Nannofossils from the Eastern Desert, Egypt
with reference to Maastrichtian Nannofossils from the USSR

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With 50 plates and 7 text-figures

1. Abstract

With a view to the great importance of the Tarawan Chalk formation in the Egyptian stratigraphy its coccolith content has been investigated and is recorded here, whereby we could refer to a sample of similar age from the Dnjepr-Donetz region USSR.

A framework for a nannoplankton-zonation for the early Tertiary of Egypt is submitted. The Tarawan Chalk proves to become younger in age in southern direction. A hiatus is supposed between this formation and the overlying Esna Shale in the Gebel Tarbouli area, although no break in the sedimentation could be observed.

Stratigraphic correlations with various localities abroad are tentatively suggested. Taxonomic problems and some new coccolith-species are discussed on the basis of 50 plates.

2. Introduction, General Discussion, Acknowledgments

One of the two main aspects in connection with the problem of an improved international geological correlation, as proposed by the scientists and the experts of the UNESCO in their meeting in Budapest (September, 1969), is the need for researches, to establish clear documentation, upon which continental and intercontinental correlation can be based.

The purpose of this paper is to present and to record the coccolith contents of the Upper Cretaceous of the Gulf of Suez region, namely Gebel Tarbouli, UAR, refering also to a sample from the USSR (Dnjepr-

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Donetz region). In addition a framework of the nannofossil assemblages of the early Tertiary from several sections, cropping out along the western side of both the Gulf of Suez and the Red Sea, is also given.

The coccoliths are tiny scales, secreted by unicellular marine phytoflagellates of the family Coccolithophoridae. They occur either on the surface or embedded in the layer of the mucilage, located just exterior to the cell membrane of the coccolithophorid cell. The coccolithophorids are biflagellate "protists". However, PARKE & ADAMS (1960) and recently PIENAAR (1969) have shown, that a third flagellum (the haptonema) is occasionally found situated between the two flagella of the coccolithophorid cell. Together with diatoms and dinoflagellates, the coccolithophorids form the third group of the autotrophic phytoplankton. Nevertheless COHEN (1965) considered, that species of the coccolithophorids, living in the deep water layers, are probably heterotrophic.

The two-phase life cycle of the coccolithophores produces two types of coccoliths. The holococcoliths represent the motile stage of the life cycle of the coccolithophores. Their skeletal plates are built of elements uniform in size and shape. On the other hand, the non-motile stage produces the heterococcoliths, which are constituted of elements varying in size and shape. Studies on the recent coccolithophores suggest, that the fossil coccoliths represent only the non-motile stage (the heterococcoliths) of the life cycle mainly.

The discoasters are stellate or rosette-like calcareous forms, most probably extinct. They have been found in Cenozoic strata. LECAL (1952) described a recent planktonic protist from the Mediterranean Sea as *Discoaster planctonicus*, the surface of which was covered with many five- and six-rayed stars *). Nevertheless, these organisms are not generally accepted yet as living representatives of the fossil Discoasteridae. The exact systematic position of this group of fossils is still uncertain, hence they are considered here as fossils "incertae sedis".

TAN SIN HOK (1927) was the first, to present the systematics of these forms. He introduced the term "discoaster" as a systematic unit, within his new family of Discoasteridae. SUJKOWSKI (1931) and PAREJAS (1934) described discoasters, but they were using the generic taxon *Actiniscus* EHRENBERG. DEFLANDRE (1950) arranged the Discoasteridae on account of their optical property behaving as single crystals in his new order of the Ortholithae, together with the Thoracosphaeridae and the Braarudosphaeridae. BRAMLETTE and RIEDEL (1954) drew the attention to the stratigraphic significance of these microfossils.

Collectively the term "calcareous nannofossils or calcareous nannoplankton" is applied to coccoliths, discoasters and related minute calcareous fossils. The calcareous nannofossils (nannos = dwarf) are among the typical means by which local, regional as well as transoceanic correlation

*) BURSA (1964) described discoaster-producing flagellates, which he found in arctic waters and which he named *Discoasteromonas calciferus*.

could be established. Their rapid evolution, especially of many distinctive forms, is now evident. Their planktonic characteristics together with their minute size (generally from 1 to 20 µ in diameter), explains their wide distribution. HAY (1963) noted that "coccoliths settle much more slowly than the tests of planktonic foraminifera ...". However, results of the recent studies by McINTYRE (in press) indicate, that important quantities of the coccoliths do reach the ocean floor directly from the overlying water mass. Rapid sinking is accomplished via fecal pellets of the zooplankton.

The "assemblage" as a group of associated fossils could be used as a valuable stratigraphic indicator with great success especially in the case of the calcareous nannofossils. Moreover, when the state of preservation of a sample is not too perfect, it is easier and more appropriate to recognize an assemblage than a certain species. The one and the same species might be differently recognized and interpreted by different authors. It has been noticed by the present author, that the examination of a sample under the light microscope and the investigation of its carbon replica under the electron transmission microscope shows often apparent differences in the state of fossilization. Again, this represents another difficulty for the exact identification of a certain species, but not so much for the exact recognition of a certain assemblage.

Due to their minute size, the calcareous nannofossils are easily reworked and may appear in younger strata. The use of the assemblage, as recommended by this study, could reduce mistakes, caused by reworking of these tiny fossils. In addition, the problem of reworking could be partly solved, if the first occurence of the species is given the most consideration within the successive assemblages.

The use of the calcareous nannoplankton assemblages, provided that they show an evolutionary trend, could help solving the controversies about the subdivision of some of the stratigraphical units, e. g. Paleocene.

After recognizing well-established assemblages of the calcareous nannofossils for stratigraphical units, it will be possible, to express the probability of a correlation numerically, making use of the large numbers, in which calcareous nannoplankton occurs. This could be achieved by using the concurrent-rangezones of the different members of the successive assemblages, thus applying the probability theory to the biostratigraphic correlation.

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3. Field Geology

The Tarbouli section, the main of this paper, was sampled by the author during summer 1969, as the latest part of his project of studying and sampling most of the Upper Cretaceous-Lower Tertiary deposits cropping out in the Gulf of Suez Region and the Red Sea Coast, Egypt. As far as the writer is aware, nothing has been published up till now about Gebel Tarbouli. It represents the northern most tip of the so called Ash El-Mellaha range sediments. It stands as a topographic cone about 100 m above the surrounding plains. It is separated from the main body of the Ash El-Mellaha sediments by some small dissected wadies. Apparently it is bounded from its eastern and western sides by two main normal faults. Some minor faults, having a general NNW-SSE trend, were observed by the author within the Gebel Tarbouli itself.

4. Stratigraphy

The Upper Cretaceous-Lower Tertiary deposits of the western side of both the Gulf of Suez and the Red Sea are found by the author as isolated hills representing structurally basinlike hills. They are up to 565 meters thick in the Gebel Duwi, and consist of six easily recognizable lithostratigraphic units (from below) the Nubia Formation, the Quesseir (variegated) Shale, the Duwi (Phosphate) Formation, the Dakhla Shale, the Tarawan Chalk and the Esna Shale. They are often caped by the Thebes Formation (Lower Eocene). The formational names given here are in general accordance with those given by SAID (1962). The lower three units sampled from many localities, show that they are nonfossiliferous, mainly as far as the microscopic fossils are concerned. The other three formations are abundantly fossiliferous.

