.75	.35	104	98	6	4	5	4
1286	.80	.35	102	119	5	4	5	4
1316	.90	.35	105	109	6	4	5	4
1320	.90	.35	101	117	5	5	5	4
1331	.80	.35	111	105	5	4	5	4
1348	.85	.35	91	103	4	4	5	5
1352	.85	.35	85	93	6	3	7	3
1354	.75	.30	101	115	5	4	5	4
1365	.75	.20	95	101	4	4	5	4
1371	.75	.25	108	120	6	4	5	4
1383	.75	.35	93	97	6	5	5	4
1390	.75	.40	95	110	5	3	5	3
1402		.30						
1428	.75	.25						
1437		.35						
1443	.70	.30	110	117	6	4	5	4
1447	.60	.35						
1465	.80	.30	100	98	5	4	5	4
1477	.75?	.30						
1488	.75	.35						
1500	.75	.30						
1505	.75	.25	104	115	5	4	6	5
1512	.75	.35	117	114	5	5	6	4
1528	.75	.25						
1540	.70	.25	103	110	5	4	5	4
1551	.70	.25	109	133	5	4	5	4
1556		.30	83	98	5	4	5	4

to be continued

spec. no.	Dm(mm)	Th(mm)	P (in units of .96 micron)	D (in units of .96 micron)	p_1 (Y)	p_2	d_1	d_2
1568	.80	.30	114	153	5	4	5	4
1590	.70	.30	63	77	5	3	5	3
1607	.70	.35	83	103	5	4	5	4
1631	.70	.25	96	95	5	4	5	4
1636	.65	.25	88	108	5	3	5	4
1685	.65	.25						
1691	.65	.25	83	91	5	4	5	4
1708	.65	.35	94	102				
1710	.65	.30	89	101	5	4	5	4
1712	.65	.25	80	90	5	3	6	3
1769	.70	.20	80	94	5	3	5	3
1774	.65	.25	126	129	5	4	5	4
1783	.55	.20	52	63	6	–	5	–
1788	.60	.20	132	155	5	4	6	5
1798	.55	.25						
1800	.65	.20	108	119	5	4	5	4
1812	.70	.25						
1819	.65	.25						
1844	.65	.25	116	134	5	3	6	4
1869	.65	.35						
1894	.70	.25						
1901		.40	101	111	5	4		
1912	.70	.25						
1926	.55	.20	105	105	5	4	5	4
1942	.60	.20	113	113	6	4	5	4
1948	.60	.30	122	107	5	5	6	3
1959	.60	.25	90	100	5	3	5	3
1969	.65	.25						
2019	.50	.25	106	101	5	4		
2033	.55	.25	90	108	6	3		
2052	.50	.25	106	113	5	4	5	4
2055	.50	.15	103	109	5	4	5	4
2060	.50	.20						
2086		.25	107	115	5	4	5	4
2091	.50	.20	106	124	5?	4?	5	4
2102	.45	.20						
2108	.55	.25	82	83	5	4	5	4
2173	.50	.20	124	127	5	4	5	4
2179	.55	.25	112	109	5	4	4	4
2209	.55	.30	125	125				
2229	.50	.35	110	99	5	4	5	4
2235	.50	.15	102	141	5	5	6	
2248	.55	.25						
2254	.55	.30	100	124	5	4	5	4
2264	.65	.35						
2272	.50	.25	88	99	5	4	5	4
2299	.45	.20						
2310	.45	.20	94	94	5	4	5	4
2344	.50	.20	90	99	5	4	5	4
2347	.45	.25	111	99	5	4	5	4
2354	.45	.15	112	116	5	4	5	4
2380	.45	.20	102	103	5	4	5	4
2389	.35	.15						
2405	.35	.15						
2419	.35	.10	94	96	5	4	5	4
2425	.45	.20	76	82	5	3	6	3
2447	.35	.25	93	115	5	3		
2457	.35	.15	119	126	5	4	5	4
2473		.30	105	98	5	5	5	4
2496	.40	.15						
2514	.35	.20	117	129	5	4	5	4

TABLE 8. SAMPLE J 3686 (SUNDERLAND INLIER, JAMAICA)

Microspheric form:

spec. no.	Dm(mm)	Th(mm)	P (in units of .96 micron)	Y
4	2.45	.75		

Megalospheric forms:

spec. no.	Dm(mm)	Th(mm)	P (in units of .96 micron)	D	p_1 (Y)	p_2	d_1	d_2
6	2.20	.55	142	149	5	4		
10	1.95	.60	94	132	5	4		
11	2.05	.40	125	142	5	4	5	4
15	1.70	.75	127	146				
17	1.80	.55	115	116	5	4	5	4
19	1.85		115	122	5	4		
21			86	92	5	3	5	3?
23	2.10	.60	105	118	5	4		
29	1.75?	.65	110	136				
31	1.90	.60	120	115	6	4	5	5
35	2.10	.50	98	106	5	4	5	4
41	1.50	.50	81	106				
47	1.40	.50	108	121				
52	.80	.30	153	161				

TABLE 9. SAMPLE J 3688 (SUNDERLAND INLIER, JAMAICA)

Microspheric forms:

spec. no.	Dm(mm)	Th(mm)	P (in units of .96 micron)	Y
1	4.45	.80		
33	2.00	.55		

Megalospheric forms:

spec. no.	Dm(mm)	Th(mm)	P (in units of .96 micron)	D	p_1 (Y)	p_2	d_1	d_2
5	2.25	.50	109	123	5	4	5	4
13	2.00		105	112	5	4	6	4
17	2.00	.75	121	122	5	4	5	4
19	2.10	.50	119	129	6?	5?		
21	2.10	.60	123	133	5	4	5	4
31	2.05	.50	133	141				
37	2.25	.60	110	129	5	4	5	5
39	1.75	.55	94	105	5	4	6	4
41	1.85	.55	114	119	5	4	4	5
53	2.05	.55	110	106	5	4	5	4
61	1.80	.55	116	125	6	5	6	5
67	1.65	.55	149	152	5	5	6	4
71	1.80	.55	91	100	5	4	5	4
75	1.70	.50	128	132				
77	1.80	.45	130	142	5	4	5	4
79	1.75	.65	110	142	5	4	5	4
81	1.75?		97	100				

to be continued

spec. no.	Dm(mm)	Th(mm)	P	D	p_1	ρ_2	d_1	d_2
			(in units of .96 micron)		(Y)			
85	1.50?	.45	148	159	5	5	4	5
99	1.20	.40	148	196	5	4	6	5
101	1.65	.55	100	130	6	3	6	5
111	1.50	.40	139	141	6	5	5	4
113	1.65	.45	121	122	6	5	5	5
115	1.40	.30	116	126	5	3	4	4
117			110	119				
125			121	133	5	5	6	5
127	1.25	.45	103	93	5	4	5	4
129	1.55	.45	85	94	5	4	5	4
131	1.55	.45	121	145				
133	1.15	.30	113	129	6?	4?		
135	1.10	.35	111	127			5	4
137	1.00	.25	138	155	5	4	4?	5?
143	.90	.30	113	134	6	4	5	5
159			77	99	7	–	5	–
163	1.50	.35	113	120	6	4	6	4
165	1.15	.35	111	128	5	4	5	4
169	1.55	.45	97	115				
179	.85	.30	113	124	5	4	6	4
181	.80	.20	133	135				
183	1.00	.30	87	99	5	4	5	4
193	.60	.20	133	164	5	4	5	4
199	.65	.30	101	118	6	4	5	4
213			107	117				
215	.95	.25	93	106	5	4	5	5
225	.80	.25	123	136	5	4	5	4
229	.90	.25	116	113	5	4	5	5?
233	.65	.25	125	120				
241	.50	.25	122	141	5	4	5	4
243	.95	.30	96	122	4	4	5	4
251	.50	.20	135	140	6	5	5	4
255			97	106	5	4		
259	.45	.20	99	108	5	4	5	4
267	.65	.35	124	165	5	4		
273	.40	.20	104	114?				
281	.40	.10	90	103				
287	1.95	.50	112	113	5	4	5	4
289	2.00	.45	178	182	5	4	5	5
293	1.35	.45	114	129	5	5	5	4
295	1.15	.35	130	131	5	4	6	5
307	1.00	.30	109	114	5	4	5	4
309			118	122	5	4	5	4
311	.60	.25	154	171	5	4?	5	4
315	.45	.20	154	187	5	4		
319	.45	.25	121	118	6	5	5	4
321	.35	.15	120	135	5	4	5	4
323	.45	.15	110	145	5	4	5	4
329	.60	.20	123	131	5	4	5	4
331			85	99	8	–	6	–
337	.45	.15	77	86	5	4	5	3
339	.45	.15	93	105	5	4		

TABLE 10. NUMBER OF OBSERVATIONS, AND MEAN AND STANDARD DEVIATION OF Y IN THE VARIOUS SAMPLES, WITH $s = \sqrt{\frac{\Sigma x^2 - \frac{(\Sigma x)^2}{n}}{n} - \frac{h^2}{12}}$

Samples	Megalospheric forms n	$\bar{Y}$	s_Y	Microspheric forms n	$\bar{Y}$	s_Y
X 6002 / J 5129	17	27.24	4.42	—	—	—
J 3416	21	19.67	2.57	1	37	—
J 3978	104	6.34	1.53	12	17.75	2.15
J 3700	55	5.33	.42	1	13	—
J 3697	80	4.94	.35	6	17.67	1.21
J 3601	43	5.12	.63	8	15.50	.96
J 3680	143	5.08	.32	1	10	—
J 3686	9	5.11	.12	—	—	—
J 3688	57	5.26	.53	—	—	—

TABLE 11. NUMBER OF OBSERVATIONS, AND MEAN AND STANDARD DEVIATION OF P AND D IN THE VARIOUS SAMPLES, WITH $s = \sqrt{\frac{\Sigma x^2 - \frac{(\Sigma x)^2}{n}}{n} - \frac{h^2}{12}}$

Samples	Megalospheric forms n	$\bar{P}$	s_P	$\bar{D}$	s_D	Microspheric forms n	$\bar{P}$	s_P
X 6002 / J 5129	—	51.92 (n = 12)	11.78	48.40 (n = 5)	7.03	—	—	—
J 3416	23	64.09	8.69	53.57	8.07	1	23	—
J 3978	123	102.15	26.67	103.52	27.93	13	27.77	4.40
J 3700	55	107.82	18.09	116.87	18.29	1	28	—
J 3697	96	154.54	35.41	167.60	39.36	10	27.00	3.39
J 3601	45	140.42	33.65	148.49	36.20	9	23.56	3.76
J 3680	148	98.30	15.06	107.01	16.27	1	28	—
J 3686	14	112.79	19.41	125.86	18.57	—	—	—
J 3688	69	115.07	18.98	127.19	22.04	—	—	—

TABLE 12. TEST FOR NORMALITY OF THE DISTRIBUTION OF P AND D (MEGALOSPHERIC FORMS) IN THE VARIOUS SAMPLES, USING THE χ^2-TEST (SEE DIXON AND MASSEY P. 227)

samples		$\chi^2 = \frac{(f_i - F_i)^2}{F_i}$	df	$\chi^2_{.95}$	conclusion
X 6002 / J 5129		—	—	—	—
J 3416		—	—	—	—
J 3978:	P:	7.51	3	7.81	not significant
	D:	5.29	3	7.81	not significant
J 3700:	P:	2.58	2	5.99	not significant
	D:	1.14	2	5.99	not significant
J 3601:	P:	2.20	3	7.81	not significant
	D:	5.73	4	9.49	not significant
J 3697:	P:	3.97	4	9.49	not significant
	D:	3.83	4	9.49	not significant
J 3680:	P:	.63	1	3.84	not significant
	D:	1.03	1	3.84	not significant
J 3686		—	—	—	—
J 3788:	P:	.15	1	3.84	not significant
	D:	1.90	2	5.99	not significant

TABLE 13. TEST FOR LINEARITY OF REGRESSION OF D AND P (MEGALOSPHERIC FORMS) IN THE VARIOUS SAMPLES, USING THE ANALYSIS-OF-VARIANCE TEST (SEE DIXON AND MASSEY P. 197).

samples	computed F-value	df	$F_{.95}$	conclusion
X 6002 ⎫ J 5129 ⎭	—	—	—	—
J 3416	1.12	17; 4	±5.80	not significant
J 3978	.66	6; 115	±2.18	not significant
J 3700	.90	3; 50	2.80	not significant
J 3601	1.31	6; 37	±2.34	not significant
J 3697	.30	8; 86	±2.06	not significant
J 3680	.79	3; 143	±2.70	not significant
J 3686	.12	2; 10	4.10	not significant
J 3688	1.00	4; 63	±2.53	not significant

TABLE 14a. PROPERTIES OF THE REDUCED MAJOR AXIS, PLOTTING D AGAINST P IN THE VARIOUS SAMPLES (SEE MILLER AND KAHN P. 205)

samples	slope(K)	intercept(b)	standard error slope (s_K)	standard error intercept (s_b)
X 6002 ⎫ J 5129 ⎭	—	—	—	—
J 3416	.93	-5.93	.139	9.00
J 3978	1.05	-3.83	.057	6.03
J 3700	1.01	7.88	.081	8.87
J 3601	1.08	-2.55	.090	13.01
J 3697	1.11	-4.20	.046	7.28
J 3680	1.08	.86	.054	5.38
J 3686	.96	17.96	.139	15.91
J 3688	1.16	-6.39	.068	10.54

TABLE 14b. PROBABILITIES OF EXCEEDANCE, TESTING COINCIDENCE OF THE SLOPE K BETWEEN THE VARIOUS SAMPLES WITH $Z = \frac{K_1 - K_2}{s^2_{K_1} + s^2_{K_2}}$ (SEE MILLER AND KAHN, P. 206)

	X 6002 J 5129	J 3416	J 3978	J 3700	J 3601	J 3697	J 3680	J 3686	J 3688
X 6002 ⎫ J 5129 ⎭	—								
J 4316	—	—							
J 3978	—	.412	—						
J 3700	—	.610	.689	—					
J 3601	—	.374	.818	.596	—				
J 3697	—	.211	.407	.281	.719	—			
J 3680	—	.308	.712	.478	.968	.653	—		
J 3686	—	.889	.631	.734	.472	.289	.380	—	
J 3688	—	.131	.211	.156	.447	.549	.347	.187	—

TABLE 15a. FREQUENCY OF OCCURRENCE OF THE NUMBER OF PRIMARY CHAMBERS (Y) IN MEGALOSPHERIC FORMS

Y	X 6002 J 5129	J 3416	J 3978	J 3700	J 3697	J 3601	J 3680	J 3686	J 3688
4					10	5	7		1
5			31	38	66	31	118	8	43
6			49	16	3	4	17	1	11
7			5	1	1	3	1		1
8			8						1
9			6						
10			2						
11			1						
12			1						
13			1						
14, 15									
16		2							
17		3							
18		3							
19		3							
20		3							
21	1	3							
22	2								
23		1							
24	3	2							
25	1	1							
26									
27	3								
28	1								
29	1								
30	2								
31									
32	2								
33-38									
39	1								

TABLE 15b. PROBABILITIES OF EXCEEDANCE, TESTING COINCIDENCE OF THE VARIATIONAL SPREAD OF Y BETWEEN THE VARIOUS SAMPLES, USING THE WILCOXON-TEST. VERTICAL LINES INDICATE THE SIGNIFICANT BREAKS AT THE 1% LEVEL.

	X 6002 J 5129	J 3416	J 3978	J 3700	J 3697	J 3601	J 3680	J 3686	J 3688
X 6002 } J 5129 }									
J 3416	.000								
J 3978	.000	.000							
J 3700	.000	.000	.000						
J 3697	.000	.000	.000	.000					
J 3601	.000	.000	.000	.028	.166				
J 3680	.000	.000	.000	.001	.010	.820			
J 3686	.000	.000	.000	.226	.202	.799	.835		
J 3688	.000	.000	.000	.315	.000	.146	.042	.498	

TABLE 16. FREQUENCY OF OCCURRENCE OF THE NUMBER OF PRIMARY CHAMBERS (Y) IN MICROSPHERIC FORMS.