Though the lithology of the Tarawan Chalk varies in different places from marl, marly limestone to pure chalk, its constant position between the two shale formations (namely the Dakhla Shale below and the Esna Shale above) and its wide geographical distribution, from the Kharga, Dakhla, and Abu Mungar oases in the Western Desert, to the Esna-Idfu region in the Nile Valley, to the Quesseir Safaga and Ash El-Mellaha at the Red Sea Coast and Gulf of Suez Region, make it one of the best stratigraphic markers in the Upper Cretaceous-Lower Tertiary of Egypt. Due to the great importance of the Tarawan Chalk in the Egyptian stratigraphy, the main part of this paper is devoted to the documentation of its coccolith assemblage.

The Tarawan Chalk at the Gebel Tarbouli constitutes nearly the lower half of the section, its base being not exposed. The exposed part of the Tarawan Chalk in the studied area is 48,60 meters thick. Its lithology is mainly marl to marly limestone. The contact between the Tarawan Chalk and the underlying Dakhla Shale, as exposed in the south at Ash El-Mellaha range, itself is sharp, while less conspicuous contact-conditions could be observed at the boundary between the Tarawan Chalk and the overlying Esna Shale in the Gebel Tarbouli. Amongst the megafossils found in this rock unit in the area under consideration, *Pecten farafrensis* Zittel, is abundant.

The Esna Shale at Gebel Tarbouli attains its minimum thickness, 10 m; it is a clayey shale or shale to marl with some salt and gypsum as veinlets. The Esna Shale at Tarbouli section grades downwards and upwards into the Tarawan Chalk and into the Thebes Formation respectively.

5. Material studied and Method of Study

The coccoliths presented and photographed in this paper are from Gebel Tarbouli, Gulf of Suez Region, Egypt (Lat. 27° 55′ N and Long. 33° 5′ E); and from the Maastrichtian of the USSR *).

Text-figure 1 represents a location map of the Tarbouli section and also of most of the Upper Cretaceous-Lower Tertiary sections of the Gulf of Suez Region and the Red Sea Coast. A columnar section of the Gebel Tarbouli is given by text-figure 2.

The method of preparation and study of the coccoliths is the same as given by Adamiker in Stradner et al (1968), with some slight modifications when required. The negatives of the microphotographs belonging to this study are deposited in the ELMI laboratory at the Geological Survey of Austria, Vienna.

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*) The Dnjepr-Donetz region (Sinev-Shuravnin drilling, depth 278/279 m.).

Fig. 1

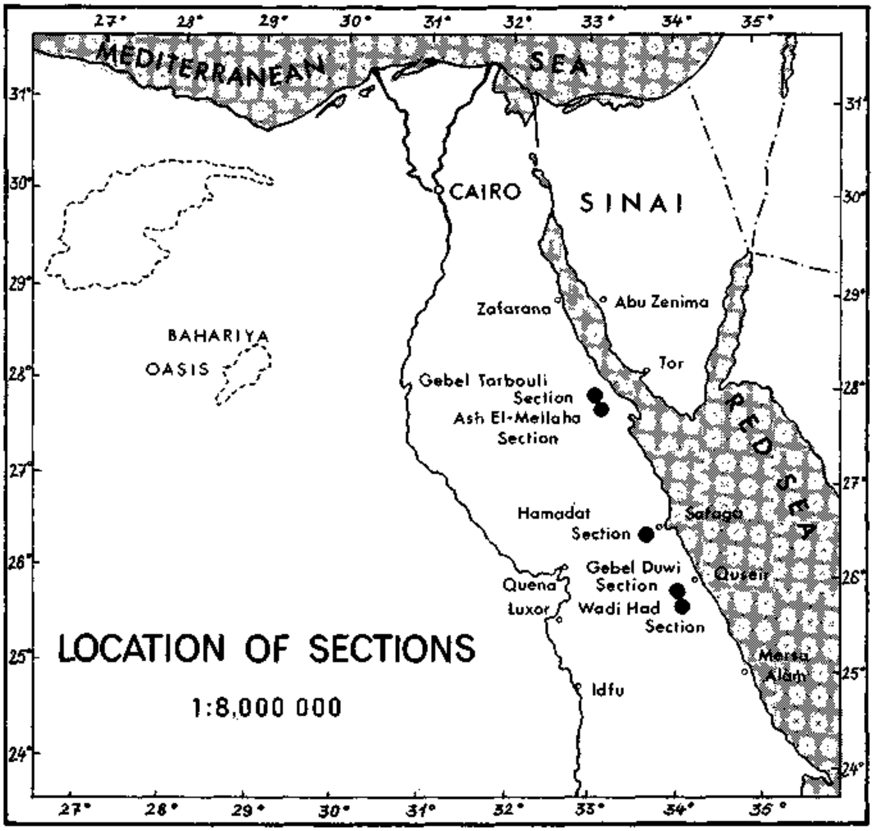

Fig. 1: Orientation map showing the geographic position of the studied sections in Egypt.

6. Succession of Nannoplankton Assemblages

The nannoplankton assemblage of the Tarawan Chalk of the Tarbouli section, Egypt, and those from the Dnjepr-Donetz region (Sinev-Shuravnin drilling, depth 278/279 m). are given below. The assemblages recorded here for the two localities are found to be typical for the Upper Maastrichtian; their correlation is possible.

The following species are found in the Maastrichtian of both the Tarbouli section, Gulf of Suez, Egypt, and of the Dnjepr-Donetz region (Sinev-Shuravnin drilling, depth 278/279 m.):

Arkhangelskiella cymbiformis VEKSHINA
Biscutum constans (GORKA) BLACK
Biscutum testudinarium BLACK
Eiffellithus trabeculatus (GORKA) REINHARDT & GORKA

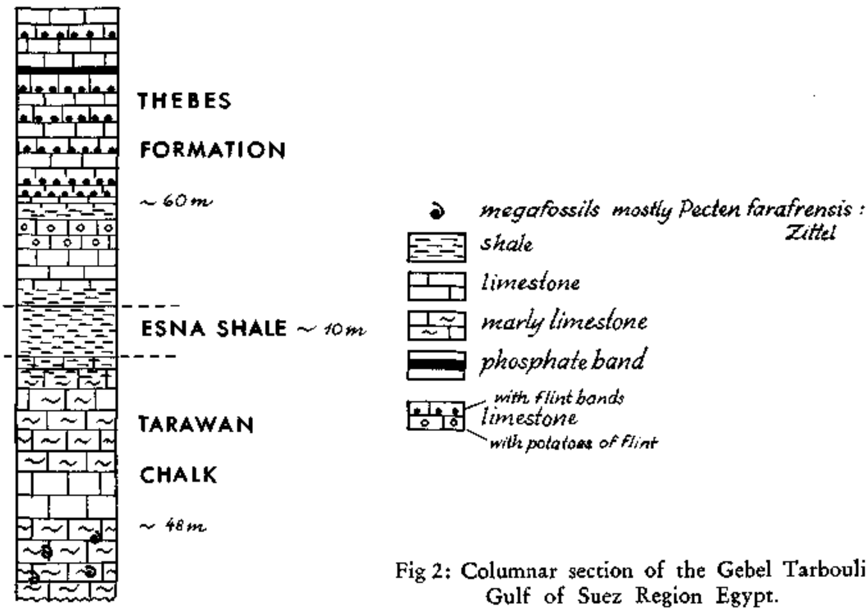

Fig 2: Columnar section of the Gebel Tarbouli, Gulf of Suez Region Egypt.