Y	X 6002 J 5129	J 3416	J 3978	J 3700	J 3697	J 3601	J 3680	J 3686	J 3688
1 - 9									
10							1		
11									
12									
13				1					
14						2			
15			3			1			
16					1	4			
17			3		2	1			
18			2		2				
19			2						
20					1				
21			1						
22			1						
23-36									
37		1							

TABLE 17a. FREQUENCY OF OCCURRENCE OF THE DIAMETER (WIDTH) OF THE PROTOCONCH (P) IN MEGALOSPHERIC FORMS

Class midpoints of P	X 6002 J 5129	J 3416	J 3978	J 3700	J 3697	J 3601	J 3680	J 3686	J 3688
29.5	1								
49.5	8	8	10				2		
69.5	3	15	12	1	1	2	12		2
89.5			27	17	4	3	61	4	13
109.5			45	24	12	6	62	5	27
129.5			20	10	19	12	11	3	21
149.5			7	3	18	10		2	5
169.5			1		14	9			1
189.5			1		17				
209.5					9	2			
229.5					1				
249.5					1	1			

TABLE 17b. PROBABILITIES OF EXCEEDANCE, TESTING COINCIDENCE OF THE VARIATIONAL SPREAD OF P BETWEEN THE VARIOUS SAMPLES, USING THE WILCOXON-TEST. VERTICAL LINES INDICATE THE SIGNIFICANT BREAKS AT THE 1% LEVEL

	X 6002 J 5129	J 3416	J 3978	J 3700	J 3697	J 3601	J 3680	J 3686	J 3688
X 6002 J 5129									
J 3416	.008								
J 3978	.000	.000							
J 3700	.000	.000	.212						
J 3697	.000	.000	.000	.000					
J 3601	.000	.000	.000	.000	.021				
J 3680	.000	.000	.071	.002	.000	.000			
J 3686	.000	.000	.126	.433	.000	.004	.008		
J 3688	.000	.000	.000	.037	.000	.000	.000	.679	

TABLE 18. FREQUENCY OF OCCURRENCE OF THE DIAMETER (WIDTH) OF THE PROTOCONCH (P) IN MICROSPHERIC FORMS

P	X 6002 J 5129	J 3416	J 3978	J 3700	J 3697	J 3601	J 3680	J 3686	J 3688
1-17									
18						2			
19									
20			1						
21					1	1			
22			1		1				
23		1				1			
24			1			1			
25			1						
26					1	3			
27			1		3				
28			4	1	2		1		
29			1						
30						1			
31			1		1				
32									
33					1				
34			1						
35									
36									
37			1						

Appendix 2

PLATES 1-27

Explanation of Plate 1

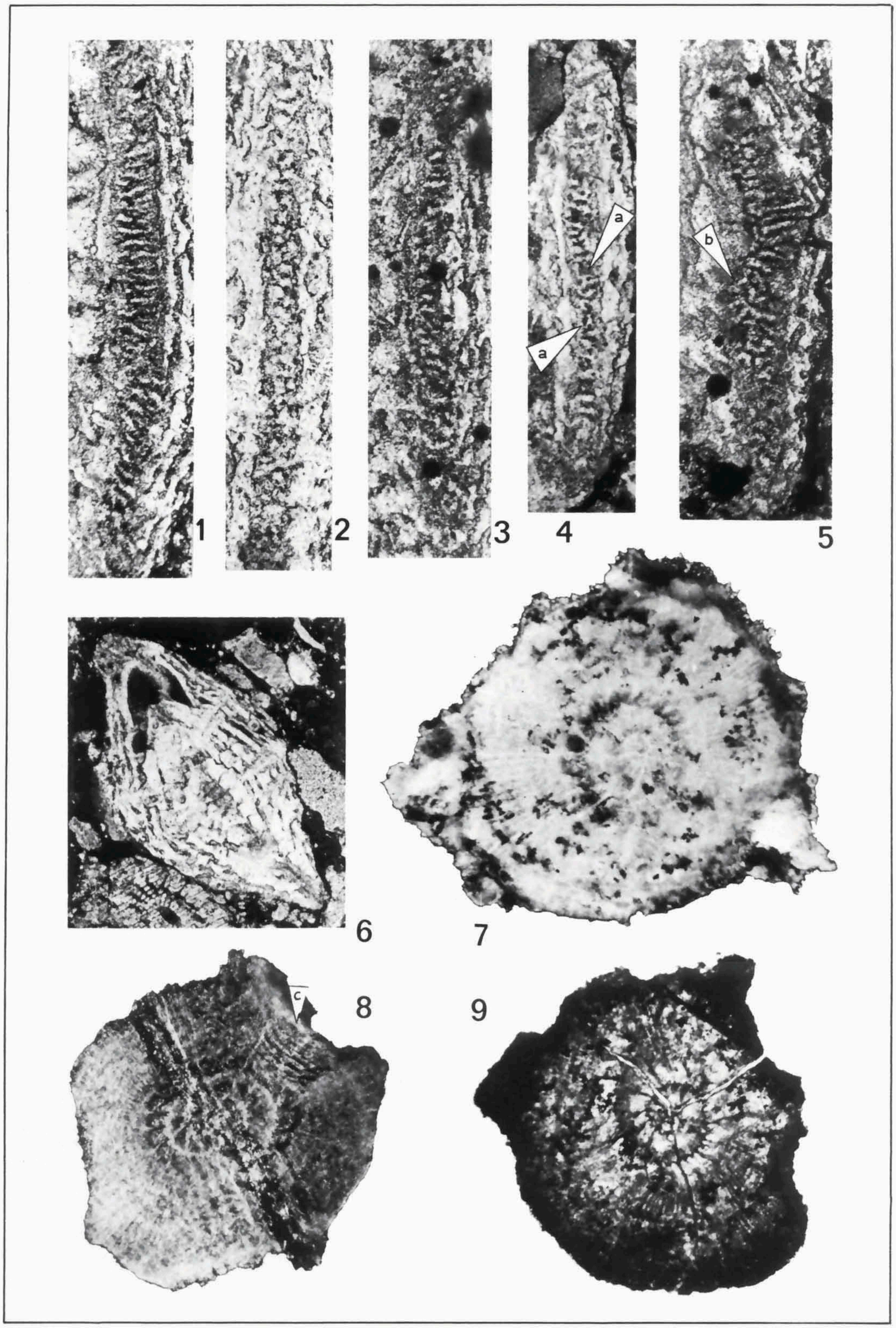
Pseudorbitoides curacaoensis Krijnen, 1967 from locality X 6002 (J 5128 and J 5129) near St. Jan (Cas Abao), Curaçao (type locality).

Figs. 1-5: Eccentrical vertical sections, showing various types of radial elements in cross-section: fig. 1: pseudorbitoid radial plates, fig. 2: sulcorbitoid radial rods, fig. 3: ? sulcorbitoid radial rods and pseudorbitoid radial plates, figs. 4 and 5: 'historbitoid' radial plates with irregular horizontal interconnections (a) and an 'incipient radius' *sensu* P. Brönnimann (b).
Specimen nrs.: J 5128-1 (69×); Fig. 2: J 5129-22 (69×); Fig. 3: J 5129-20 (58×); Fig. 4: J 5129-21 (66×); Fig. 5: J 5129-19 (66×).

Fig. 6: Nearly central vertical section, showing the large primary chambers. Specimen no. J 5129-23 (35×).

Figs. 7-9: Central horizontal sections, showing the large primary chamber spiral. Radial elements are clearly visible starting from the last whorl of the primary chambers. Though damaged, the specimen of figure 8 shows the presence of one rather large aktinorbitoid interradius, indicated by concave rows of lateral chambers (c) (as seen from the peripheral margin), interrupting the equatorial layer. As a result of recrystallization the 'orbitoid' pattern of secondary chambers has been lost.
Specimen nrs.: J 5129-9 (30×); Fig. 8: J 5129-3 (26×); Fig. 9: J 5129-1 (30×).

PLATE 1

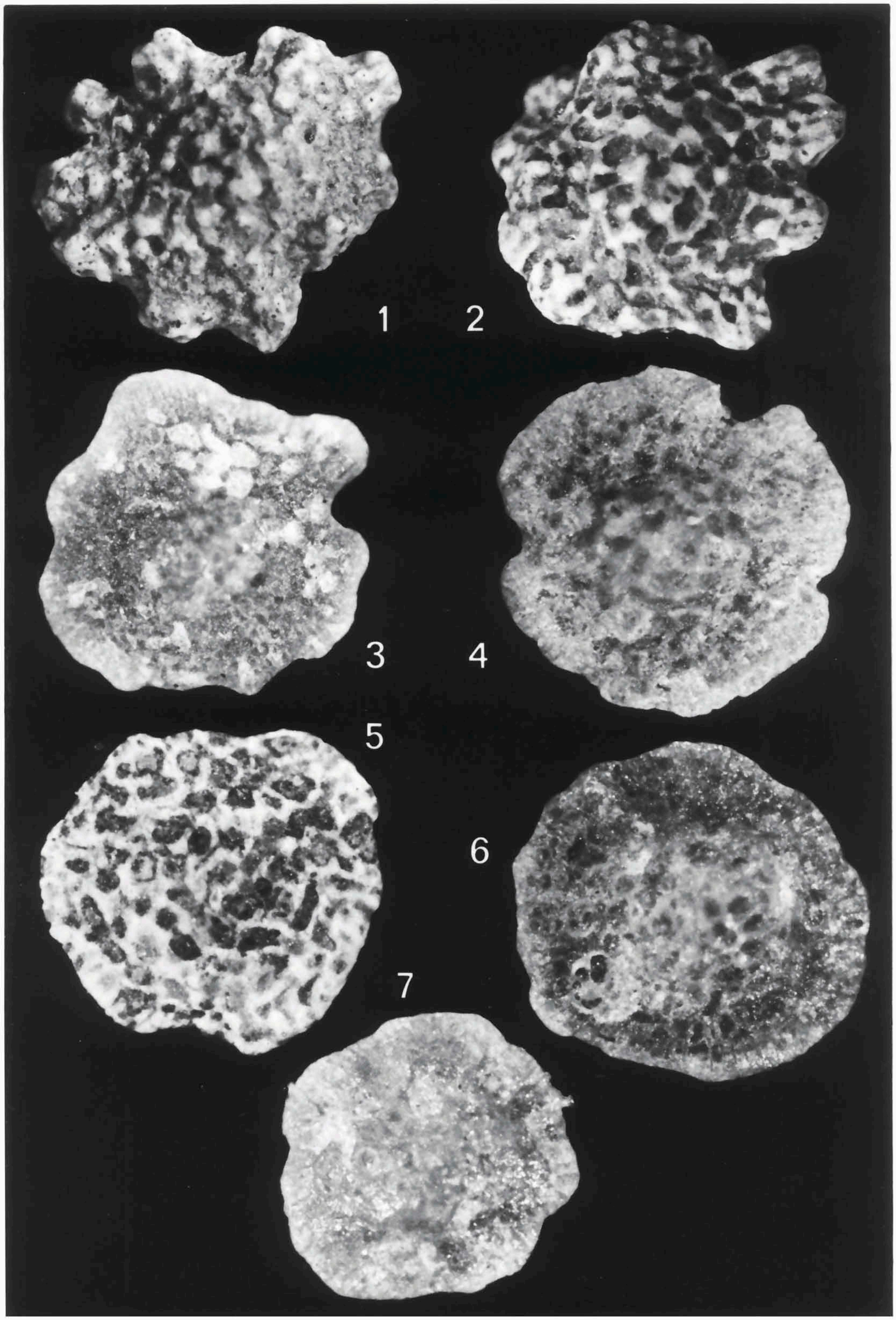


Explanation of Plate 2

Pseudorbitoides cf. *P.* (?) *chubbi* Brönnimann, 1958 from locality J 3416, Sunderland Inlier, Jamaica.

Figs. 1-7: Exterior view of megalospherical forms. The test is sub-circular to distinctly radiate in outline depending on the number of aktinorbitoid interradii present. Lateral chambers cover the equatorial layer completely or nearly completely, radial elements being occasionally visible in the peripheral portion of some tests. Small pillars are distributed fairly regularly at the angular points of the lateral chambers.
Specimen nrs.: J 3416-16 (38×); Fig. 2: J 3416-1 (45×); Fig. 3: J 3416-15 (41×); Fig. 4: 3416-4 (46×); Fig. 5: J 3416-30 (50×); Fig. 6: J 3416-2 (45×); Fig. 7: J 3416-11 (61×).

PLATE 2



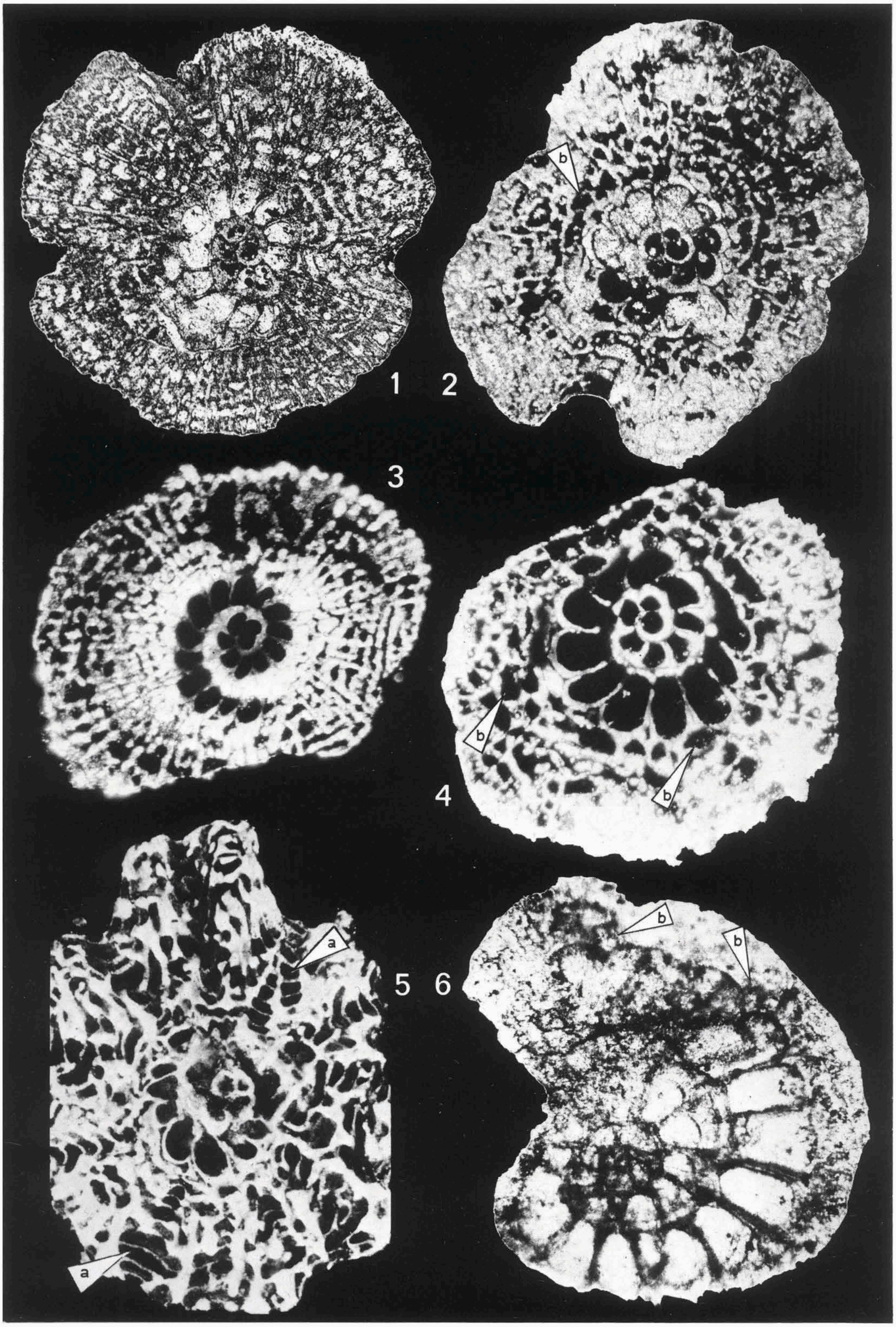
Explanation of Plate 3

Pseudorbitoides cf. *P.* (?) *chubbi* Brönnimann, 1958 from locality J 3416, Sunderland Inlier, Jamaica.

Figs. 1-5: Central horizontal sections of megalospherical forms. In all sections the uniserial juvenarium is clearly visible. Figures 3 and 4 denote more or less circular forms, but in figures 1, 2 and 5 distinct actinate (radiate) tests are shown, caused by the presence of aktinorbitoid interradii filled with curved lateral chambers (concave towards the peripheral margin). Figure 5 shows a very large number of interradii (about 9) of which the curved lateral chambers are well exposed (some of them indicated with 'a'). Note the irregular primary chamber spiral in this figure. The presence of aktinorbitoid interradii and the deformation of the primary chambers is supposed to be the result of simultaneous growth of the primary chambers and early lateral chambers. Generally the radial elements are not straight, having a slight zig-zag course in detail (figs. 1 and 2). The pattern of 'orbitoid' secondary chambers is difficult to observe because of the complicating affect of the radial elements. Nevertheless, secondary chambers are occasionally visible (b).
Specimen nrs.: J 3416-4 (53×); Fig. 2: J 3416-3 (see textfigure 5) (53×); Fig. 3: J 3416-8 (48×); Fig. 4: J 3416-33 (67×); Fig. 5: J 3416-1 (60×).

Fig. 6: Central horizontal section of a microspherical specimen. In this section, secondary chambers can be seen between the final part of the last whorl of the primary chambers, and the preceding one, as well as adjacent to the primary chambers of the last primary chamber whorl (b). The primary chamber spiral tends to widen (see also textfigure 6). Specimen no.: J 3416-67 (97×).

PLATE 3



Explanation of Plate 4

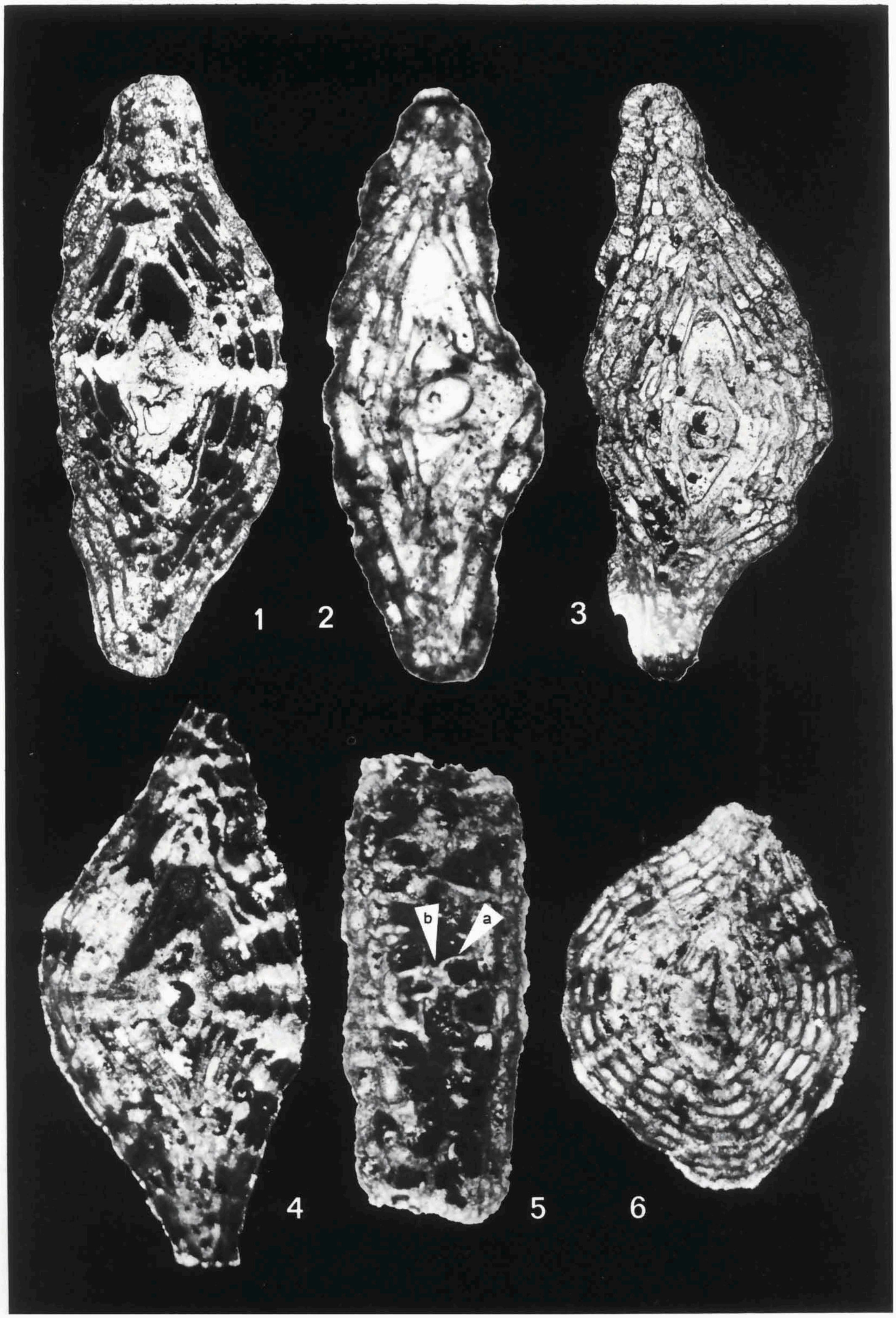
Pseudorbitoides cf. *P.* (?) *chubbi* Brönnimann, 1958 from locality J 3416, Sunderland Inlier, Jamaica.

Figs. 1-4: Central vertical sections of megalospherical forms, showing the large juvenarium (somewhat trochoid to nearly planispiral in shape) in the centre of the test.
Specimen nrs.: J 3416-22 (73×); Fig. 2: J 3416-48 (85×); Fig. 3: J 3416-2 (59×); Fig. 4: J 3416-13 (69×).

Fig. 5: Tangential (peripheral) vertical section, showing a cross-section of the pseudorbitoid layer. The radial elements appear to be plate-like (a) with irregular interconnections (b).
Specimen no.: J 3416-22 (125×).

Fig. 6: Nearly central vertical section of a megalospherical form, sectioned across an interradius (lower part). This photograph confirms Brönnimann's interpretation of the interradii: interradii are devoid of equatorial chambers and are occupied by lateral chambers which connect the layers of lateral chambers on one side of the test with those of the other side.
Specimen no.: J 3416-5 (51×).

PLATE 4



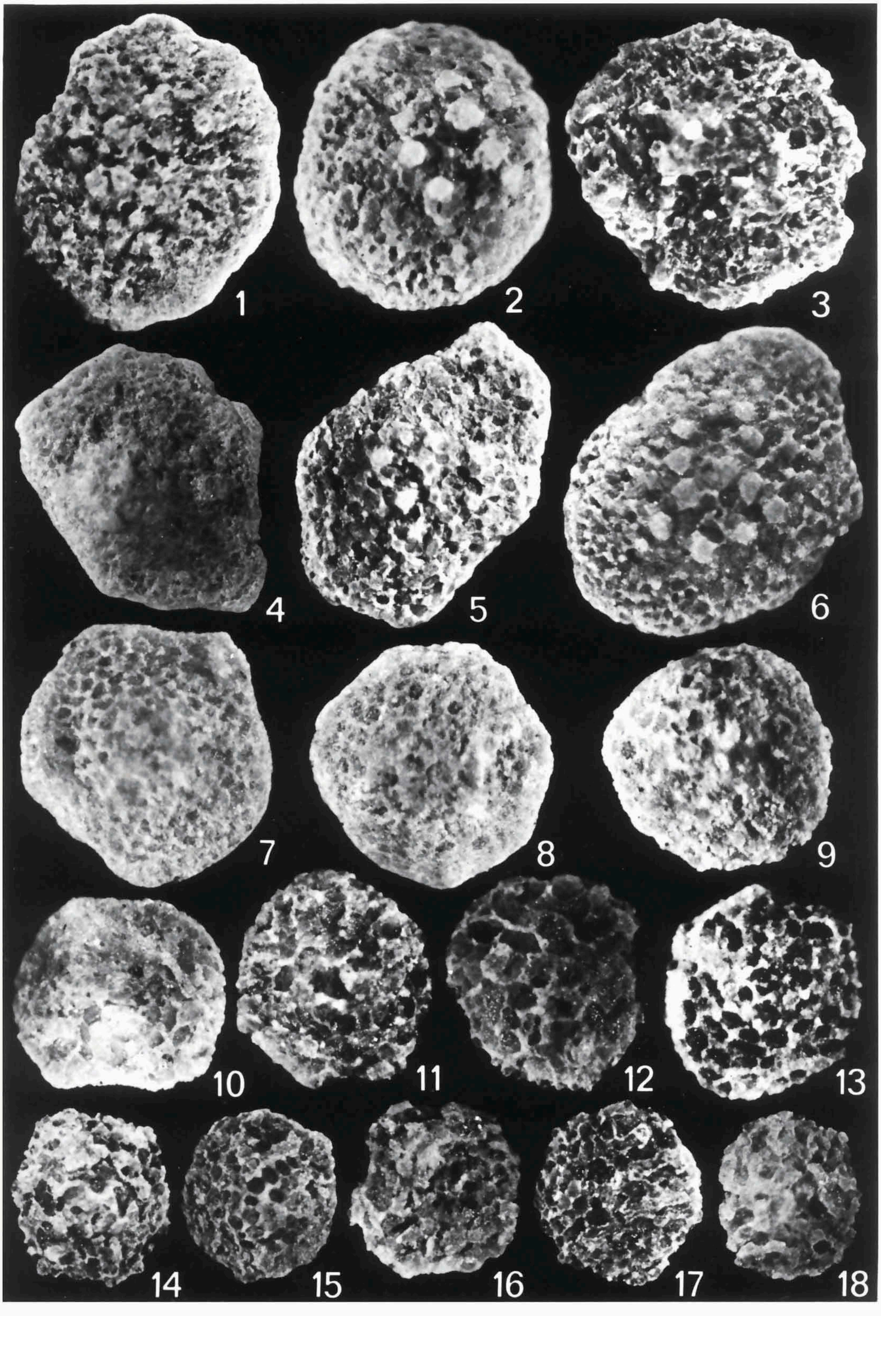
EXPLANATION OF PLATE 5

Pseudorbitoides trechmanni trechmanni Douvillé, 1922 from locality J 3978 near Green Island, Jamaica (type locality).

Figs. 1-6: External view of microspherical forms. Circular to sub-circular in outline. The test is completely covered by lateral chambers, usually with a more or less regular distribution of small papillae between the lateral chambers. Heavier pillars are present but restricted to the umbonal region.
Specimen nrs.: J 3978-168 (24×); Fig. 2: J 3978-319 (28×); Fig. 3: J 3978-164 (34×); Fig. 4: J 3978-461 (18×); Fig. 5: J 3978-378 (23×); Fig. 6: J 3978-290 (28×).

Figs. 7-18: External view of megalospherical forms. Circular to sub-circular in outline. Polygonal lateral chambers cover the equatorial layer completely. The test is papillate throughout without heavier pillars as in microspherical forms.
Specimen nrs.: J 3978-314 (31×); Fig. 8: J 3978-207 (28×); Fig. 9: 3978-402 (36×); Fig. 10: J 3978-370 (36×); Fig. 11: J 3978-740 (47×); Fig. 12: J 3978-737 (45×); Fig. 13: J 3978-740 (47×); Fig. 14: J 3978-545 (32×); Fig. 15: J 3978-518 (33×); Fig. 16: J 3978-665 (40×); Fig. 17: J 3978-552 (35×); Fig. 18: J 3978-538 (32×).

PLATE 5

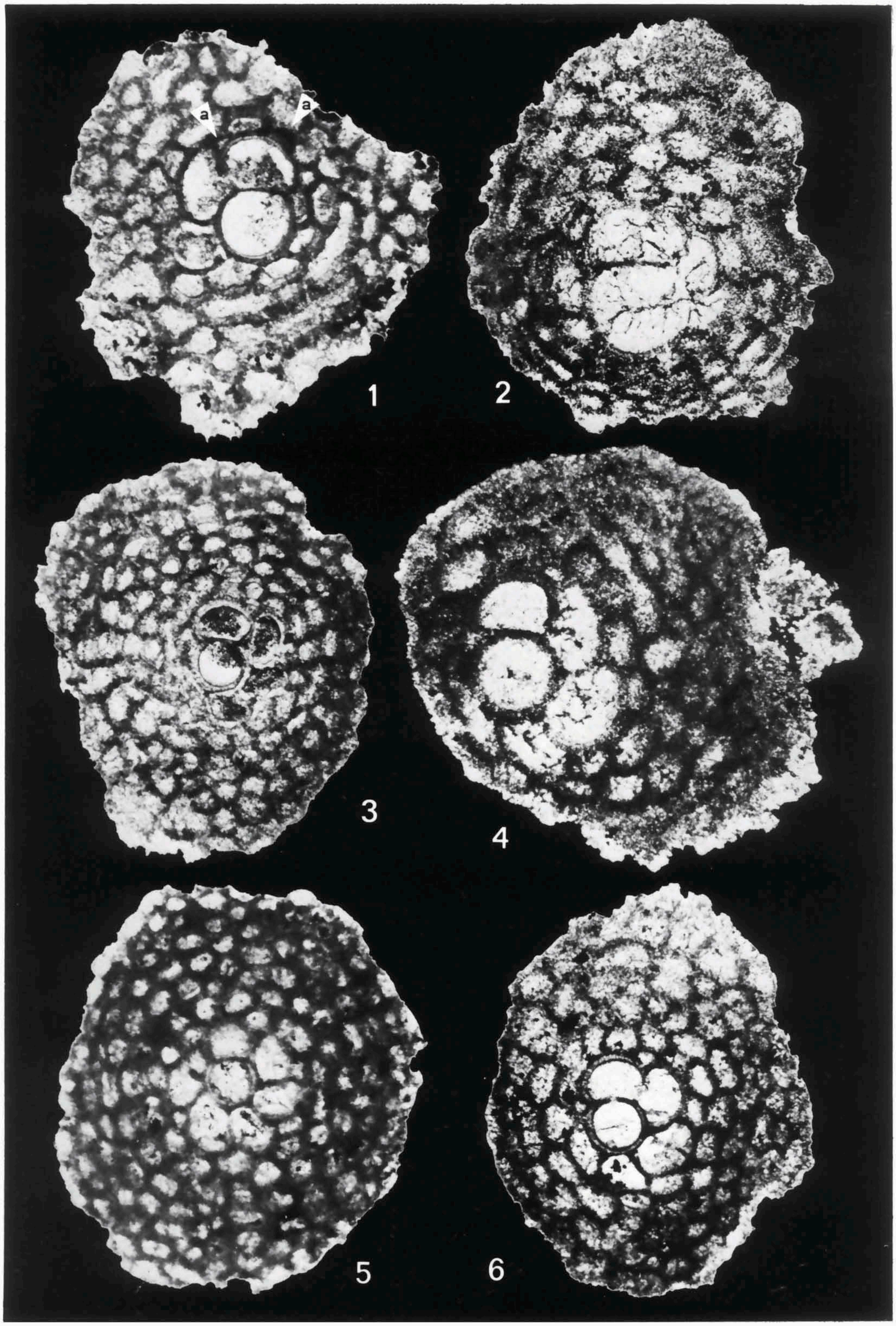


EXPLANATION OF PLATE 6

Pseudorbitoides trechmanni trechmanni Douvillé, 1922 from locality J 3978 near Green Island, Jamaica (type locality).

Figs. 1-6: Central horizontal sections of megalospherical forms. In all specimens a second principal auxiliary chamber has developed: the juvenaria are quadriserial (figures 1, 2 and 4) and triserial (figures 3, 5 and 6). It is assumed that the specimen of figure 1 has developed two small adauxiliary chambers (a). In these examples the radial elements have disappeared almost completely as the result of a slight recrystallization. Traces of the radial elements may be seen on figures 1 and 3 (in the upper left part of the photographs).
Specimen nrs.: Fig. 1: J 3978-545 (77×); Fig. 2: J 3978-218 (80×); Fig. 3: J 3978-455 (68×); Fig. 4: J 3978-91 (104×); Fig. 5: J 3978-592 (77×); Fig. 6: J 3978-349 (76×).

PLATE 6

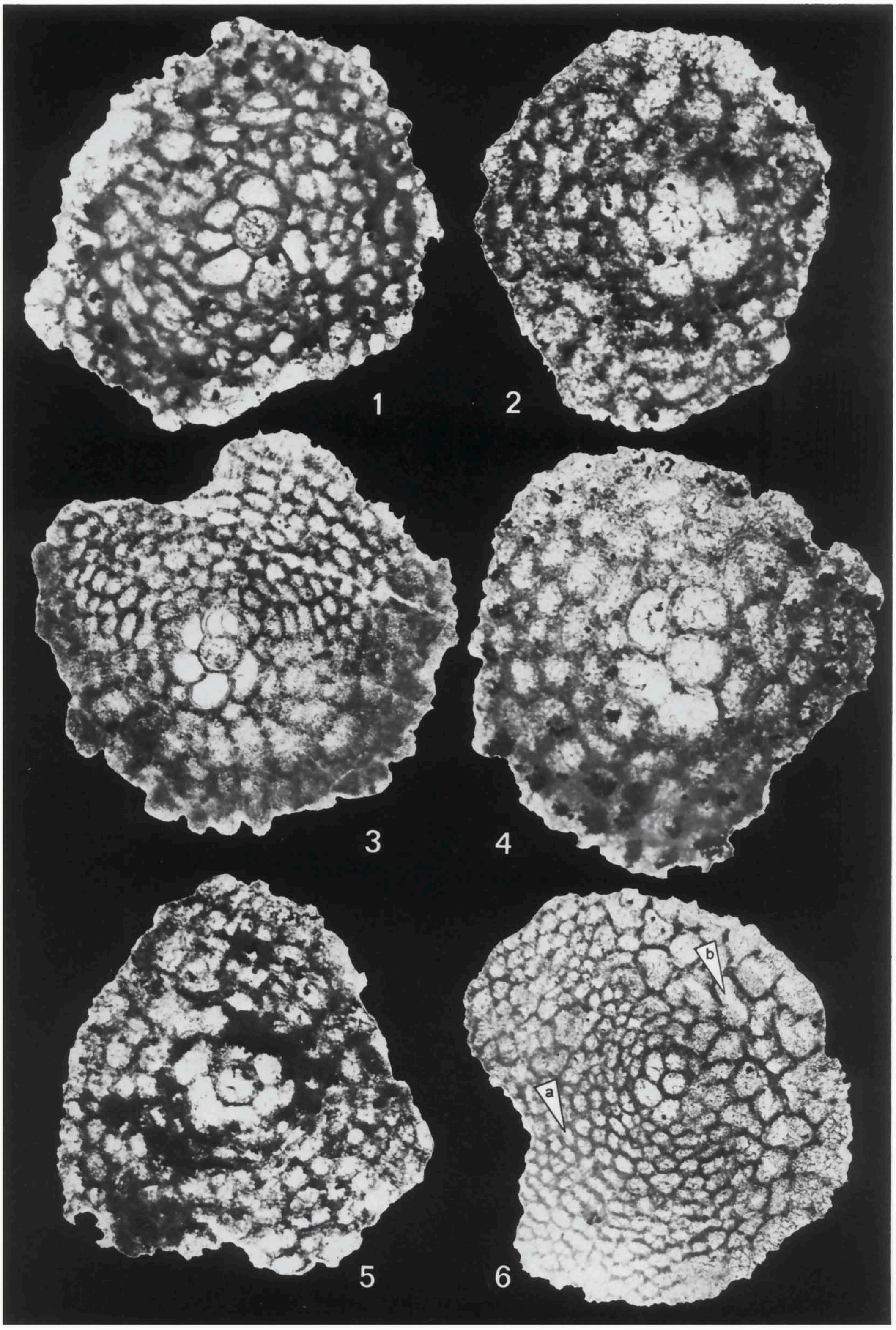


EXPLANATION OF PLATE 7

Pseudorbitoides trechmanni trechmanni Douvillé, 1922 from locality J 3978 near Green Island, Jamaica (type locality).

Figs. 1-6: Central horizontal sections of megalospherical forms. The juvenarium is considered to be biserial with two principal auxiliary chambers (figures 1-4). The radial elements are presumably effaced by recrystallization except in figures 3 and 6 where they are faintly visible. The morphological difference between equatorial and lateral chambers is perfectly shown in figure 6, in which the equatorial chambers, arcuate in shape (a), can easily be distinguished from the polygonal lateral chambers (b).
Specimen nrs.: Fig. 1: J 3978-552 (81×); Fig. 2: J 3978-595 (85×); Fig. 3: J 3978-337 (57×); Fig. 4: J 3978-740 (92×); Fig. 5: J 3978-849 (92×); Fig. 6: J 3978-479 (48×).

PLATE 7



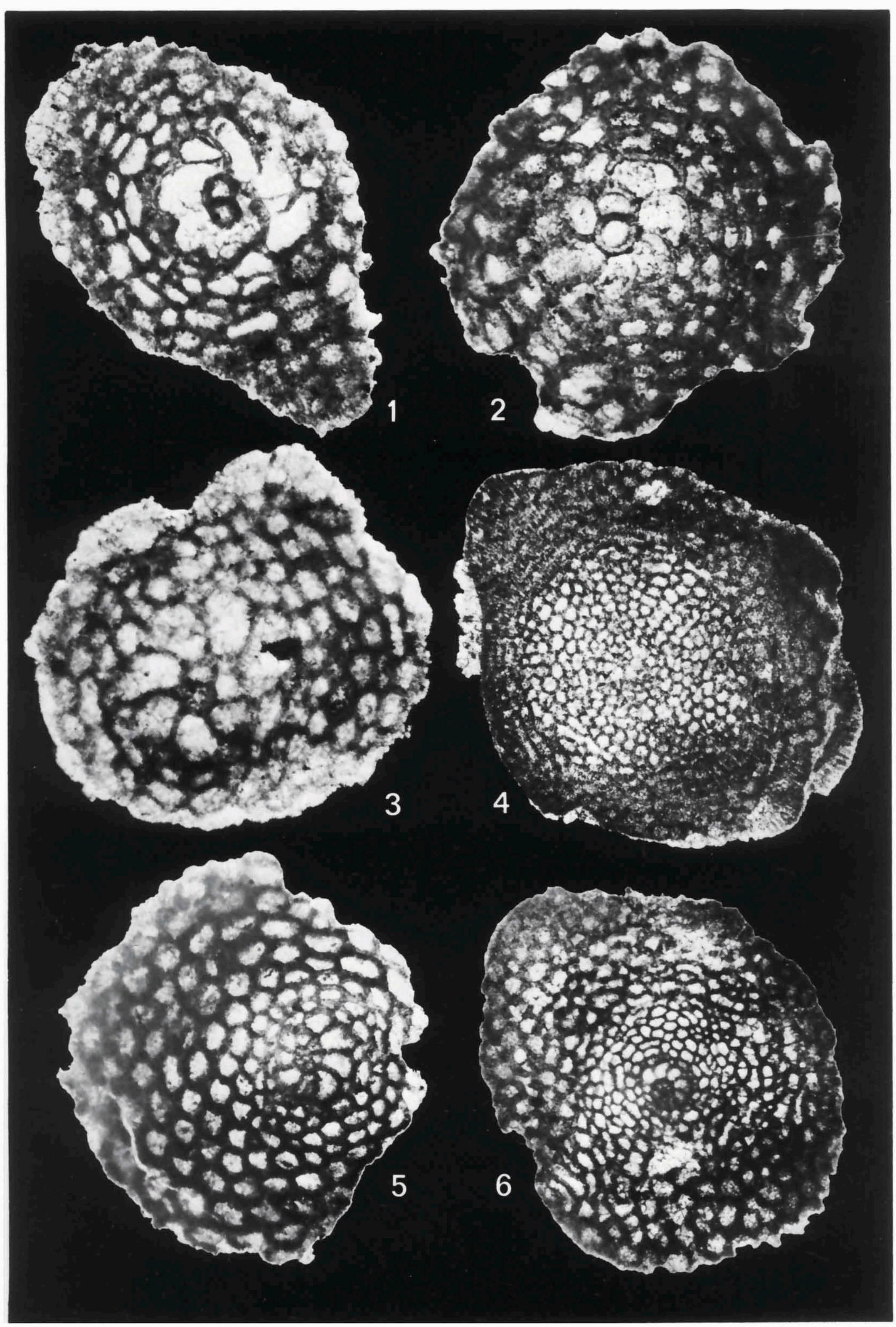
EXPLANATION OF PLATE 8

Pseudorbitoides trechmanni trechmanni Douvillé, 1922 from locality J 3978 near Green Island, Jamaica (type locality).