Kamptnerius magnificus DEFLANDRE
Lithraphidites quadratus BRAMLETTE & MARTINI
Micula staurophora (GARDET) STRADNER
Polypodorhabdus crenulatus (BRAMLETTE & MARTINI) nov. comb.
Prediscosphaera honjoi BUKRY
Reinhardtites mirabilis PERCH-NIELSEN
Rhagodiscus plebeius PERCH-NIELSEN
Vekshinella crux (DEFLANDRE & FERT) nov. comb.
Watznaueria barnesae (BLACK) PERCH-NIELSEN
Zygodiscus spiralis BRAMLETTE & MARTINI
Zygolithus erectus DEFLANDRE

The following is a list of the coccoliths encountered only in the Tarawan Chalk of the Tarbouli section and n o t in the Russian sample:

Corollithion exiguum STRADNER
Cribrosphaerella numerosa (GORKA) REINHARDT & GORKA
Cylindralithus serratus BRAMLETTE & MARTINI
Kamptnerius punctatus STRADNER
Podorhabdus dietzmanni (REINHARDT) REINHARDT
Polypodorhabdus pienaari nov. spec.
Polypodorhabdus schizobrachiatus (GARTNER) nov. comb.
Pontosphaera multicarinata (GARTNER) nov. comb.
Rhabdolithina splendens (DEFLANDRE) REINHARDT
Stephanolithion laffittei NOEL

Vekshinella elliptica GARTNER
Zygodiscus tarboulensis nov. spec.

The following species are found only in the Russian material and n o t in the Egyptian samples:

Ahmuellerella octoradiata (GORKA) REINHARDT
Eiffellithus anceps (GORKA) REINHARDT & GORKA
Markalius inversus (DEFLANDRE) BRAMLETTE & MARTINI
Nephrolithus frequens GORKA
Prediscosphaera stoveri PERCH-NIELSEN
Vekshinella cruciata (NOEL) nov. comb.
Zygodiscus acanthus (REINHARDT) REINHARDT
Zygolithus cf. *diplogrammus* DEFLANDRE

A study of the planktonic foraminiferal content of the Tarawan Chalk of the Gebel Tarbouli reveals, that the fossils are to be located within the vertical limits of the *Abathomphalus mayoroensis* zone. This result ascertains the age of the Tarawan Chalk of the Gebel Tarbouli to be Upper Maastrichtian.

In an attempt to correlate the nannoplankton assemblages of both the Esna Shale and the Tarawan Chalk of Gebel Tarbouli with those of the same two formations exposed at the Gulf of Suez region and the Red Sea coast, it was possible to recognize some nannoplankton zones; however, the zonation outlined below is merely a framework; the details of such a zonation should be the subject of further studies.

The assemblages recognized are the following:

T o p:

a) *DISCOASTER BINODOSUS ZONE:* the definition of this zone as given by HAY et al. (1967) is followed here. The upper half of the Esna Shale of the Gebel Tarbouli, and only the uppermost part of the same formation of the Hamraween section and the Gebel Duwi belong to this zone. Among the nannoplankton species found in this zone are the following:

Discoaster binodosus MARTINI, *Discoaster mediosus* BRAMLETTE & SULLIVAN, *Marthasterites tribrachiatus* (BRAMLETTE & RIEDEL) DEFLANDRE, *Discoaster diastypus* BRAMLETTE & SULLIVAN and *Coccolithus* spp.

This zone is characterized in the Egyptian sections by the flood of *Discoaster binodosus* MARTINI and by the absence of both the *Marthasterites contortus* (STRADNER) DEFLANDRE and *M. bramlettei* BRÖNNIMANN & STRADNER.

b) *MARTHASTERITES CONTORTUS ZONE:* the author follows the definition of this zone given by HAY (1964 b). The common species are: *Marthasterites contortus* (STRADNER) DEFLANDRE, *Marthasterites bramlettei* BRÖNNIMANN & STRADNER, *Discoaster binodosus* MARTINI, *Discoaster* *diastypus* BRAMLETTE & SULLIVAN, *Discoaster multiradiatus* BRAMLETTE & SULLIVAN and *Discoaster mediosus* BRAMLETTE & SULLIVAN.

This zone is present in the Esna Shale of Gebel Duwi, and Gebel Hamraween. The lowermost part of the Esna Shale of Hamadat section and Gebel Tarbouli also belong to this zone.

c) *MARTHASTERITES SPINEUS ZONE:* this zone is recognized for the first time here and is defined by the interval between the first occurrence of *Marthasterites spineus* nov. spec. and the first occurrence of *Marthasterites bramlettei* BRÖNNIMANN & STRADNER. Common species are: *Marthasterites spineus* nov. spec., *Discoaster diastypus* BRAMLETTE & SULLIVAN and *Discoaster multiradiatus* BRAMLETTE & RIEDEL.

This zone has been observed in the Esna Shale of the Wadi Had section (south Gebel Duwi) and in the same formation of the Ash El-Mellaha range sediments. It is worth to mention that these two localities are almost 200 km distant, as shown in text-figure 1. This zone has not been found in the Gebel Tarbouli Section.

Type section: The Ash El-Mellaha range Esna shale, Western Red Sea Coast, Egypt.

d) *DISCOASTER MULTIRADIATUS ZONE:* this zone is defined by the vertical interval between the first occurence of *Discoaster multiradiatus* BRAMLETTE & RIEDEL and first occurrence of *Marthasterites spineus* nov. spec. This zone is readily recognizeable in most of the sections of the Red Sea coast. It is well-developed in the Hamraween section and in Gebel Duwi in the Esna shale, it is absent in the Tarbouli section. Together with *Discoaster multiradiatus* BRAMLETTE & RIEDEL, the following nannofossil species are present: *Discoaster delicatus* BRAMLETTE & SULLIVAN, *D. lenticularis* BRAMLETTE & SULLIVAN, *D. limbatus* BRAMLETTE & SULLIVAN, *D. mediosus* BRAMLETTE & SULLIVAN and *Heliolithus riedeli* BRAMLETTE & SULLIVAN.

e) *HELIOLITHUS RIEDELI ZONE:* the range of this zone extends from the first occurrence of *Heliolithus riedeli* BRAMLETTE & SULLIVAN until the first occurrence of *Discoaster multiradiatus* BRAMLETTE & RIEDEL. This zone is well-developed in the Tarawan Chalk of the Gebel Duwi and it is absent in the Tarbouli section. The common nannoplankton species of this zone are: *Heliolithus riedeli* BRAMLETTE & SULLIVAN, *Discoaster delicatus* BRAMLETTE & SULLIVAN, *Discoaster limbatus* BRAMLETTE & SULLIVAN and *Discoaster helianthus* BRAMLETTE & SULLIVAN.

Though the above-mentioned nannoplankton zonation is preliminary, the author ventures to conclude, that the lithostratigraphic units assigned to the Upper Cretaceous-Lower Tertiary of the Gulf of Suez region and the Red Sea coast become younger toward the south. This conclusion is clearly proved by the nannoplankton content of the Tarawan Chalk rock unit, being of Upper Maastrichtian in the north at Gebel Tarbouli and of Lower Landenian in the south at Gebel Duwi. This result is also confirmed in other parts of Egypt by authors working on foraminifera (e. g. SAID [1961]; SHAFIK [1968], Msc. THESIS).