Figs. 1-3: Central horizontal sections of megalospherical forms. The juvenarium is uniserial in these specimens, which strongly resemble *Pseudorbitoides israelskyi* Vaughan and Cole. Radial elements are faintly visible in the lower part of figure 1.
Specimen nrs.: Fig. 1: J 3978-610 (92×); Fig. 2: J 3978-655 (82×); Fig. 3: J 3978-13 (see also textfigure 5), (92×).

Figs. 4-6: Central horizontal sections of microspherical forms. The small uniserial juvenarium is particularly well shown in figures 5 and 6. Rather delicate radial elements are visible in figures 4 and 6. They are densely spaced, each equatorial chamber containing three to four of them (about 60 per quadrant).
Specimen nrs.: Fig. 4: J 3978-149 (30×); Fig. 5: J 3978-303 (59×); Fig. 6: J 3978-290 (35×).

PLATE 8



EXPLANATION OF PLATE 9

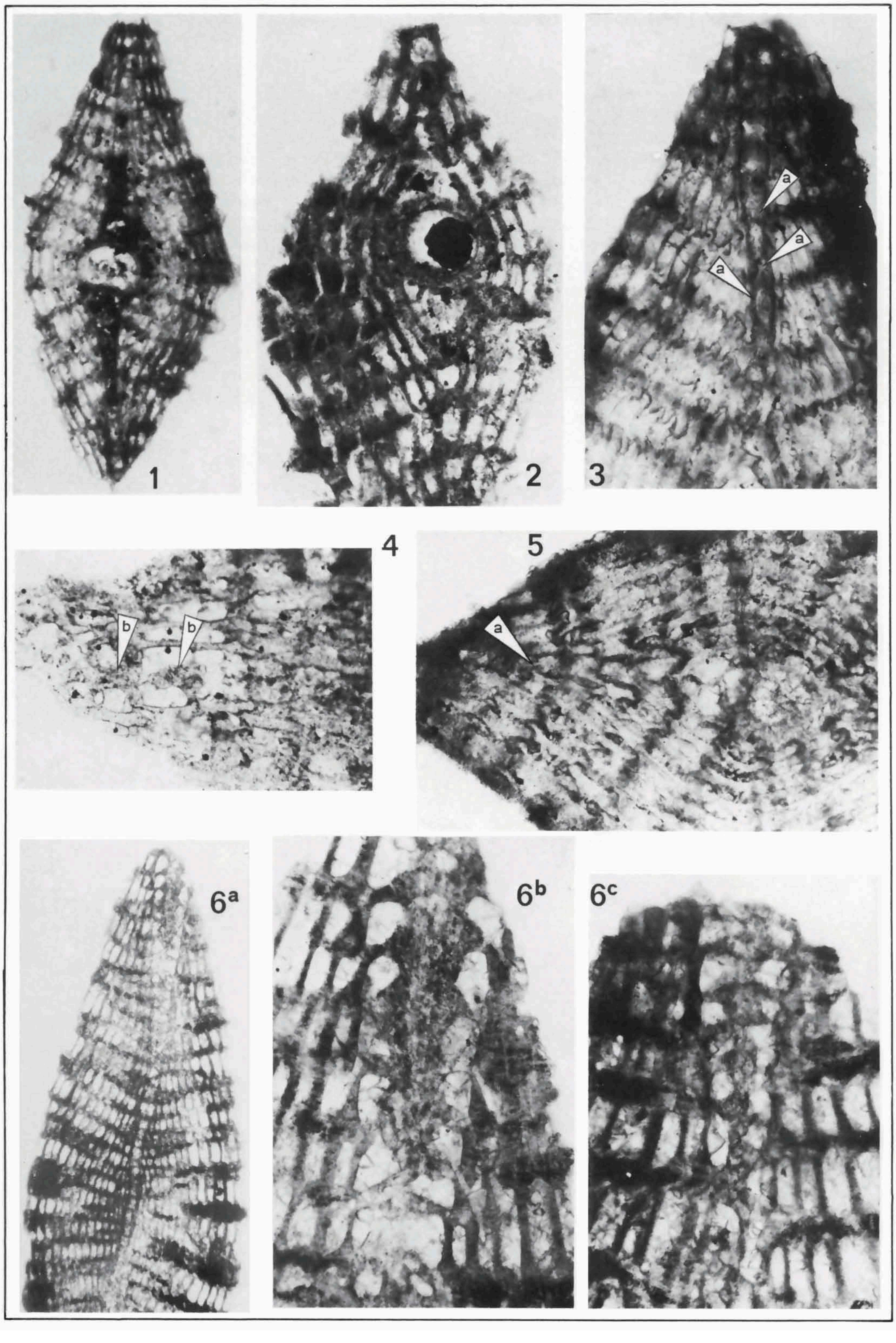
Pseudorbitoides trechmanni trechmanni Douvillé, 1922 from locality J 3978 near Green Island, Jamaica (type locality).

Figs. 1, 2: Central vertical sections of megalospherical forms, in which the early post-juvenile secondary chambers do not seem to be divided by the pseudorbitoid layer yet (figure 2).
Specimen nrs.: Fig. 1: J 3978-49 (55×); Fig. 2: J 3978-58 (105×).

Figs. 3-5: Parts of central vertical sections of megalospherical forms. In figures 3 and 5 the greater part of the equatorial layer seems to be sectioned between two adjacent radial elements and occasional stolons may be seen (a). In figure 4 several adjacent radial elements are sectioned obliquely (b).
Specimen nrs.: Fig. 3: J 3978-60 (101×); Fig. 4: J 3978- 119 (142×); Fig. 5: J 3978-67 (102×).

Figs. 6a-c: Central vertical section of a microspherical specimen, which shows a sudden thickening of the pseudorbitoid layer: upper part figure 6a (= 6b). It is considered that this feature corresponds with a partition of the equatorial layer in which convergently growing radial elements 'run into one another' (as would be seen in a horizontal section). The pseudorbitoid layer gives a faint impression to consist of more or less radial, minute canals.
Specimen no.: J 3978-83 (fig. 6a: 29×; figs. 6b and 6c: 117×).

PLATE 9

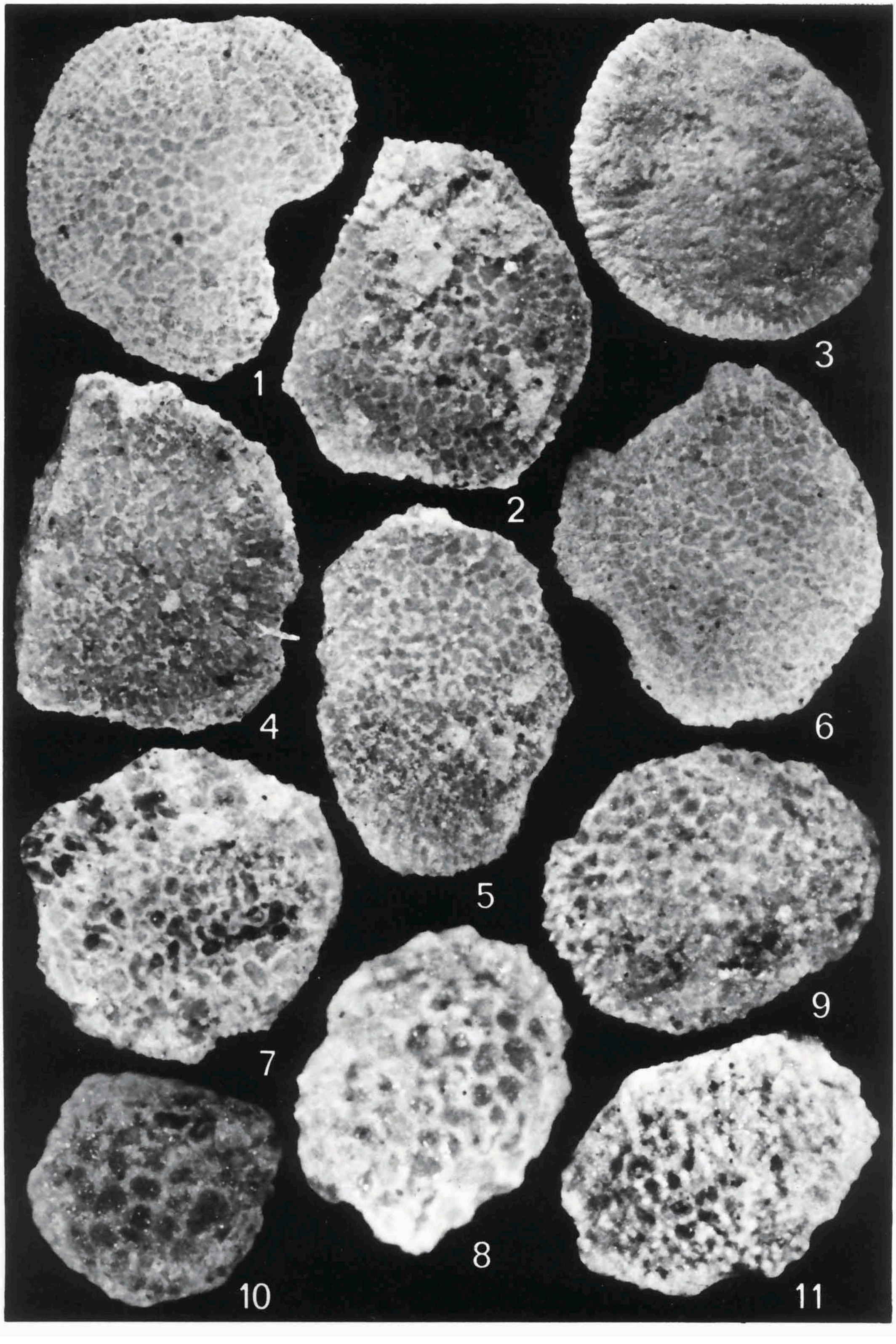


EXPLANATION OF PLATE 10

Pseudorbitoides trechmanni pectinata subsp. nov. from locality J 3700, Sunderland Inlier, Jamaica.

Figs. 1-11: External view of megalospherical forms. Though generally damaged, the outline is considered to be circular to sub-circular and somewhat pectinate by slightly protruding radial elements beyond the periphery. Only one specimen has been encountered showing a deep inward curvation interrupting the almost circular outline as the result of the development of an aktinorbitoid interradius (fig. 1, see also Plate 11, fig. 2). The test is lenticular with a distinct flange. The radial elements are clearly visible due to a slight protrusion of these structural elements beyond the lateral surface of the flange. The umbonal region of the test is covered by polygonal lateral chambers at whose angular points small papillae have developed.
Specimen nrs.: Fig. 1: J 3700-812 (39×); Fig. 2: J 3700-97 (47×); Fig. 3: J 3700-58 (32×); Fig. 4: J 3700-102 (36×); Fig. 5: J 3700-114 (43×); Fig. 6: J 3700-121 (40×); Fig. 7: J 3700-242 (57×); Fig. 8: J 3700-588 (104×); Fig. 9: J 3700-359 (64×); Fig. 10: J 3700-701 (105×); Fig. 11: J 3700-391 (69×).

PLATE 10



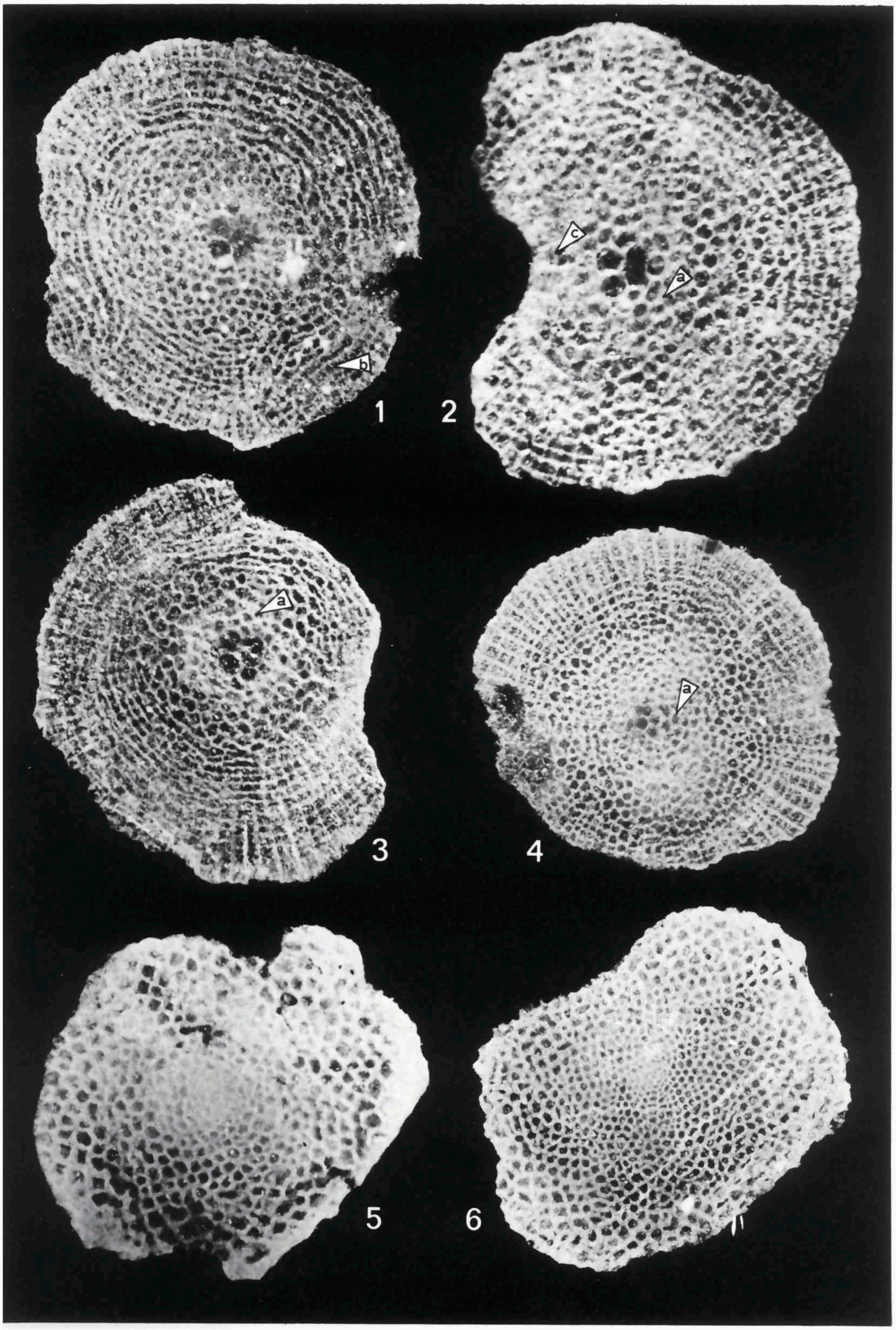
EXPLANATION OF PLATE 11

Pseudorbitoides trechmanni pectinata subsp. nov. from locality J 3700, Sunderland Inlier, Jamaica.

Figs. 1-4: Central horizontal sections of megalospherical forms, clearly showing the protoconch, deuteroconch and one comparatively large first principal auxiliary chamber. The early part of the cyclical phase (a) appears to consist of an 'orbitoid' pattern of undivided secondary chambers. Once the radial elements are introduced ontogenetically, the arrangement of secondary equatorial chambers becomes radiate with radial rows of chambers separated by prominent radial elements. In this ontogenetical stage the arrangement of secondary chambers becomes annular which, however, is still far from perfect as is shown in figures 1 and 3 (no concentrical arrangement of secondary chambers with the same budding stage number; occasional convergent growth of the radial elements (b). Figure 2 shows the presence of an aktinorbitoid interradius (left side of the photograph), in which concave rows of lateral chambers (c) are faintly visible.
Specimen nrs.: Fig. 1: J 3700-28 (38×); Fig. 2: J 3700-812 (49×); Fig. 3: J 3700-53 (37×); Fig. 4: J 3700-58 (35×).

Figs. 5, 6: Central horizontal sections of microspherical forms, showing the large zone of arcuate undivided secondary chambers prior to the appearance of the radial elements. Radial elements are seen to be introduced ontogenetically in the lowermost portion of figure 6.
Specimen nrs.: Fig. 5: J 3700-167 (40×); Fig. 6: J 3700-8 (26×).