7. Global correlation and results obtained

Among the calcareous nannoplankton zones of New Zealand given by EDWARDS (1970), is the *Nephrolites frequens* zone, which according to him is of Maastrichtian age. Unfortunately, this zone, as shown in his table, lies vertically between unsuitable facies. The *Nephrolithus frequens* zone was found well developed in the Russian material, while no single specimen of this species could be found in the Egyptian samples. These results are found to be in harmony with the findings of MARTINI (1970), who pointed out that the two of the latest Maastrichtian nannofossil index species, *Tetralithus murus* and *Nephrolithus frequens*, are climatically restricted. *N. frequens* occurs towards the poles, its vertical range is reduced towards the equator. Contrarily *T. murus* occurs towards the equator, its stratigraphic range is diminishing towards the higher latitudes. Therefore, it seems, that the Russian locality falls geographically within the *N. frequens* domains, while the Egyptian section lies within the low latitude region of *T. murus*.

It is worthy to mention, that in most of the Maastrichtian samples of Austria the *N. frequens* is missing, however, it is found frequently reworked in the Paleocene of Reingruberhöhe (Lower Austria). It might be concluded that *Nephrolithus frequens* was probably occuring in the latitude of Austria too.

The oldest known species of the genus *Pontosphaera* was found by KAMPTNER (1963) in the Eocene (Pacific ocean). However one species of this genus ist recorded by the present authors in the Upper Maastrichtian of the Gulf of Suez Region, Egypt, by use of the electron microscope. Moreover, checking the same sample by the light microscope reveals again this genus being represented by one species (Pontosphaera multicarinata [GARTNER] nov. comb.). Therefore it could be concluded, that *Pontosphaera* may have its first occurrence at least in the Upper Maastrichtian.

BUKRY (1970) established the *Zygodiscus macleodae* zone from the Lower Campanian of Texas. He did not find this species in his overlying *Prediscosphaera germanica* zone. Therefore and owing to the apparent differences between these two zones, he concluded, that there is an unstudied interval inbetween his two zones, not represented in his samples. In the Egyptian Maastrichtian *Zygodiscus tarboulensis* nov. spec. could be discovered, which is a close relative to the abovementioned *Z. macleodae* BUKRY.

Though a gradational contact is observed by the author between the Tarawan Chalk and the overlying Esna Shale at the Gebel Tarbouli, thus suggesting a continuous sedimentation, by means of the nannofossils a hiatus along this contact is indicated. This hiatus represents the missing of the entire Danian and most of the Landenian, therefore, indicating a great interruption in sedimentation. This disconformity may explain the unusually reduced thickness of the Esna Shale rock unit (10 m.) at the Gebel Tarbouli.

The electron transmission microscope investigation of the Egyptian coccoliths dealt with in this study shows, that they had suffered some sort of dissolution or corrosion, while the Russian coccoliths seem to be somewhat recrystalised. However it is not impossible to compare both the Egyptian and the Russian coccoliths, though they show extremes as to the state of their preservation. Many coccolith species are common to the Egyptian and the Russian materials. This indicates that the two localities are easily correlated by means of their coccolith contents, regardless their wide geographic separation.

8. Special taxonomic problems

The taxonomy of the coccolithophoridae seems to be in a state of confusion. It is well known that the systematic classification of the coccolithophoridae is based mainly on the structure and the morphology of the hard parts (coccoliths). Therefore, a detailed study of the structure of the coccoliths is necessary. However, inspite of the fact that the analysis of the ultrastructures of the coccoliths is beyond the resolution power of the light microscope, many workers have utilized the light microscope in their study and description of the coccoliths. On the other hand, other workers have made use of the much higher degree of resolution of the electron microscope. It is quite clear that the results obtained by these two groups of workers are not easily to be compared. PERCH-NIELSEN (1967) introduced a method by which the same coccolith can be studied using a light microscope and subsequently by an electron microscope. Unfortunately, this method has not gained much support among most of the workers yet.

The lack of a continuous contact between the numerous workers in the different countries increases the difficulties met with in classifying the coccolithophoridae systematically.

The coccolithophoridae possess some of the characters of both plants and animals. Botanical and zoological nomenclature have been used with almost equal frequency for the coccoliths by different scientists. LOEBLICH & TAPPAN (1966) in their "Annotated index and bibliography of the calcareous nannoplankton" have solved many of the objective nomenclatural problems.

The coccolith dimorphism could be also a problem in the systematics of the coccolithophoridae. One form possesses two types of coccoliths on one cell (e. g. *Acanthoica*); when found as fossils, these would be given two different names. More work should be done by the neontologists on the coccolith morphology, the coccolith dimorphism and the life cycles of the living representatives of the coccolithophoridae.

A given coccolith has a different structural pattern in the distal and proximal view. In the electron microscope study the erection of a new genus or species is based often on the description of only one view of a coccolith. In some cases both the distal and the proximal view of the same coccolith have been described by different authors as two different species or even genera. This could be avoided firstly by studying the coccolith in a liquid medium (silicone oil) using the light microscope to recognise its two views, and then using the method given by PERCH-NIELSEN (1967) for studying the same coccolith, using the light microscope followed by the electron microscope for the two views of the coccolith.

The left-right reversed microphotographs of the nannofossils given by a few workers, could also add to the confusion as to the recognition of the nannofossils and hence their systematics.

9. Systematic Paleontology

A detailed description of all coccoliths and discoasters found in the Maastrichtian and Paleogene of Egypt would go beyond the scope of this paper, which as the result of the authors' part-time occupation with these samples during the 1969/70 UNESCO Postgraduate Training Course on Geology can only be considered as an initial study, no more.

The following short comments and the selected synonymy therefore are rather fragmentary: a small plattform only for continued future work on these sections, on a broader scale, as we hope; and maybe some help for those of our younger colleagues, who just start working on similar samples.

Ahmuellerella octoradiata (GORKA) REINHARDT

(Plate 23, fig. 1—4)

1957 GORKA, p. 259, pl. 4, fig. 10. *Discolithus octoradiatus.*
1964 REINHARDT, p. 751, pl. 2, fig. 6. *Ahmuellerella limbitenuis.*
1967 REINHARDT, p. 166, Abb. 1, Abb. 7: 1, 2, 3. *Ahmuellerella octoradiata.*
1969 BUKRY, p. 58, pl. 33, figs. 5—7. *Vagalapilla octoradiata.*

Comments: Biserial crossbars, which are diverging along the median suture from the centre to the rim.

Central cross not in all specimens exactly in axial direction.

Closely related to the species of the genera *Vekshinella* and *Reinhardtites.*

Arkhangelskiella cymbiformis VEKSHINA

(Plate 5—7)

1912 ARKHANGELSKY, pl. 6, fig. 24. *Coccolith of uncertain affinity.*
1959 VEKSHINA, p. 66, pl. 2, figs. 3 a, 3 b.
1963 STRADNER, p. 170, pl. 1, figs. 4 a, 4 b.
1965 REINHARDT, p. 31, pl. 2, fig. 6.
1966 REINHARDT, p. 31, pl. 6, figs. 1—3; pl. 22, figs. 14—19.
1969 BUKRY, p. 21, pl. 1, figs. 1—3.

Comments: Distal and proximal shield subdivided by a marginal groove into two tiers each (see pl. 6, fig. 2). Central area with axial sutures on the distal side and axial plus diagonal sutures on the proximal side. Perforations of central area sometimes transversed by a septum (pl. 5, fig. 3).