PLATE 11

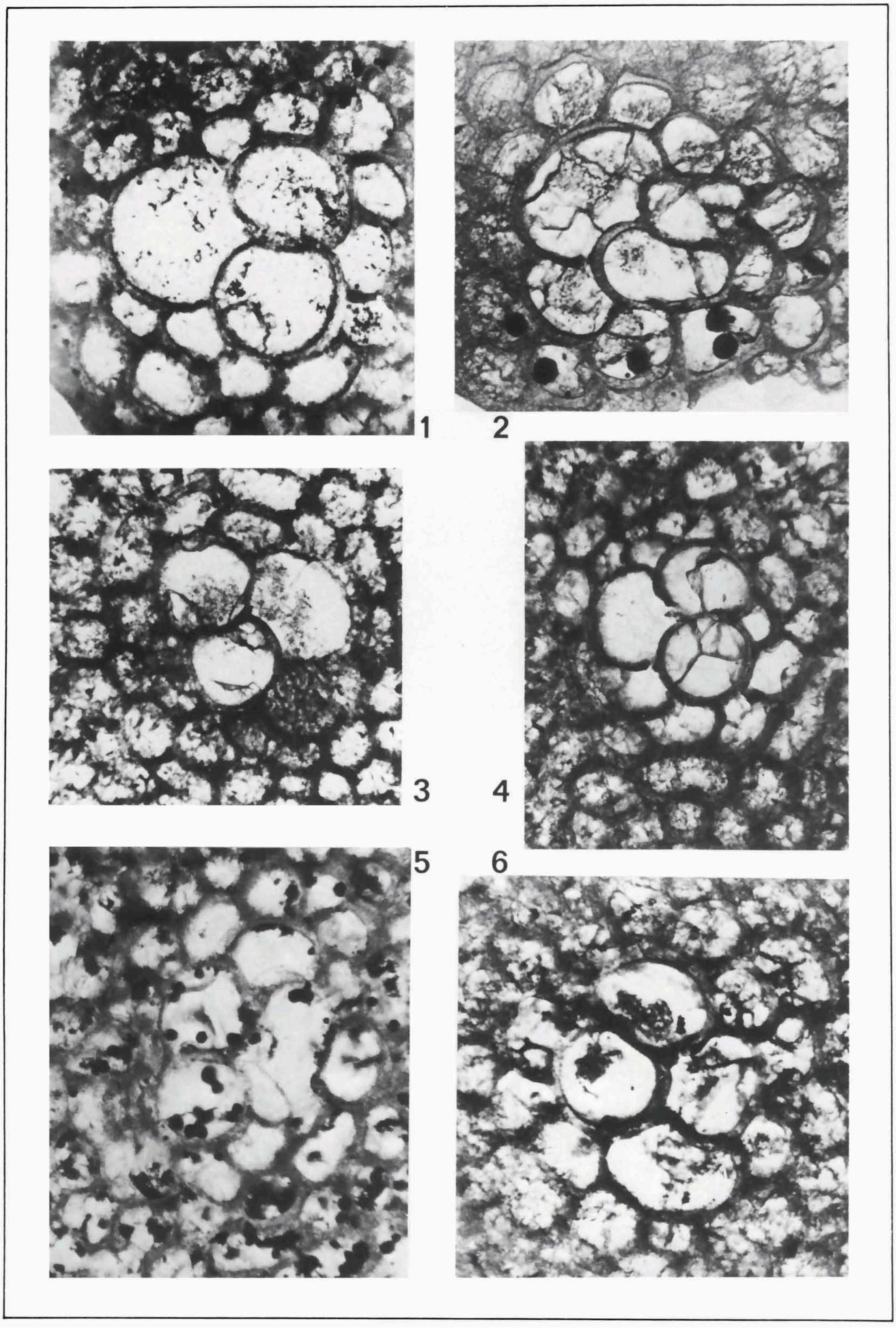


EXPLANATION OF PLATE 12

Pseudorbitoides trechmanni pectinata subsp. nov. from locality J 3700, Sunderland Inlier, Jamaica.

Figs. 1-6: Central horizontal sections of megalospherical forms, clearly showing the subspherical protoconch, the arcuate deuteroconch and the presence of two principal auxiliary chambers (in all specimens the first retrovert aperture is considered to be situated in the deuteroconch). The first principal auxiliary chamber is distinctly larger than the second one. Radial elements are not visible. These photographs are supposed to show only that part of the equatorial layer prior to the ontogenetical appearance of the radial elements (juvenarium, zone of undivided chambers surrounding the juvenarium).
Specimen nrs.: Fig. 1: J 3700-406 (151×); Fig. 2: J 3700-561 (169×); Fig. 3: J 3700-218 (116×); Fig. 4: J 3700- 206 (132×); Fig. 5: J 3700-812 (see also Plate 10 fig. 1 and Plate 11, fig. 2) (166×); Fig. 6: J 3700-427 (188×).

PLATE 12



EXPLANATION OF PLATE 13

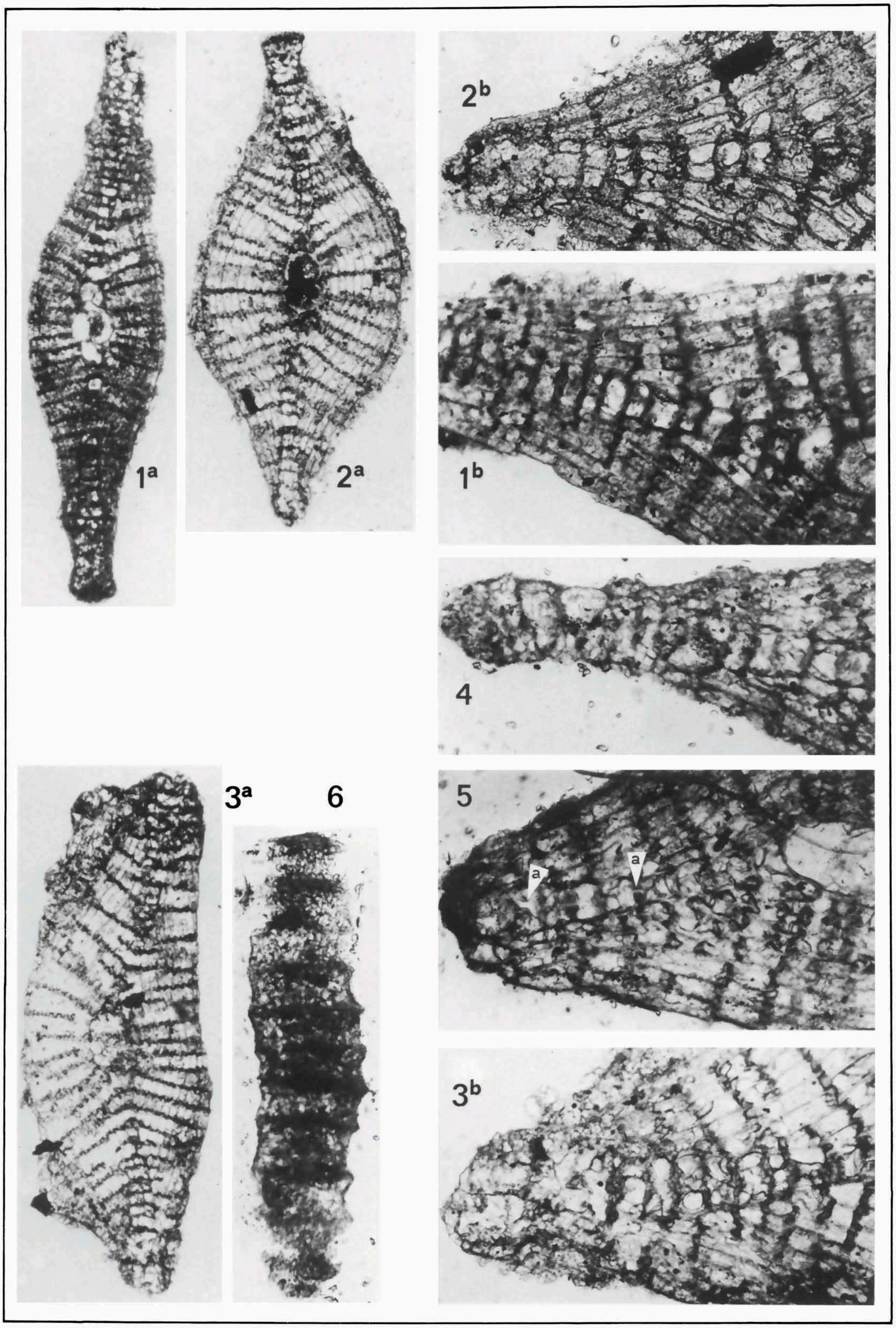
Pseudorbitoides trechmanni pectinata subsp. nov. from locality J 3700, Sunderland Inlier, Jamaica.

Figs. 1a, 2a, 3a: Central vertical sections of megalospherical forms, showing the lenticular test and the distinct flange which almost completely consists of the equatorial layer alone.
Specimen nrs.: Fig. 1a: J 3700-6 (42×); Fig. 2a: J 3700-9 (39×); Fig. 3a: J 3700-30 (35×).

Figs. 1b, 2b, 3b, 4, 5: Peripheral parts of central vertical sections of megalospherical forms. The equatorial layer is clearly visible, having equatorial chambers which increase to about 4 to 5 times their original height during ontogeny. The pseudorbitoid layer can be seen within the equatorial chambers early in the development of the cyclical phase. In a later ontogenetical stage, presence of chambers which appear to be undivided by the pseudorbitoid layer, may be due to the radial elements running between the equatorial chambers instead of traversing them. Occasionally, radial stolons (a) are visible in the equatorial chamber walls (see figure 5).
Figs. 1b, 2b, 3b: see figs. 1a, 2a, 3a (91×); Fig. 4, 5: Specimen no.: J 3700-52 (111×).

Fig. 6: Tangential vertical section close to the peripheral margin, showing the plate-like radial elements, and moreover, the lateral extension of the radial elements which slightly protrude beyond the lateral surface of the flange.
Specimen no.: J 3700-36 (105×).

PLATE 13



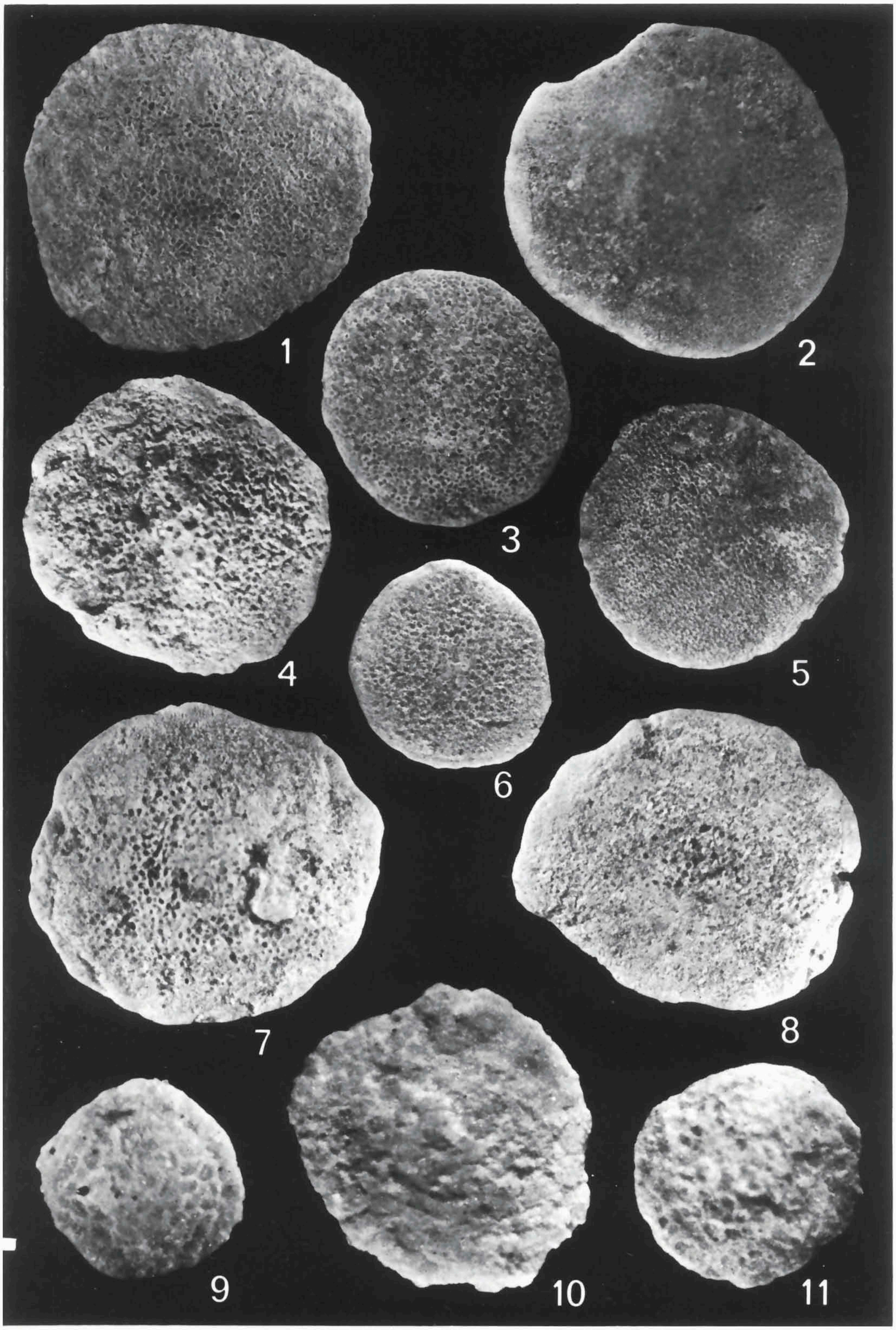
EXPLANATION OF PLATE 14

Pseudorbitoides trechmanni trechmanni Douvillé, 1922 from localities J 3697 and J 3601, Sunderland Inlier, Jamaica.

Figs. 1-8: Exterior view of microspherical forms. Outline circular to sub-circular with some narrow notches and/or slight inward curvations as a result of irregularities in the cyclical arrangement of the equatorial chambers. Strong pillars are absent; the test is completely covered by polygonal lateral chambers; surface papillate. Occasionally, in case of good preservation, the radial elements are visible as small striations on the marginal face (fig. 2).
Specimen nrs.: Fig. 1: 'S'J 3697-3 (15×); Fig. 2: 'S'J 3697-1 (16×); Fig. 3: 'S'J 3697-11 (11×); Fig. 4: J 3601-53 (11×); Fig. 5: 'S'J 3697-2 (14×); Fig. 6: J 3601-85 (11×); Fig. 7: J 3601-36 (11×); Fig. 8: J 3601-41 (11×).

Figs. 9-11: Exterior view of megalospherical forms. Outline circular to sub-circular. Test covered by lateral chambers; surface papillate without strong pillars.
Specimen nrs.: Fig. 9: J 3601-399 (52×); Fig. 10: J 3601-256 (46×); Fig. 11: J 3601-217 (32×).

PLATE 14

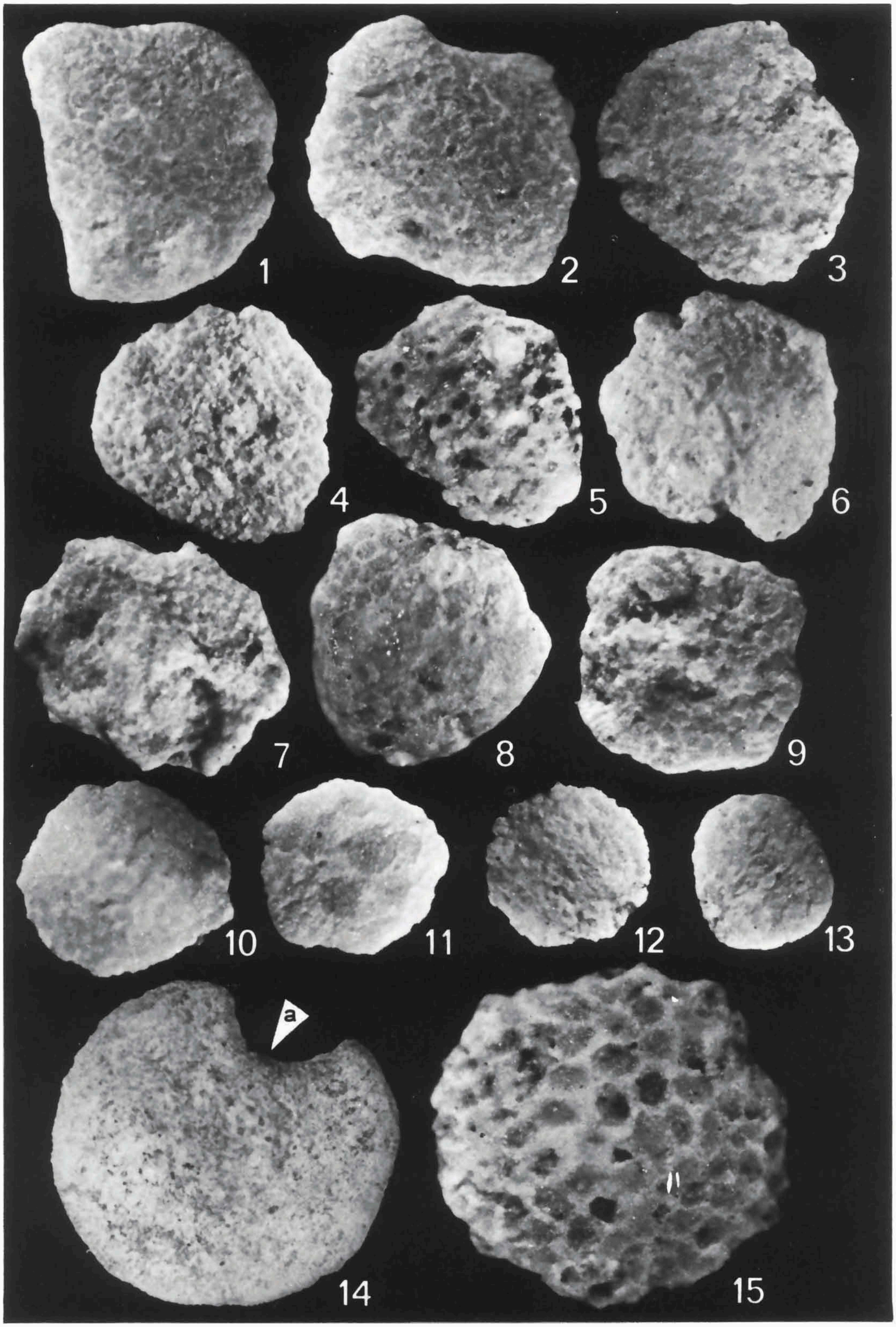


Explanation of Plate 15

Pseudorbitoides trechmanni trechmanni Douvillé, 1922 from localities J 3697 and J 3601, Sunderland Inlier, Jamaica.

Figs. 1-15: Exterior view of generally damaged megalospherical forms. Surface completely covered by polygonal lateral chambers with small papillae at the angular points of the lateral chambers; no strong pillars. The outline is assumed to be circular to subcircular, with exception of the specimen of figure 14. Here an interradius has developed, similar to those of *Aktinorbitoides* Brönnimann. The interradius is indicated by the deep inward curvation (a), interrupting the circular outline of the test. Small notches interrupting the outline of another specimen (fig. 6) are due to irregularities in the cyclical arrangement of the equatorial chambers.
Specimen nrs.: Fig. 1: J 3601-190 (33×); Fig. 2: J 3601-264 (44×); Fig. 3: J 3601-278 (44×); Fig. 4: J 3601-193 (34×); Fig. 5: J 3601-329 (45×); Fig. 6: J 3601-187 (34×); Fig. 7: J 3601-215 (33×); Fig. 8: J 3601-296 (47×); Fig. 9: J 3601-214 (32×); Fig. 10: J 3601-233 (33×); Fig. 11: J 3601-489 (66×); Fig. 12: J 3601-441 (45×); Fig. 13: J 3601-439 (45×); Fig. 14: J 3697-2 (24×); Fig. 15: J 3697-594 (72×).