Central area more subject to recrystallisation than the shields.

Biscutum constans (GORKA) BLACK

(Plate 2)

1957 GORKA, p. 279, pl. 4, fig. 7. *Discolithus constans.*
1967 BLACK, p. 139.
1968 PERCH-NIELSEN, p. 78, pl. 27, figs. 1—11, text-fig. 39.

Comments: Those elements of the distal and the proximal shield, which lie in direction of the main axis of the elliptical shields, are wider than those lying in direction of the transverse axis.

Centre of proximal side with granulae, which could be proximal ends of wall elements lining the crater of the distal side.

Crooked sutures of the distal shield suggest the existence of an intermediary crystal-ring.

Biscutum testudinarium BLACK

(Plate 3, figs. 1, 2; plate 4, fig. 1)

1959 BLACK, in BLACK & BARNES, p. 325, pl. 10, fig. 1.
1966 REINHARDT, p. 30, pl. 19, fig. 1.
1968 STRADNER, in STRADNER, ADAMIKER & MARESCH, p. 29, pls. 11—12.
1969 BUKRY, p. 28, pl. 8, figs. 7—12.

Comments: Coccoliths circular or subcircular, with shield elements of almost identical width. An internal view of a fragmentary coccosphere (pl. 4, fig. 1) shows the overlapping of adjacent coccoliths. The number of coccoliths in a coccosphere seems to exceed 24.

Corollithion exiguum STRADNER

(Plate 46, figs. 1—4)

1961 STRADNER, p. 83, text-figs. 58—61.
1964 BRAMLETTE & MARTINI, p. 308, pl. 5, figs. 8, 9.
1966 MARESCH, p. 381, pl. 3, fig. 4.
1968 GARTNER, p. 35, pl. 10, fig. 26.
1969 BUKRY, p. 40—41, pl. 18, fig. 12; pl. 19, fig. 1.

Comments: Rim consisting of imbricating crystal plates, which are aligned along the hexagonal outline of the rim and are slightly slanted. Central sixrayed structure with or without knob.

Corollithion rhombicum (STRADNER & ADAMIKER) BUKRY

(Plate 47, fig. 3)

1966 STRADNER & ADAMIKER, p. 339, pl. 2, fig. 1, text-figs. 5—7. *Zygolithus rhombicus.*
1969 BUKRY, p. 41, pl. 19, figs. 2—4.

Comments: Only a single specimen of this species was found in the Upper Maastrichtian Chalk of Tarbouli section, Egypt. *C. rhombicum* was not met with in the Russian material studied.

Cribrosphaera laughtoni (Black) Bukry

(Plate 30, figs. 1—4; plate 31, figs. 1—4)

1964 Black, p. 313 pl. 53, figs. 1, 2. *Favocentrum laughtoni.*
1969 Bukry, p. 45, pl. 23, figs. 1—9.

Comments: This species differs from the rather similar *Cribrosphaera ehrenbergi* Arkhangelskii by "the absence of a regular set of throughgoing perforations" (Bukry). In the USSR material intermediate forms with some pores between the crystal triplets could be found (pl. 30). Secondary crystal growth might account for the closing of the pores in some materials.

Cribrosphaera numerosa (Gorka) Reinhardt & Gorka

(Plate 32, figs. 1, 2)

1957 Gorka, p. 257, pl. 4, fig. 5. *Discolithus numerosus.*
1967 Reinhardt & Gorka, p. 243, pl. 33, fig. 2, text-fig. 1.

Comments: Central area perforated by hexagonal pores between a grid of crystaltriplets. The arrangement of pores and crystal structures is in quincunx pattern.

Found in the Tarbouli Chalk, Egypt, where nannofossils are not overcalcified.

Cylindralithus serratus Bramlette & Martini

(Plate 45, figs. 1—4)

1964 Bramlette & Martini, p. 310, pl. 5, figs. 18—20.
1966 Stover, p. 141, pl. 4, figs. 31—33. *C. crassus.*
1968 Gartner, p. 47, pl. 10, fig. 9.
1969 Bukry, p. 43, pl. 20, figs. 11, 12.

Comments: In axial view two rings with different diameters can be discerned, one having the crystal elements inclined clockwise, the other counter-clockwise (pl. 45, fig. 1). One specimen (pl. 45, fig. 2), which is tentatively assigned here, has something like a reticulate membrane filling the central window. Not present in USSR material, but found in Tarbouli, Egypt.

Eiffellithus anceps (Gorka) Reinhardt & Gorka

(Plate 44, figs. 1—4)

1957 Gorka, p. 252, pl. 3, fig. 4. *Discolithus anceps.*
1965 Reinhardt, p. 38, pl. 8, fig. 2; pl. 11, fig. 3 a, b, text-fig. 19. *Eiffellithus turriseiffeli inturratus.*
1967 Reinhardt & Gorka, p. 251, pl. 31, figs. 15, 16, text-fig. 6.

Comments: Elliptical rim composed of up to 70 dextrally imbricate elements. Inner cycle consisting of heavy blocks, which are readily recrystallized (compare pl. 42, fig. 1 and fig. 3).

X-shaped crossbars composed of two elements of equal size.

Eiffellithus trabeculatus (GORKA) REINHARDT & GORKA

(Plate 43, fig. 2)

1957 GORKA, p. 255, pl. 3, fig. 9. *Discolithus trabeculatus.*
1966 REINHARDT, p. 39, pl. 19, fig. 2. *Eiffellithus testaceus.*
1966 STOVER, p. 142, pl. 2, figs. 11, 12. *Discolithus disgregatus.*
1969 BUKRY, p. 49, pl. 27, figs. 1—4. *Chiastozygus disgregatus.*

Comments: Elliptical rim composed of up to 40 dextrally imbricate elements. Two of the diagonal crossbars do not meet at the centre, but are offset. The inner cycle of rim elements is flat and lining the inner wall of the rim.

Kamptnerius magnificus DEFLANDRE

(Plate 8—10, 11, fig. 1)

1959 DEFLANDRE, p. 135, pl. 1, figs. 1—4.
1968 GARTNER, p. 39, pl. 2, figs. 1—2.
1968 PERCH-NIELSEN, p. 41, pl. 6, figs. 1—3, 5.
1969 BUKRY, p. 25, pl. 5, figs. 7—9.

Comments: Large elliptical coccoliths with flaring asymmetric outer rim, a derivate of the distal shield. The width of the flange is rather variable, as shown by pl. 8, fig. 1 and pl. 11, fig. 1. The proximal side of the central area is subdivided by a double ridge of crystals along the main axis. In some specimens the central area is open, the elongate slot lying in the direction of main axis (pl. 9).

Kamptnerius percivalii BUKRY

(Plate 11, fig. 2)

1969 BUKRY, p. 25, pl. 6, figs. 1—3.

Comments: Only poorly preserved specimen encountered. The arrangement of the pores in the central area corresponds to *K. percivalii* rather than to *K. punctatus*.

Lithraphidites quadratus BRAMLETTE & MARTINI

(Plate 49)

1964 BRAMLETTE & MARTINI, p. 310, pl. 6, figs. 16—17; pl. 7, fig. 8.
1968 GARTNER, p. 43, pl. 2, fig. 3; pl. 3, fig. 3; pl. 5, figs. 1, 2; pl. 6, fig. 9.

Comments: Similar to *L. grossopectinatus* BUKRY the four keels consist of two closely appressed lamellae. As indicated by GARTNER the four keels may differ in their dimensions (pl. 49, fig. 1).

Markalius inversus (DEFLANDRE) BRAMLETTE & MARTINI

(Plate 3, figs. 3, 4)

1954 DEFLANDRE, in DEFLANDRE & FERT, p. 150, pl. 9, figs. 4—5. *Cyclococcolithus leptoporus var. inversus.*
1964 BRAMLETTE & MARTINI, p. 302, pl. 2, figs. 4—9.
1968 PERCH-NIELSEN, p. 72, pl. 24, figs. 1—8; pl. 25, fig. 1.

Comments: Circular coccoliths with 2 shields consisting of about 30 elements. The inner part of the deep crater of the distal side is lined with flat crystal plates in conical arrangement.

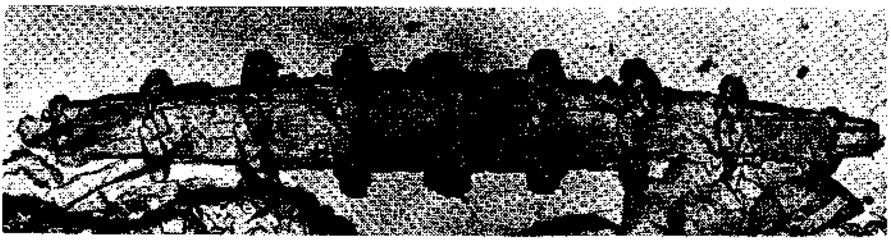

Fig. 3: *Microhabdulus belgicus* HAY. Magnification appr. × 12.500. Gebel Tarbouli, Egypt.

Microhabdulus belgicus HAY

(Text-fig. 3)

1963 HAY, p. 95, p. 95, pl. 1.
1963 DEFLANDRE, p. 3486, figs. 12—18. *M. margaritatus.*
1963 STRADNER, p. 11, pl. 4, fig. 13. *M. nodosus.*
1968 GARTNER, p. 44, pl. 6, fig. 13.
1969 BUKRY, p. 66, pl. 39, figs. 9—11.

Comments: Elongate rod, tapering on both ends, with evenly spaced cycles of subrhomboidal nodes.

The rare specimen from Tarbouli, Egypt, has both ends intact.

Micula staurophora (GARDET) STRADNER

(Plate 50)

1955 GARDET, p. 534, pl. 10, fig. 96. *Discoaster staurophorus.*
1959 VEKSHINA, p. 71, pl. 1, fig. 6. *Micula decussata.*
1963 STRADNER, p. 8, fig. 12 a—c. *Micula staurophora.*
1964 BRAMLETTE & MARTINI, p. 318, pl. 6, figs. 7—11.
1968 GARTNER, p. 47, pl. 2, figs. 5—8; pl. 4, fig. 18; pl. 9, figs. 18—20; etc. *M. decussata.*
1969 BUKRY, p. 67, pl. 40, figs. 5—6. *M. decussata.*

Comments: Six-sided cubes with concave faces. When well preserved and after suitable metal-shadowing the concave craters reveal some ultrastructural details. Only one size of microcrystals is used to build up the entire fossil, thus indicating that Micula might be a "holoccolith" (?).

In older literature only one half of *Micula* was shown, due to difficulties in interpreting its real structure with the light microscope.

Nephrolithus frequens GORKA

(Plate 28, 29)

1957 GORKA, p. 263, pl. 5, fig. 7.
1968 PERCH-NIELSEN, p. 56, pl. 7, figs. 12—14; pl. 18, figs. 1—9.
1970 MARTINI, pp. 1242—1243.

Comments: Coccoliths kidney-shaped. Very small specimes are elliptical (pl. 29, fig. 1). The central area is filled with from 2 to 15 rings of granulae with a throughgoing pore.

In agreement with MARTINI's regional distribution charts *N. frequens* was found only in the high latitude USSR material and not in the low latitude Egyptian samples.

Podorhabdus dietzmanni (REINHARDT) REINHARDT

(Plate 17)

1965 REINHARDT, p. 30, pl. 1, fig. 1. *Ahmuellerella dietzmanni.*
1967 REINHARDT, p. 169, fig. 4.
1969 BUKRY, p. 37, pl. 16, figs. 1—3.

Comments: Rim composed of a proximal and an overlapping distal shield. Wide central area spanned by an elongate hexagonal structure, which leaves open four large perforations — one in each quadrant — and extends into a hollow central tube. In both speciments of pl. 17 the central tube is broken off.

Podorhabdus granulatus (REINHARDT) BUKRY

(Plate 16)

1965 REINHARDT, p. 39, pl. 3, fig. 2. *Ahmuellerella? granulata.*
1966 REINHARDT, p. 27, pl. 8, fig. 1. *Cretarhabdus? granulatus.*
1969 BUKRY, p. 37, pl. 16, figs. 4—6.

Comments: Elliptical bilamellar rim. Intermediate crystalring of distal side very narrow. Central area spanned by an diagonal cross composed of many small elongate crystal elements. Openings in direction of the longer main axis wider than those along the shorter axis. Hollow central tube.

Polypodorhabdus crenulatus (BRAMLETTE & MARTINI) PERCH-NIELSEN

(Plate 12, 13)

1964 BRAMLETTE & MARTINI, p. 306, pl. 2, figs. 21—24. *Cretarhabdus crenulatus.*
1968 PERCH-NIELSEN, p. 48, pl. 11, figs. 2—5.

Comments: Assuming a wide variety among this species also those specimen with only a faintly indicated axial cross and those with a pronounced cross were included here. Appearance in light-microscope of "*crenulatus*" type: with crenulated margin of central area.

Polypodorhabdus pienaari nov. spec.

(Plate 14, figs. 1—4, text-fig. 4)

1969 PIENAAR, p. 92, pl. 8, fig. 8. *Cretarhabdus decorus.*
non
1954 DEFLANDRE, in DEFLANDRE & FERT, p. p. 45, pl. 13, figs. 4—6, text fig. 87.
non
1964 BRAMLETTE & MARTINI, p. 300, pl. 3, figs. 9—12.

New Description: Elliptical coccoliths with bilamellar rim and a wide central area spanned by a complicated symmetric structure, which according to PIENAAR, is described as follows: "Two parallel bars originate halfway down the longitudinal and transverse arms of the cross and are attached to the distal shield. From each of these bars two further bars develop opposite each other. These small bars fuse resulting in 4 pores in each quadrant.".

The central stalk was not found to be hollow, but compact and quadrangular in cross-station.

Holotype: EM no. 1395, Pl. 14, fig. 4.

Paratypes: EM no. 1119 u. 1467, Pl. 14, figs. 1 u. 3.

Type-locality: Gebel Tarbouli, Egypt, Stat. Nr. 6.

Type-level: Upper Maastrichtian.

Comments: Differential diagnosis: *Polypodorhabdus pienaari* does not have a hollow stem as indicated by microphotographs showing *C. decorus* in side view (see DEFLANDRE, BRAMLETTE & MARTINI, and PIENAAR, pl. 11, fig. 8). All available electronmicrographs give evidence of a compact stalk. Therefore a distinction from *Cretarhabdus decorus* seems justified.

Derivatio nominis: This new species is dedicated to Richard N. PIENAAR, University of Natal, Durban, S. A., who published the first picture of this species in 1968.