PLATE 15

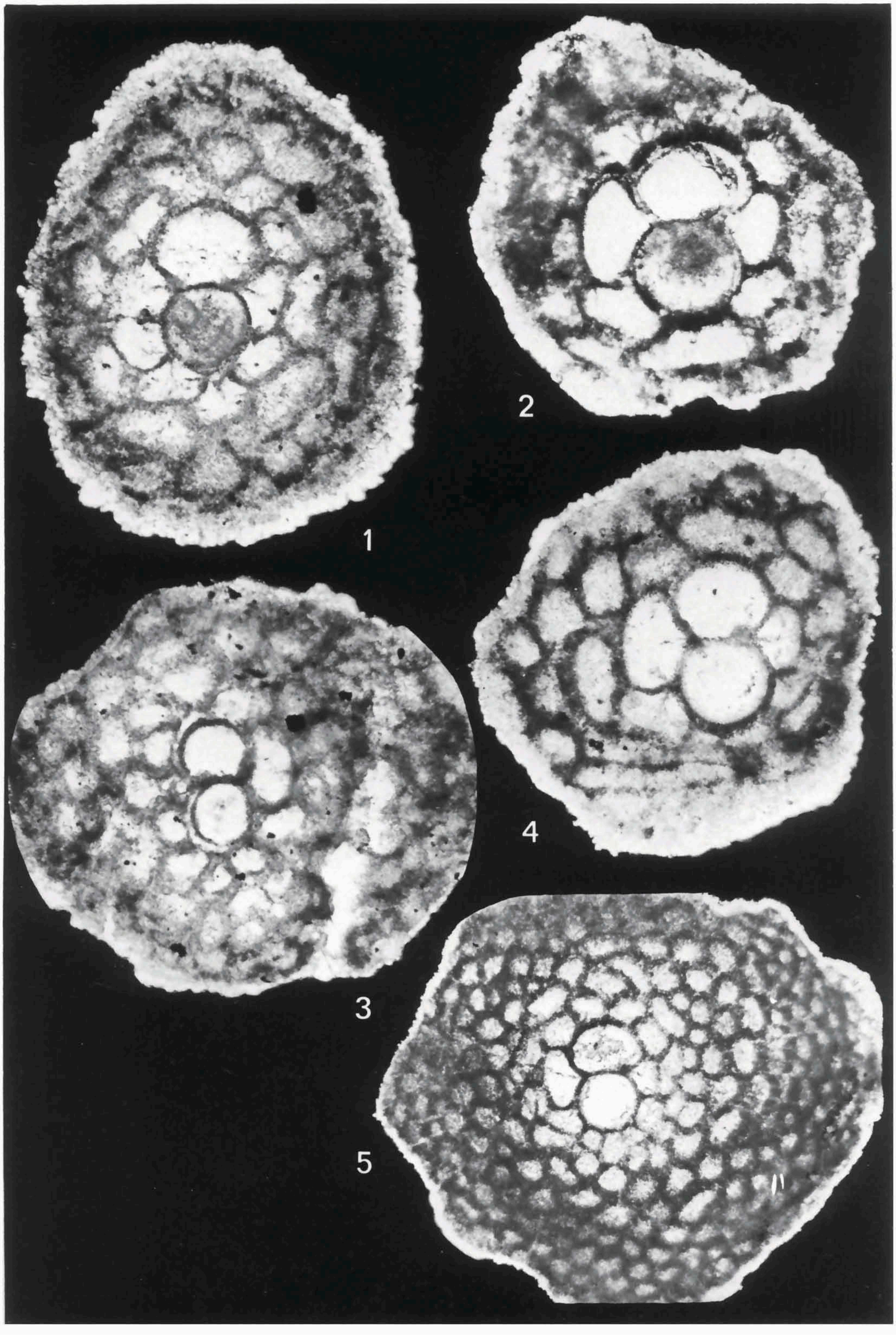


Explanation of Plate 16

Pseudorbitoides trechmanni trechmanni Douvillé, 1922 from locality J 3601, Sunderland Inlier, Jamaica.

Figs. 1-5: Central horizontal sections of megalospherical forms, all specimens having a quadriserial juvenarium. The first retrovert aperture has reached the second chamber (deuteroconch) and, accordingly, the number of sulcoperculinoid chambers is reduced to one (protoconch), the two principal auxiliary chambers issuing from the bi-apertural deuteroconch. Radial elements are visible in figure 5, though vaguely so, departing from the peri-embryonic chambers. In the other specimens, these apparently delicate structures are considered to be effaced by recrystallization.
Specimen nrs.: Fig. 1: J 3601-393 (112×); Fig. 2: J 3601-504 (112×); Fig. 3: J 3601-346 (96×); Fig. 4: J 3601-451 (114×); Fig. 5: J 3601-214 (see also textfigure 7) (70×).

PLATE 16



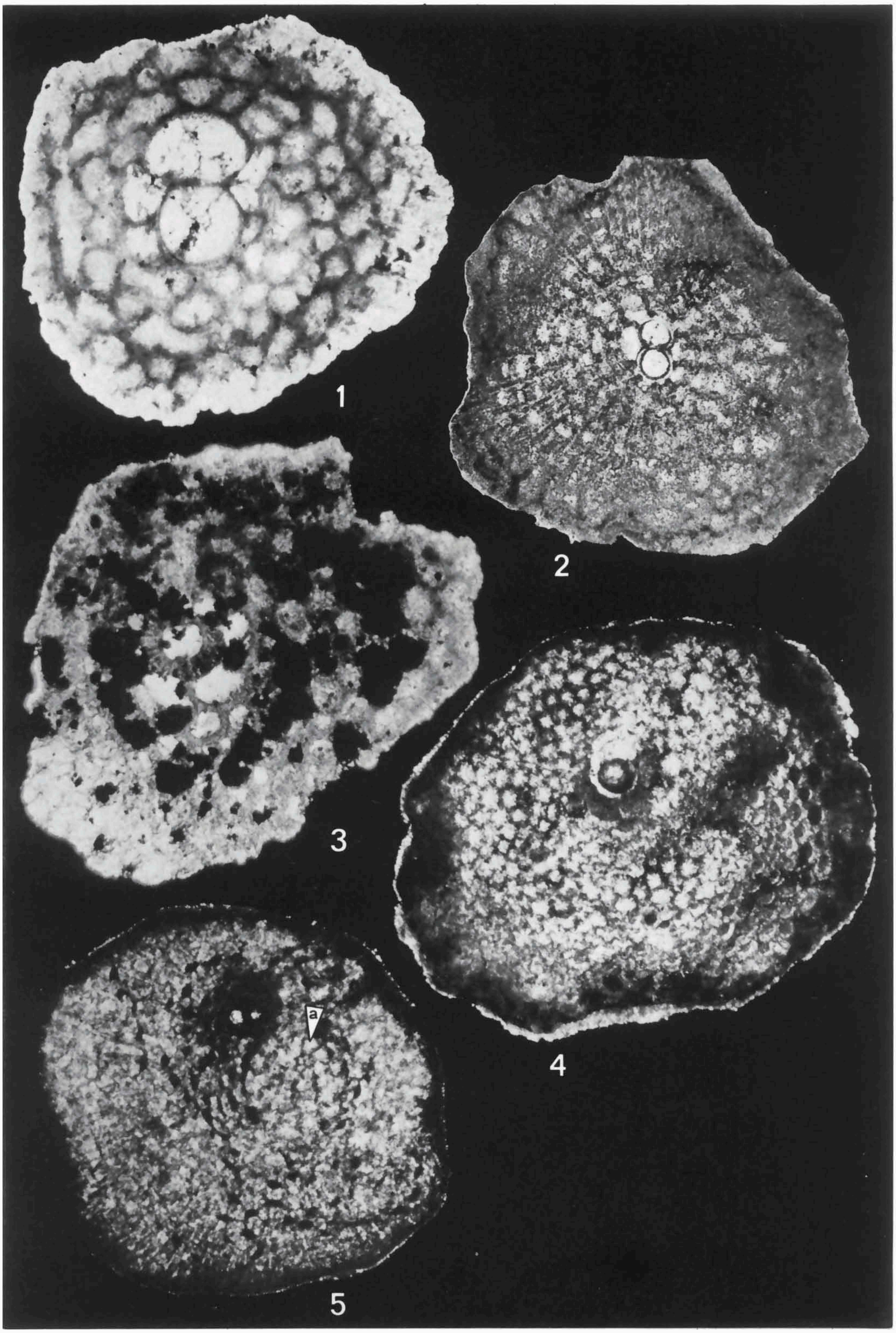
EXPLANATION OF PLATE 17

Pseudorbitoides trechmanni trechmanni Douvillé, 1922 from locality J 3601, Sunderland Inlier, Jamaica.

Figs. 1-4: Central horizontal sections of megalospherical forms. Figures 1 and 2 represent sections of quadriserial forms in which the first retrovert aperture has reached the second chamber (deuteroconch), and a second principal auxiliary chamber is formed. In these specimens radial elements are visible, in figure 1 vaguely in the right part of the photograph, and in figure 2 in the left part. Figures 3 and 4 represent sections of biserial forms in which the first retrovert aperture is situated in the third chamber, and, accordingly, only one principal auxiliary chamber is formed. In these specimens radial elements are considered to be effaced by recrystallization.
Specimen nrs.: Fig. 1: J 3601-278 (76×); Fig. 2: J 3601-187 (55×); Fig. 3: J 3601-329 (91×); Fig. 4: J 3601-169 (50×).

Fig. 5: Central horizontal section of a microspherical form. The small uniserial juvenarium is visible slightly off the centre of the picture (a). Mainly on the left side, radial elements can be seen. The juvenarium and the first part of the cyclical phase are apparently devoid of radial elements which become introduced later on in ontogeny. Specimen no.: J 3601-159 (47×).

PLATE 17



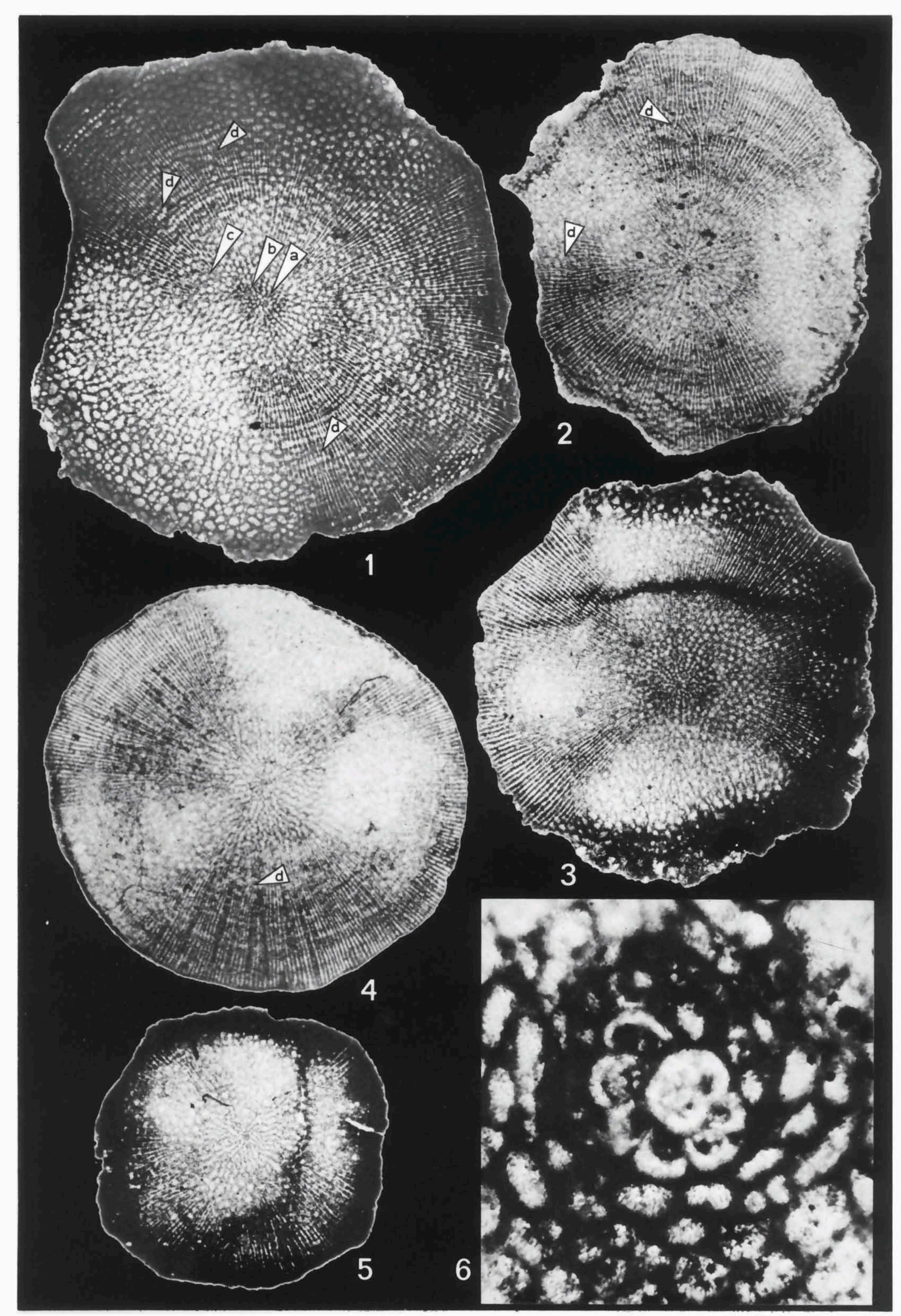
Explanation of Plate 18

Pseudorbitoides trechmanni trechmanni Douvillé, 1922 from locality J 3697, Sunderland Inlier, Jamaica.

Figs. 1-5: Central horizontal sections of microspherical forms, showing from the centre to the periphery: the small spiral of primary chambers (a), the zone of undivided arcuate secondary chambers (b), and, finally, the secondary chambers divided by the layer of radial elements (c). The secondary chambers are arcuate to truncated arcuate in shape, and differ distinctly from the polygonal lateral chambers. The secondary chambers are arranged according to the usual 'orbitoid' pattern (in figure 1, in the lower right portion), each chamber, moreover, traversed by 2 to 3 radial elements. In the lower left part of the same photograph lateral chambers are exposed. Convergent growth of radial elements is often noticed (d). Figure 2 (upper portion) shows this effect on a larger scale.
Specimen nrs.: Fig. 1: 'S'J 3697-60 (16×); Fig. 2: 'S'J 3697-67 (12×); Fig. 3: 'S'J 3697-71 (12×); Fig. 4: 'S'J 3697-23 (16×); Fig. 5: 'S'J 3697-119 (6×).

Fig. 6: Detail of a uniserial microspherical juvenarium.
Specimen no.: 'S'J 3697-24 (98×).

PLATE 18



Explanation of Plate 19

Pseudorbitoides trechmanni trechmanni Douvillé, 1922 from localities J 3697 and J 3601, Sunderland Inlier, Jamaica.

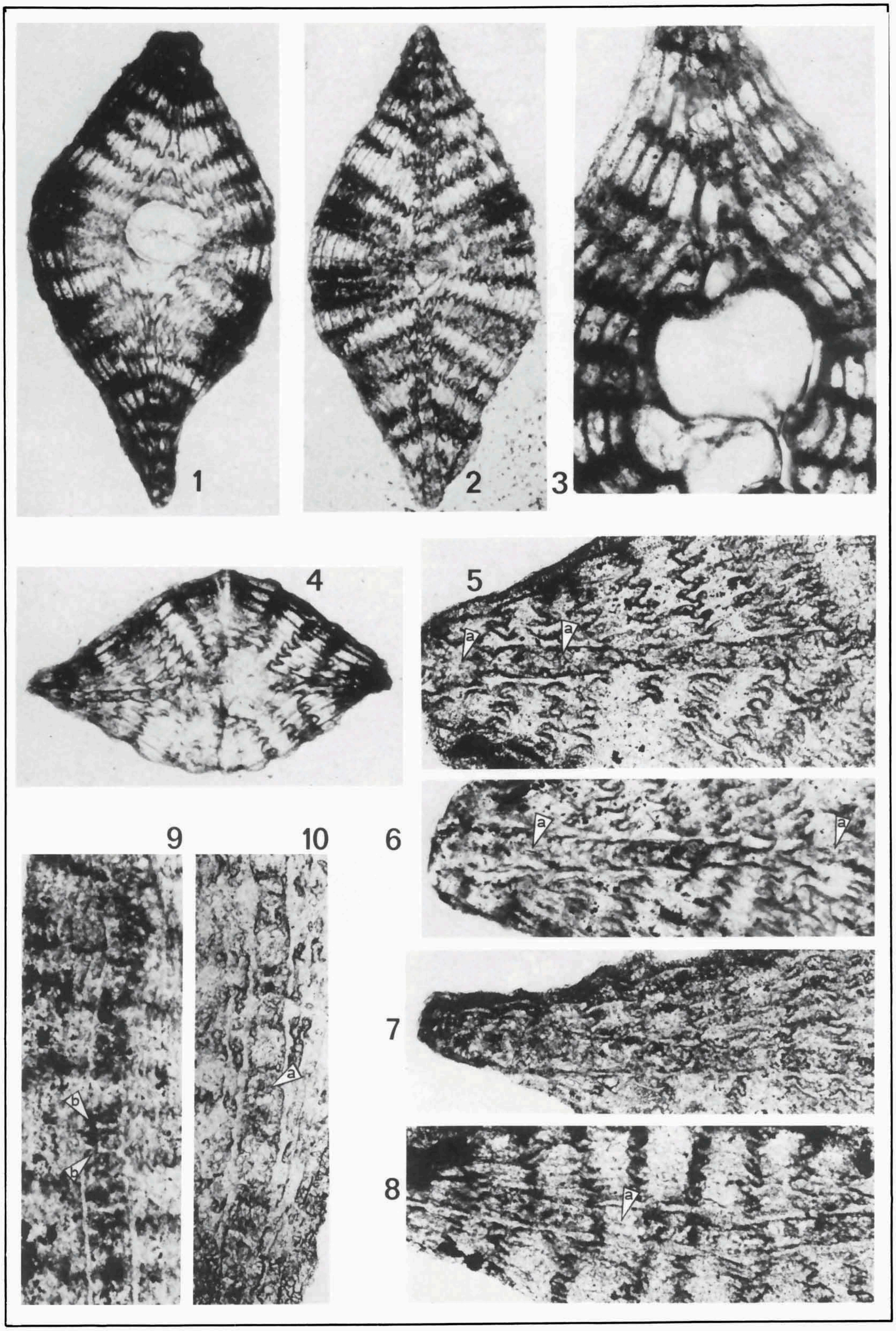
Figs. 1, 2, 4: Central vertical sections of megalospherical forms.
Specimen nrs.: Fig. 1: J 3601-166 (54×); Fig. 2: J 3601-6 (42×); Fig. 4: J 3601-12 (48×).

Fig. 3: Part of a central vertical section of a megalospherical form. A radial element is seen to start from a peri-embryonic chamber.
Specimen no.: J 3697-374 (130×).

Figs. 5-8: Parts of central or nearly central vertical sections of megalospherical forms. Small striations within the well exposed equatorial layer (a) suggest that the radial elements contain a radial canal system.
Specimen nrs.: Fig. 5: J 3697-150 (118×); Fig. 6: J 3697-141 (108×); Fig. 7: J 3697-206 (112×); Fig. 8: J 3697-238 (102×).

Figs. 9, 10: Vertical sections near the peripheral margin, showing the pseudorbitoid layer in cross-section. In figure 9 the radial elements are sectioned more or less perpendicularly, showing their plate-like nature, occasionally pierced by diagonal ? stolons (b). In figure 10, where the radial elements are sectioned slightly obliquely, small radial striations (a) might indicate the presence of a canal system within the radial elements.
Specimen nrs.: Fig. 9: J 3697-160 (118×); Fig. 10: J 3697-106 (118×).

PLATE 19



Explanation of Plate 20

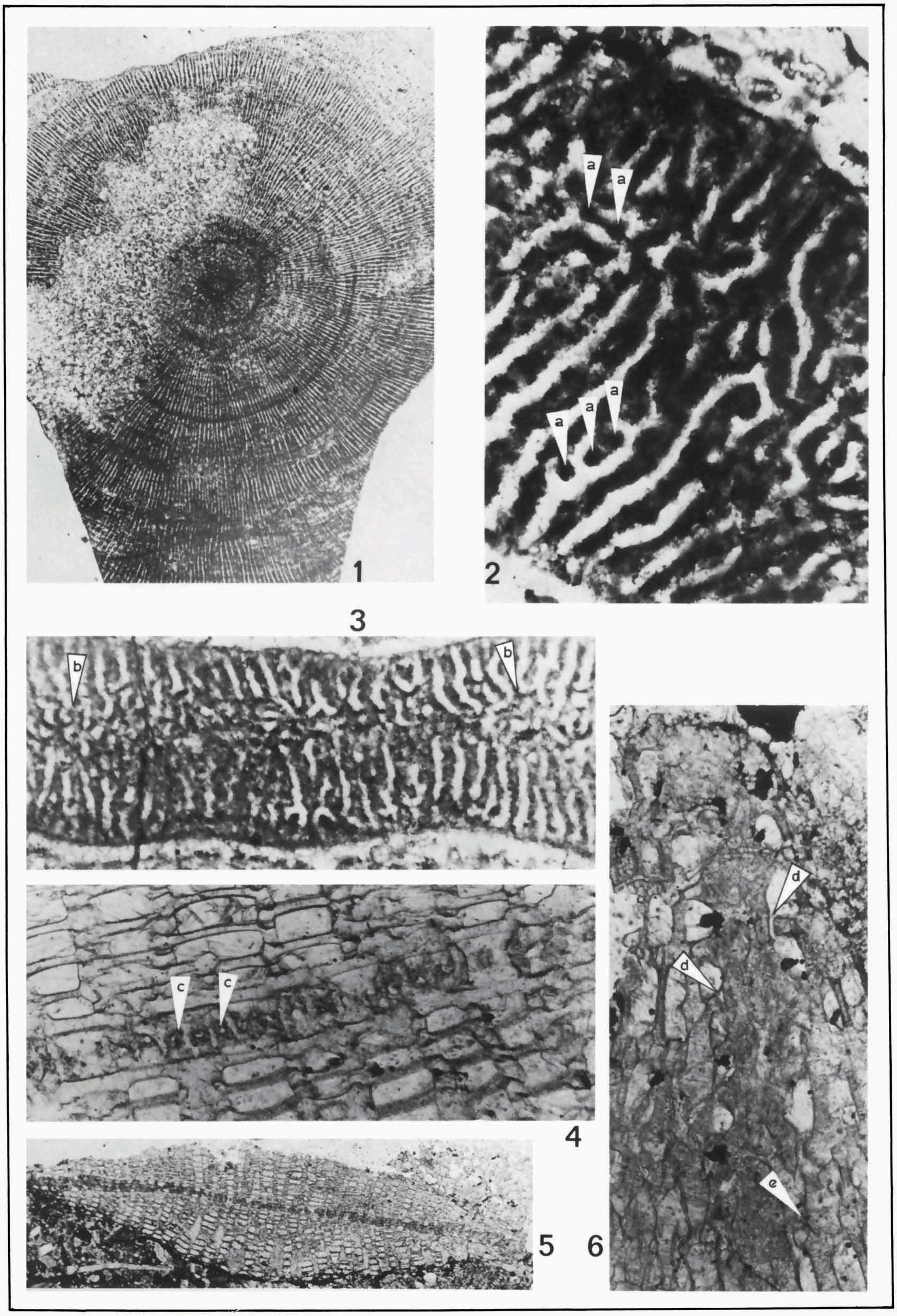
Pseudorbitoides trechmanni trechmanni Douvillé, 1922 from localities J 3697 and J 3419, Sunderland Inlier, Jamaica.

Fig. 1: Central horizontal section of a microspherical form, showing the irregular course of the radial elements.
Specimen no.: 'S'J 3697-24 (14×).

Figs. 2, 3: Vertical sections of a microspherical specimen near the peripheral margin. The pseudorbitoid layer has become a complex structure of radial passages (a). Figure 3 reveals arrangements of radial elements which resemble those in the 'incipient radii' of *Historbitoides* Brönnmann (b).
Both sections obtained from specimen no.: 'S'J 3697-24 (fig. 2: 129×; fig. 3: 49×).

Figs. 4-6: Photographs, obtained from one nearly central vertical section of a microspherical form (figure 5). Figure 4 represents an enlarged part of the centre of figure 5, in which a horizontal row of radial passages (c) in the equatorial chambers walls can be distinguished. Figure 6 is an enlarged part of the equatorial layer near the periphery (left part of figure 5). It shows the large equatorial chambers divided by the pseudorbitoid layer. Occasionally, stolons are visible in the marginal portion of the equatorial chambers (d), as well as in that part of the equatorial chamber wall which rests upon an older chamber (e). It is considered that the radial stolons (d) belong to the system of radial passages within the pseudorbitoid layer ('a' in figure 2). In all chamber walls numerous fine pores are visible: perpendicular to the direction of the wall.
Specimen no.: J 3419-1 (fig. 5: 15×; figs. 4 and 6: 94×).

PLATE 20



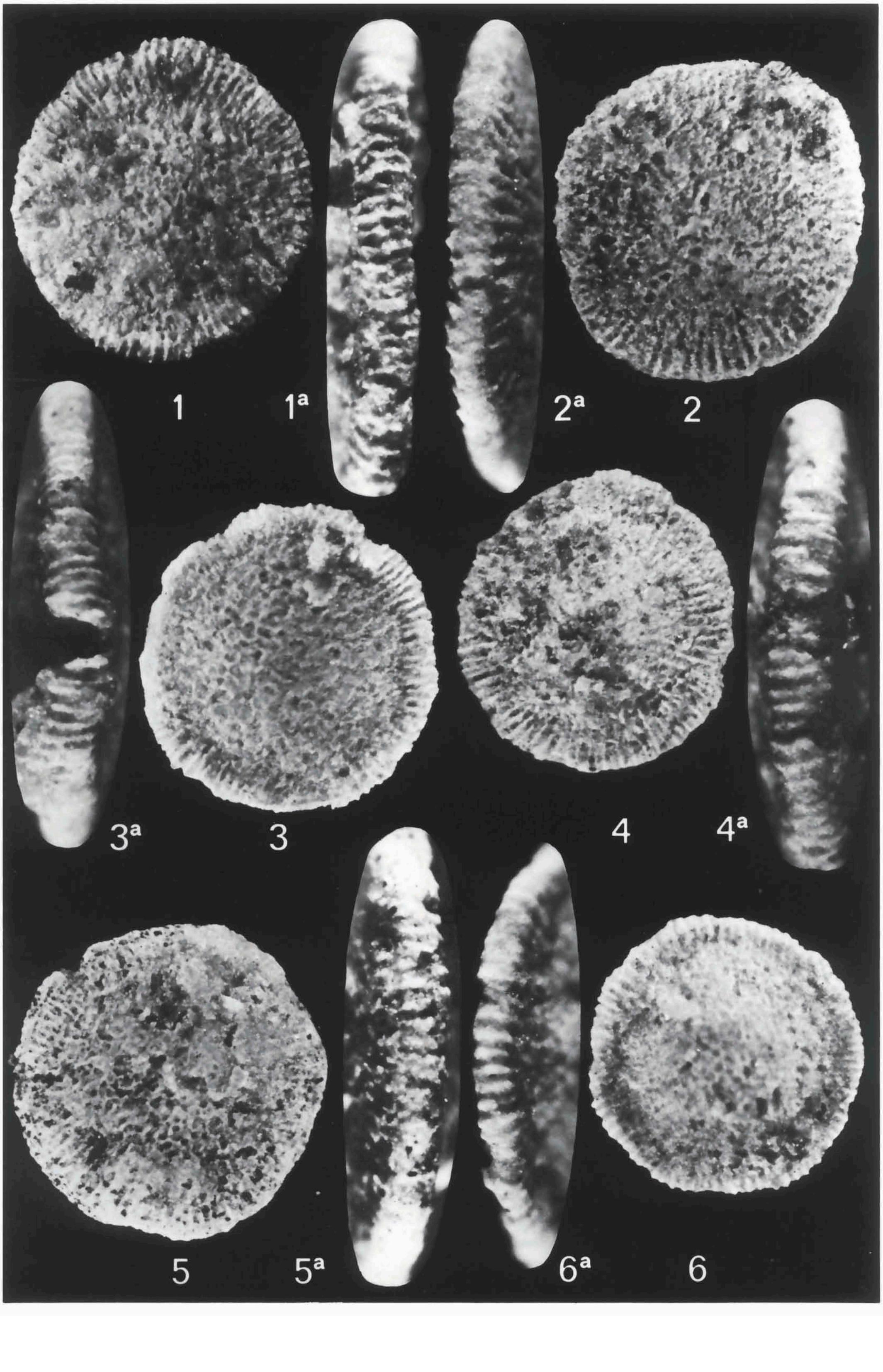
EXPLANATION OF PLATE 21

Pseudorbitoides trechmanni pectinata subsp. nov. from locality J 3680, Sunderland Inlier, Jamaica.

Figs. 1-6: Exterior view of megalospherical forms. The outline is almost circular and pectinate by protrusion of the radial elements beyond the peripheral margin. The test is lenticular with a distinct flange. The pectinate nature of the test is even more striking because of a slight protrusion of the radial elements beyond the lateral surface of the flange. As holotype is chosen specimen J 3680-61, illustrated by figures 3 and 3a (see also Plate 22, fig. 2).
Specimen nrs.: Fig. 1: J 3680-52 (26×); Fig. 2: J 3680-165 (31×); Fig. 3: J 3680-61 (30×); Fig. 4: J 3680-30 (25×); Fig. 5: J 3680-32 (29×); Fig. 6: J 3680-115 (31×).

Figs. 1a-6a: Side view of the specimens, mentioned above. The radial elements clearly show their plate-like nature.

PLATE 21



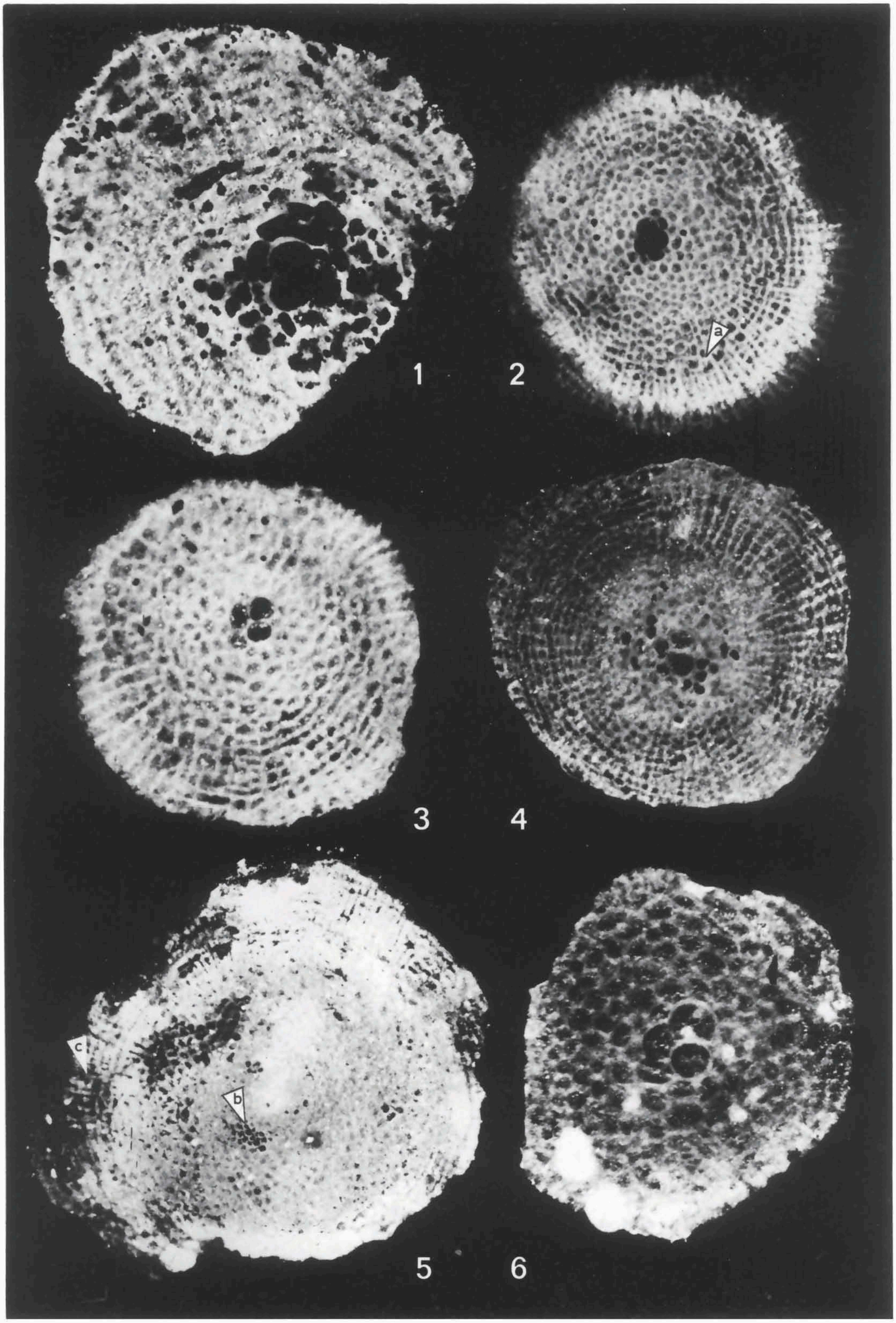
EXPLANATION OF PLATE 22

Pseudorbitoides trechmanni pectinata subsp. nov. from locality J 3680, Sunderland Inlier, Jamaica.

Figs. 1-4, 6: Central horizontal sections of megalospherical forms, showing the rather small size of the embryo, despite the advanced evolutionary stage (quadriserial juvenaria). Surrounding the juvenarium the cyclical phase clearly shows early arcuate chambers devoid of radial elements, or divided by very delicate radial elements, and followed by younger chambers, arranged in more or less radial rows, separated by prominent radial plates. New radial plates are seen to be intercalated where radial rows of equatorial chambers bifurcate (a). In a later stage in the cyclical phase, the arrangement of equatorial chambers becomes more or less annular (figures 2 to 4).
As holotype is chosen specimen no.: J 3680-61, illustrated by figure 2.
Specimen nrs.: Fig. 1: J 3680-717 (65×); Fig. 2: J 3680-61 (34×); Fig. 3: J 3680-190 (44×); Fig. 4: J 3680-107 (39×); Fig. 6: J 3680-647 (67×).

Fig. 5: Central horizontal section of a microspherical specimen, showing the zone of undivided arcuate chambers (b), as well as the younger chambers with radial elements (c).
Specimen no.: J 3680-3 (25×).

PLATE 22



EXPLANATION OF PLATE 23

Pseudorbitoides trechmanni pectinata subsp. nov. from locality J 3680, Sunderland Inlier, Jamaica.

Figs. 1, 2: Central parts of central horizontal sections of megalospherical forms, showing the advanced quadriserial juvenarium.
Specimen nrs.: Fig. 1: J 3680-1556 (145×); Fig. 2: J 3680-1025 (160×).

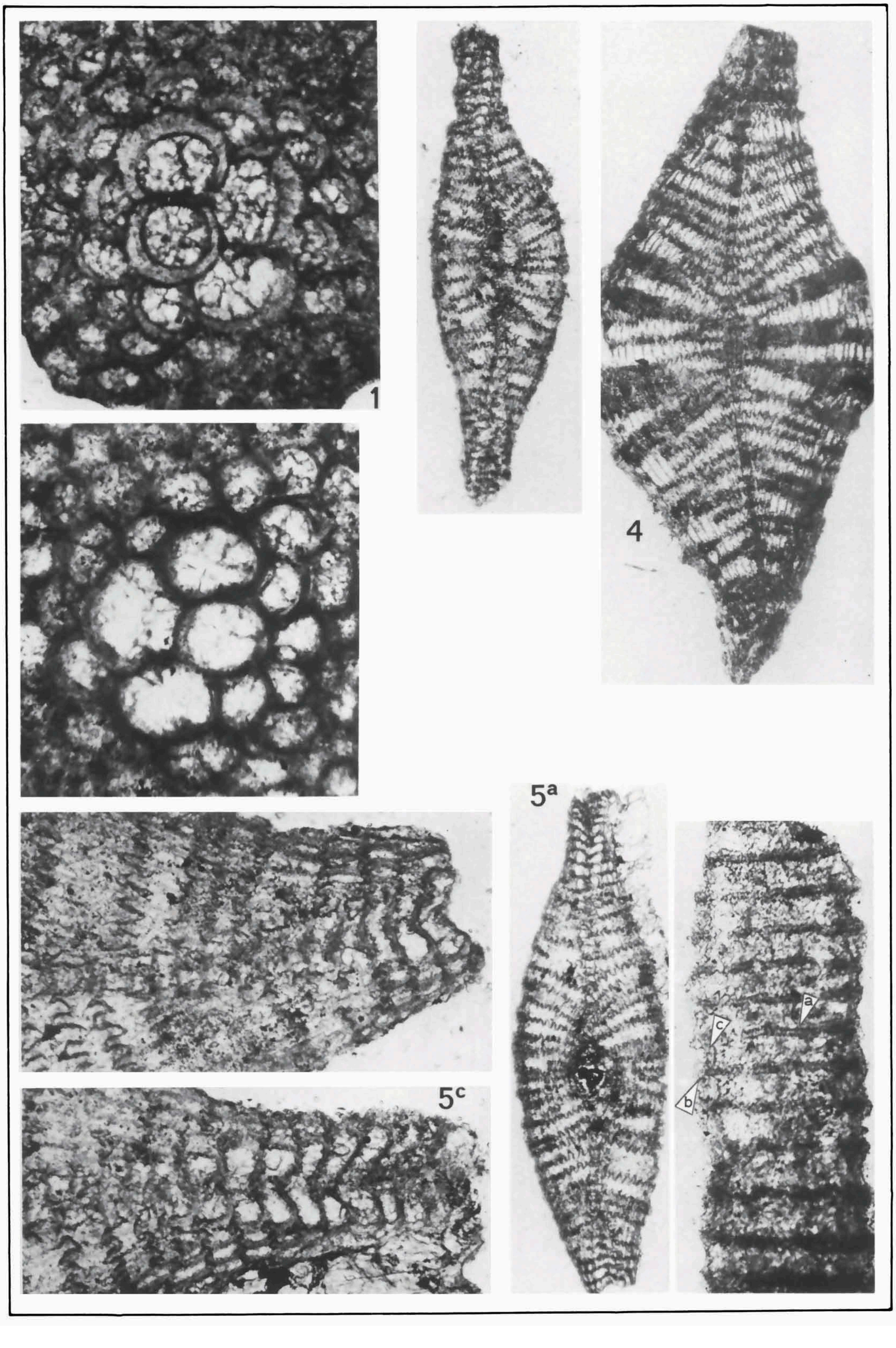
Figs. 3, 5a: Central vertical sections of megalospherical forms, showing the lenticular test. The equatorial layer increases to about five times its original height during ontogeny. Flange scarcely covered by lateral chambers.
Specimen nrs.: Fig. 3: J 3680-45 (36×); Fig. 5a: J 3680-27 (33×).