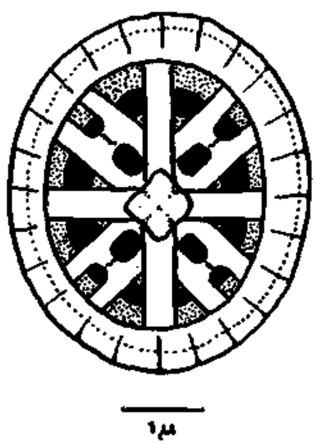

Fig. 4: *Polypodorhabdus pienaari* nov. spec. Schematized drawing of distal side; magnification appr. × 11.000. Gebel Tarbouli, Egypt.

Polypodorhabdus schizobrachiatus (GARTNER) nov. comb.

(Plate 15, figs. 1—3)

1968 GARTNER, p. 31, pl. 13, figs. 10—11; pl. 20, fig. 5. *Vekshinella schizobrachiata.*
1969 BUKRY, p. 36, pl. 15, figs. 4—6. *Cretarhabdus schizobrachiatus.*

Comments: Bilamellar coccoliths with distal and proximal shield. According to the emended generic diagnosis of the genus *Cretarhabdus* given by PERCH-NIELSEN in 1968, p. 51, that genus is reserved to coccoliths with the central area composed of many small granulae. Therefore we suggest a transfer of this species here into the genus *Polypodorhabdus* NOEL, the genus Podorhabdus NOEL being restricted to species with four pericentral openings only.

Pontosphaera multicarinata (GARTNER) nov. comb.

(Plate 48, figs. 2, 3)

1968 GARTNER, p. 41, pl. 7, figs. 10, 11. *Prolatipatella multicarinata.*

Comments: The only genuine "*Pontosphaera*" occurring in the Upper Cretaceous was registred by GARTNER in 1968 first. His description was based on lightmicroscopic pictures of this rare species. In the Gebel Tarbouli sample it is not so rare, so that also one electronmicrograph could be accomplished, showing the typical spiral microcrystal arrangement of the distal side. No indication of a multitier rim was found in the specimes from Egypt.

Prediscosphaera cretacea (ARKHANGELSKY) GARTNER

(Plate 18, 19)

1912 ARKHANGELSKY, p. 410, pl. 6, fig. 12. *Coccolithophora cretacea.*
1952 DEFLANDRE, p. 463, fig. 300 D. *Coccolithus cretaceus.*
1964 BRAMLETTE & MARTINI, p. 310, pl. 2, figs. 11—12. *Deflandrius cretaceus.*
1959 VEKSHINA, p. 73, pl. 1, figs. 8, 9. *Prediscosphaera decorata.*
1968 GARTNER, p. 19, pl. 2, figs. 10—14; pl. 3, fig. 8; pl. 4, figs. 19—24; pl. 6, figs. 14—15 etc.
1969 BUKRY, p. 38, pl. 16, fig. 12; pl. 17, figs. 1—6. *P. cretacea cretacea.*

Comments: According to BUKRY the diagnostic differences of this species in regard to the following species of *Prediscosphaera* are the interlocking sutures of the distal rim, the diagonal x-shaped crossbars and the sinistral rotation of the second internal set of crossbars.

Prediscosphaera honjo BUKRY

(Plate 22, figs. 2—4)

1969 BUKRY, p. 39, pl. 18, figs. 4—6.
1968 PERCH-NIELSEN, pl. 16, fig. 11. *Deflandrius stoveri* (pro parte).

Comments: This species differs from *P. stoveri* by the dimension of the inner cycle, which is not overlapping the distal rim, but is inserted into it and slightly depressed (pl. 22, fig. 2). Central cross in axial direction.

Also the specimen in PERCH-NIELSEN plate 16, fig. 11 (*Deflandrius stoveri*, Paratype) can be included here.

Prediscosphaera spinosa (BRAMLETTE & MARTINI) GARTNER

(Plate 20, figs. 1—4)

1964 BRAMLETTE & MARTINI, p. 301, pl. 2, figs. 17—20. *Deflandrius spinosus.*
1968 GARTNER, p. 20, pl. 1, figs. 15—16; pl. 3, figs. 9—10; pl. 5, figs. 7—9; pl. 6, fig. 16; pl. 11, fig. 17.
1969 BUKRY, p. 40, pl. 18, figs. 7—9.

Comments: Characteristic of this species are the delicate spines at the top of the stem (often altogether missing). The basal plate consists of two elliptical rims, die distal one with sutures straight and less complicated than in *P. cretacea.* The crossbars are almost in axial direction and almost completely united with the second set of crossbars.

Prediscosphaera stoveri (PERCH-NIELSEN) nov. comb.

(Plate 22, fig. 1)

1968 PERCH-NIELSEN, p. 66, pl. 16, fig. 13 (Holotype). *Deflandrius stoveri.*
1969 BUKRY, p. 39, pl. 18, figs. 1—3. *Prediscosphaera germanica.*

Comments: This species is easily recognized by the distinctive inner cycle of crystal rods, which extend onto the distal side of the distal rim. Crossbars in axial direction. The new combination is required by the priority of the description given by PERCH-NIELSEN.

Rhabdolithina splendens (DEFLANDRE) REINHARDT

(Plate 32, figs. 3, 4)

1953 DEFLANDRE, p. 1786, text-figs. 4—6. *Rhabdolithus splendens.*
1966 REINHARDT, p. 167.
1968 STRADNER, ADAMIKER & MARESCH, p. 32, pl. 21—23.

Comments: Central area filled with tightly packed crystal triplets. Central stem hollow, built of elongate crystal laths in spiral arrangment.

Rhagodiscus plebeius PERCH-NIELSEN

(Plate 26, figs. 2—4; plate 27, figs. 1, 2, 4)

1968 PERCH-NIELSEN, p. 44, pl. 7, figs. 2—6.

Comments: Rim composed of imbricated plates in "*zygodiscus*"-style. Central area filled with a granulated conical structure, which is perforated in the centre.

Reinhardtites mirabilis PERCH-NIELSEN

(Plate 24, 25)

1968 PERCH-NIELSEN, p. 40, pl. 7, fig. 1, text-fig. 15.

Comments: Simple rim of socalled "*zygodiscus*"-style, with central area spanned by an unperforated cone-shaped structure consisting of 8 imbricating double rows of crystalplates. Thus in distal view 8 ridges ascending in radial direction unite to form a central stem. The sloping of these ridges is clockwise, their overlapping counterclockwise.

Stephanolithion laffitei NOEL

(Plate 47, fig. 2)

1956 NOEL, p. 318, pl. 2, fig. 5.
1968 STRADNER, ADAMIKER & MARESCH, p. 41—42, pls. 40, 41.
1969 BUKRY, p. 43—44, pl. 21, figs. 7—11.

Comments: One typical specimen with 8 radial arms and the typical *Stephanolithion* processes was found in the Gebel Tarbouli material.

Vekshinella aachena BUKRY

(Plate 40, figs. 2, 3)

1969 BUKRY, pl. 55, pl. 31, figs. 1—6.

Comments: Ends of central cross widely flaring. Cross in axial direction, without central stem.

Vekshinella cruciata (NOEL) nov. comb.