Fig. 4: Central vertical section of a microspherical form, showing heavy pillars in the lateral chamber build, radiating from the inner portion of the test to both umbonal regions.
Specimen no.: J 3680-1 (28×).

Figs. 5b, 5c: Details of figure 5a, showing the high V-shaped equatorial chambers in the peripheral part of the test. The radial elements are considered to separate radial rows of equatorial chambers, instead of traversing them.
Specimen no.: J 3680-27 (115×).

Fig. 6: Vertical section near the periphery, showing the plate-like radial elements. Presence of a canal system may be concluded from a dark line visible in each radial plate (a). In this stage in the ontogeny the radial plates have increased in height beyond the 'roof' and 'floor' of the equatorial layer, penetrating the layer of lateral chambers (b): lateral chambers (c) are seen to fill the depressions between the radial plates rather than covering them.
Specimen no.: J 3680-35 (11×).

PLATE 23



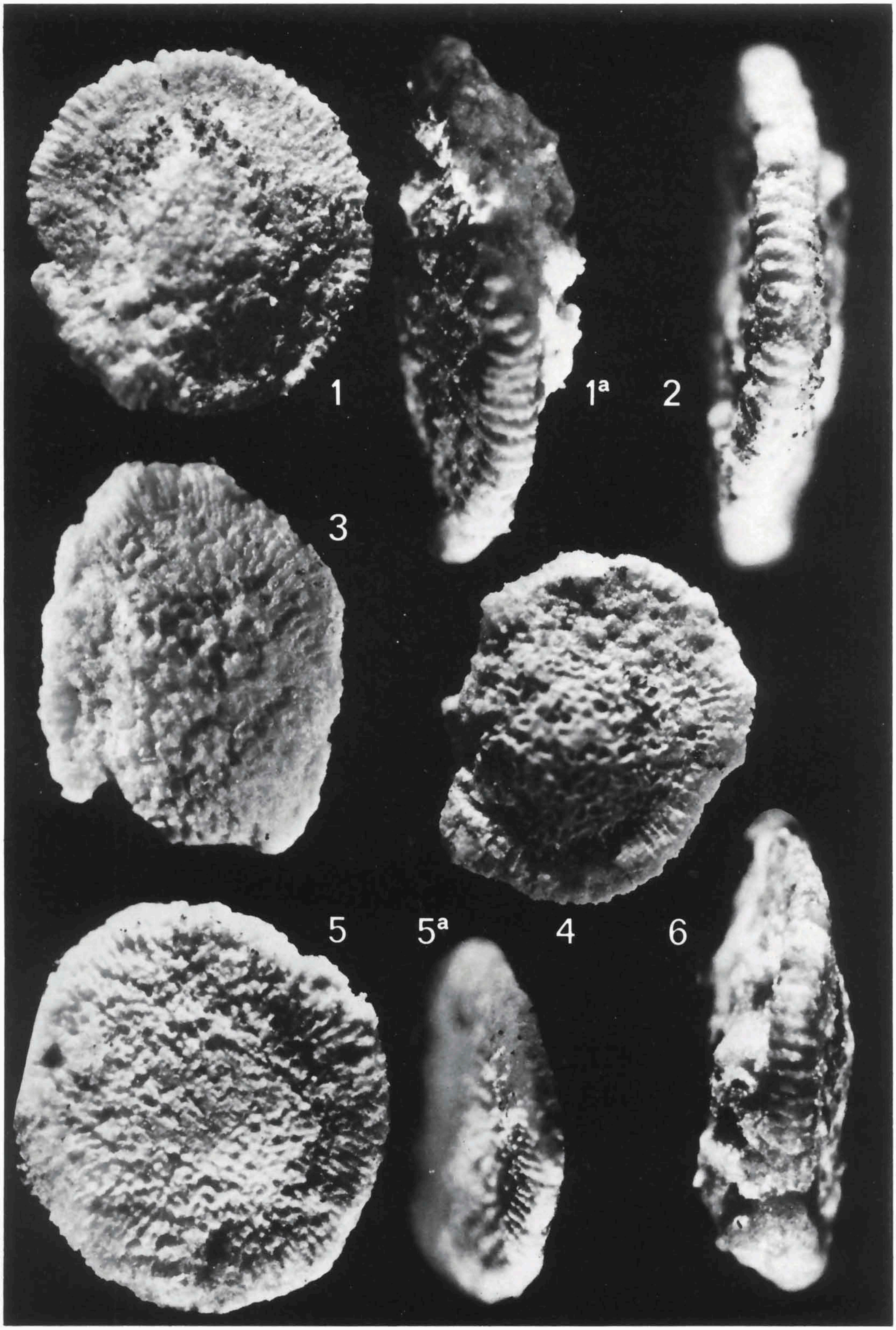
EXPLANATION OF PLATE 24

Pseudorbitoides trechmanni pectinata subsp. nov. from localities J 3686 and J 3688, Sunderland Inlier, Jamaica.

Figs. 1, 3, 4, 5: Exterior view of megalospherical forms. The outline is almost circular and pectinate by radial plates slightly protruding beyond the peripheral margin. Test lenticular with distinct flange. The radial plates protrude slightly beyond the lateral surface of the flange.
Specimen nrs.: Fig. 1: J 3686-7 (25×); Fig. 3: J 3688-130 (30×); Fig. 4: J 3688-73 (25×); Fig. 5: J 3688-20 (25×).

Figs. 1a, 2, 5a, 6: Side view of some individuals, showing the plate-like radial elements.
Specimen nrs.: Fig. 1a: J 3686-7 (35×); Fig. 2: J 3688-59 (37×); Fig. 5a: J 3688-20 (22×); Fig. 6: J 3688-7 (30×).

PLATE 24



EXPLANATION OF PLATE 25

Pseudorbitoides trechmanni pectinata subsp. nov. from locality J 3688, Sunderland Inlier, Jamaica.

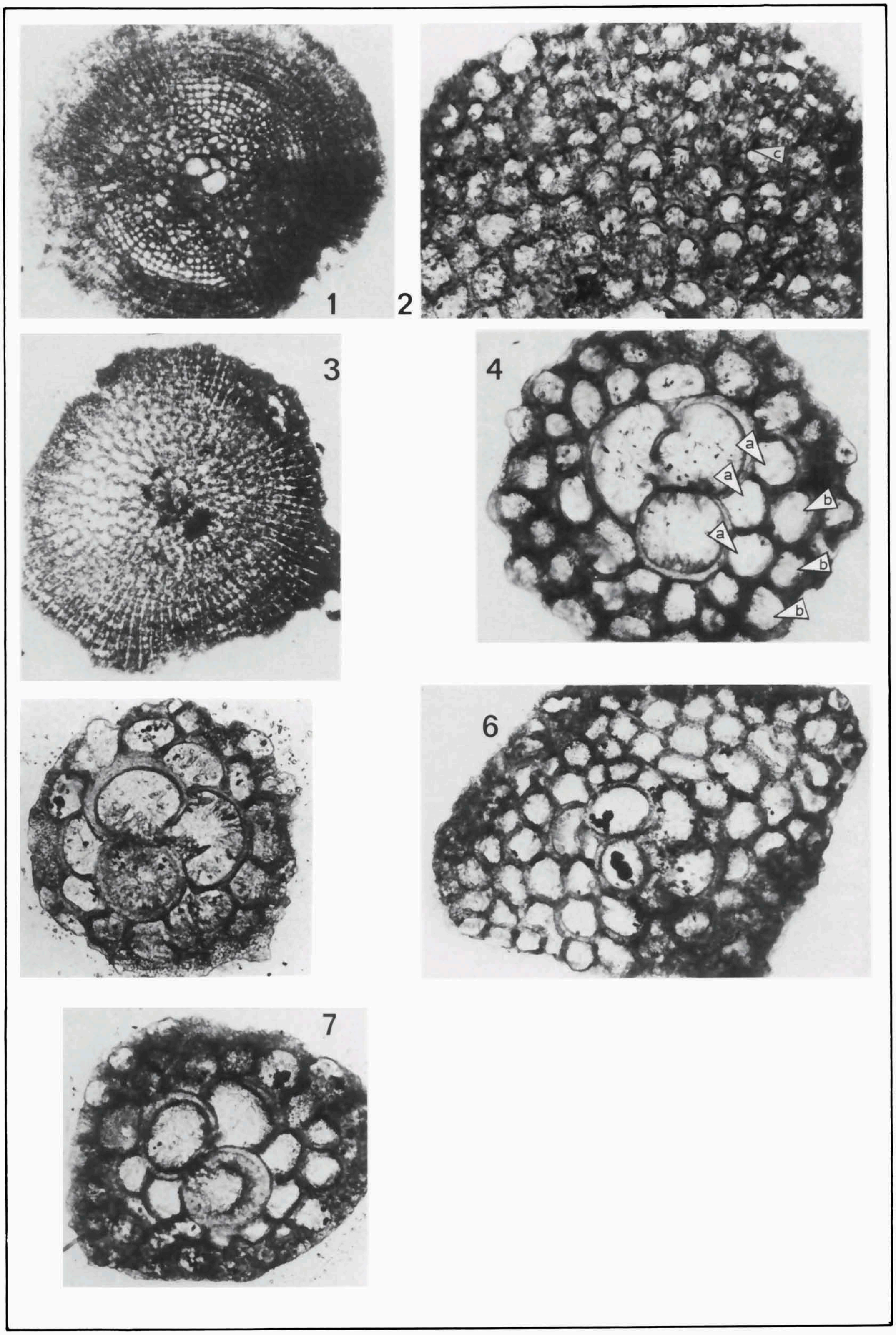
Figs. 1, 3: Central horizontal sections of megalospherical forms. The major youngest part of the equatorial layer seems to be built up by a radial (and annular) arrangement of secondary chambers, the radial rows of chambers being separated by radial elements. In this ontogenetical phase the radial elements are rather coarse, and 20 to 25 of them have been counted per quadrant.
Specimen nrs.: Fig. 1: J 3688-19 (28×); Fig. 3: J 3688-75 (32×).

Fig. 2: Part of the equatorial layer of a megalospherical specimen, in which the 'orbitoid' arrangement of equatorial chambers, early in the cyclical phase, changes into the radial (and annular) arrangement with the introduction of the radial elements (c), in a younger ontogenetical phase.
Specimen no.: J 3688-135 (85×).

Figs. 4, 5, 7: Central horizontal sections of juvenile megalospherical forms with a quadriserial juvenarium. In figure 4 some of the juvenile chambers are indicated (a), as well as some of the early secondary chambers (b) which might well belong to the cyclical phase. The pseudorbitoid layer is considered not to be introduced yet.
Specimen nrs.: Fig. 4: J 3688-251 (103×); Fig. 5: J 3688-321 (105×); Fig. 7: J 3688-319 (105×).

Fig. 6: Central horizontal section of a juvenile megalospherical form in which the second principal auxiliary chamber (on the left side of the embryo) is considered to be covered completely by the 7th and 8th primary chamber.
Specimen no.: J 3688-331 (104×).

PLATE 25



Explanation of Plate 26

Pseudorbitoides trechmanni pectinata subsp. nov. from localities J 3686 and J 3688, Sunderland Inlier, Jamaica.

Fig. 1: Part of the equatorial layer, near the periphery, of a microspherical specimen. The radial elements are seen to separate radial rows of equatorial chambers. Radial passages in the chamber walls are often noticed (a). A canal system in the radial elements may be present (b).
Specimen no.: J 3688-1 (117×).

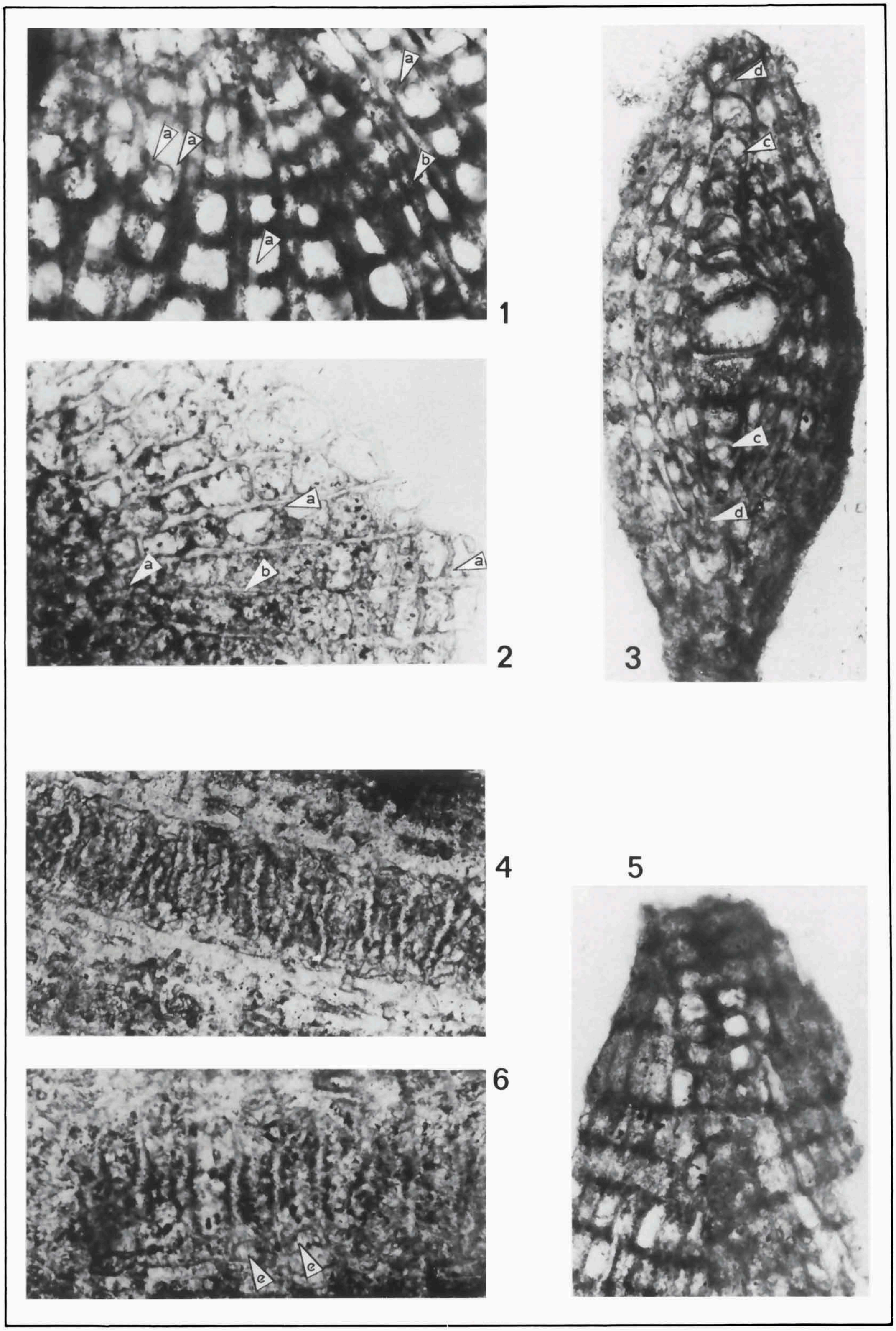
Fig. 2: Part of the equatorial layer, near the periphery, of a megalospherical form, showing the somewhat zig-zag course of the radial elements. On the peripheral side, the equatorial chambers are arranged in distinct radial rows, separated by the radial elements. Radial passages have been noticed in the equatorial chamber walls (a). A canal system may be present within the radial elements (b).
Specimen no.: J 3688-15 (117×).

Fig. 3: Central vertical section of a juvenile megalospherical form, showing the embryo and early secondary chambers (c) prior to the ontogenetical appearance of the radial elements (d).
Specimen no. J 3688-156 (97×).

Figs. 4, 6. Tangential (peripheral) vertical sections, showing the plate-like radial elements which slightly protrude (in a lateral direction) beyond the equatorial layer in the first layer of lateral chambers (e). In both sections radial passages between, and radial canals within, the radial elements, have not been recognized.
Specimen nrs.: Fig. 4: J 3686-1 (50×); Fig. 6: J 3688-52 (50×).

Fig. 5: Peripheral part of a central vertical section of a megalospherical form, showing the somewhat V-shaped equatorial chambers. The pseudorbitoid layer has not reached its maximum height, and is shown within the equatorial layer.
Specimen no.: J 3688-16 (97×).

PLATE 26



Explanation of Plate 27

Vaughanina cubensis Palmer from Bermudez Station 239, one kilometer west of Central San Antonio, Madruga, Prov. Matanzas (= R H Palmer 1214), Cuba.

Figs. 1-3: Examples of specimens, showing the presence of aktinorbitoid intterradii (i) both externally and internally. The horizontal sections clearly show the characteristical arrangement of the lateral chambers interrupting the equatorial layer.
Specimen nrs.: Figs. 1, 1a: J 9667-11 (30×, 45×); Figs. 2, 2a: J 9667-9 (30×, 45×); Figs. 3, 3a: J 9667-10 (30×, 45×).

PLATE 27