(Plate 40, figs. 1, 4)

1958 NOEL, p. 162, pl. 1, fig. 3. *Discolithus cruriatus.*
1965 REINHARDT, p. 39, pl. 3, fig. 3. *Staurolithites cruciatus.*
1968 PERCH-NIELSEN, p. 26, pl. 2, fig. 6. *St. cruciatus.*

Comments: Central cross slightly shifted counterclockwise from the direction of the main axes, especially the shorter crossbar. The ends of the crossbars are flaring.

Vekshinella crux (DEFLANDRE & FERT) nov. comb.

(Plate 39)

1952 DEFLANDRE & FERT, p. 2101, text-fig. 8.
1954 DEFLANDRE & FERT, p. 143, pl. 14, fig. 4, text-fig. 55. *Discolithus crux.*
1961 BRAMLETTE & SULLIVAN, p. 149, pl. 6, figs. 8—10. *Zygolithus crux.*
1965 REINHARDT, p. 39, pl. 3, fig. 3. *Staurolithites bochotnicae.*
1968 STRADNER, ADAMIKER & MARESCH, p. 36 pls. 28—30. *Zygolithus crux.*

Comments: The genero-type of the genus *Zygolithus* KAMPTNER is *Zygolithus dubius*, which by BLACK 1967 was transferred into the genus *Neococcolithes* SUJKOWSKY, which only contains Tertiary species. "*Zygoliths* with an axial cross" found in Mesozoic deposits were put into the genus *Vekshinella* by LOEBLICH & TAPPAN 1963.

Vekshinella elliptica GARTNER

(Plate 38, figs. 1—4)

1969 GARTNER, p. 30, pl. 25, fig. 26; pl. 17, fig. 5.

Comments: Central structure rhombical, somewhat similar to that of *Discolithus quadriarcullus* NOEL (1965, p. 74, fig. 7), from which it differs by a round or rhombical central perforation.

Watznaueria barnese (BLACK) PERCH-NIELSEN

(Plate 1, figs. 1—5)

1959 BLACK & BARNES, p. 325, pl. 9, figs. 1, 2. *Tremalithus barnesae.*
1964 REINHARDT, p. 753, pl. 2, fig. 2, text-fig. 4.
1968 PERCH-NIELSEN, p. 68, pl. 22, figs. 1—7; pl. 23, figs. 1, 4, 5, 6,text-fig. 32.

Comments: Most common of all cretaceous coccoliths. Its ultrastructure is easily reduced by recrystallization or corrosion.

One of the most prolific rockforming fossil species of the world!

Zygodiscus acanthus (REINHARDT) REINHARDT

(Plate 36, figs. 1—4)

1965 REINHARDT, p. 37, pl. 3, fig. 1. *Zeugrhabdotus acanthus.*
1966 REINHARDT, p. 40, pl. 15, fig. 5; pl. 23, fig. 8.
1969 BUKRY, p. 58, pl. 33, figs. 8—9.

Comments: Rim consisting of an outer dextrally imbricate cycle with radial sutures and an inner cycle with strongly dextrally inclined crystals. Transversal bridge with stem.

Zygodiscus spiralis BRAMLETTE & MARTINI

(Plate 33, figs. 1—4)

1964 BRAMLETTE & MARTINI, p. 303, pl. 4, figs. 6—8.
1968 GARTNER, p. 35, pl. 5, figs. 21; pl. 7, fig. 3.
1969 BUKRY, p. 61, pl. 36, figs. 1, 2. *Zygodiscus* sp. aff. *Z. sigmoides.*

Comments: According to GARTNER a radiant arrangement of the rim elements is characteristic. Transversal bridge constructed of several rods, with transversal groove on the proximal side.

Zygodiscus sisyphus GARTNER

(Plate 34, figs. 1—4)

1968 GARTNER, p. 34, pl. 25, fig. 22; pl. 14, fig. 19.
1969 BUKRY, p. 61, pl. 36, figs. 3, 4.

Comments: Elliptical "*zygodiscs*" with dextrally imbricating rim elements and slanted sutures. Central bridge broader than in *Z. spiralis.*

Zygodiscus tarboulensis nov. spec.

(Plate 37, figs. 1—3, 4, text-fig. 5)

Holotype: EM no. 1135 (fig. 2); paratypes: EM no. 443, EM no. 1147 (figs. 1, 3).

Type locality: Gebel Tarbouli, Egypt, Stat. no. 7—1.

Stratum typicum: Upper Maastrichtian.

Original description: Elliptical "zygodisc" with smooth or slightly serrate rim consisting of 30—50 dextrally imbricated elements. The central area is bridged by three elements: one transversal low bridge, from which

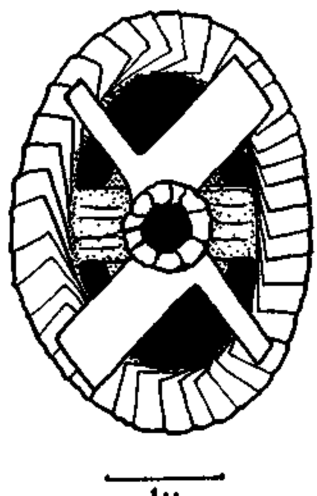

Fig. 5: *Zygodiscus tarboulensis* nov. spec. Schematized drawing of the distal side; magnification appr. × 15.000. Gebel Tarbouli, Egypt.

rises a hollow stem, and two angular structures with arms of different width. These angles support the central stem with their corners and embrace less than 90 degrees. They are not symmetrical, but identical after rotation of 180 degrees. Lines bisecting the angles bypass the central stem and run about parallel to the main axis of the elliptical rim. There are six windows with notches towards the centre, two large ones und four small ones. Also inversed specimen occur (pl. 37, fig. 4).

Comments: *Zygodiscus tarboulensis* is closely related to *Zygodiscus macleodae* BUKRY, from which it differs by the asymmetrical arrangement of the central structure and by the sharp notches of the framed perforations.

Derivatio nominis: Discovered in a sample from the Gebel *Tarbouli*, Egypt.

Zygodiscus theta (Black) Bukry

(Plate 35, figs. 1, 2)

1959 Black & Barnes, p. 327, pl. 12, fig. 1. *Discolithus theta.*
1969 Bukry, p. 62, pl. 36, figs. 7, 8.

Comments: Rim and bridge of this species are more slender than in *Z. sisyphus.* It differs from *Z. acanthus* by the lack of the inner crystal cycle (compare pl. 36).

Zygolithus cf. diplogrammus Deflandre

(Plate 35, fig. 4)

1954 Deflandre, in Deflandre & Fert, p. 148, pl. 10, fig. 7, text-fig. 57.
1968 Stradner, Adamiker & Maresch, p. 35, pl. 27, fig. 1.

Comments: The single specimen with the partly developed double bridge, which is tentatively included here also might have grown out into an other species with compact transversal bridge (?).

Zygolithus erectus Deflandre

(Plate 35, fig. 3)

1954 Deflandre, in Deflandre & Fert, p. 150, pl. 15, figs. 14—17, text-figs. 60—62.
1968 Stradner, Adamiker & Maresch, p. 34, pl. 25 and 26, figs. 1, 2.
1968 Perch-Nielsen, p. 21.

Comments: Elliptical rim composed of dextrally imbricated crystal elements. Transversal bridge of equal width, with central knob.

Possibly *Zygosdicus sisyphus* can be annexed to this species, as closest relative.

Zygolithus litterarius (Gorka) Reinhardt & Gorka

(Plate 41, fig. 1—4)

1957 Gorka, p. 251, pl. 3, fig. 3. *Discolithus litterarius.*
1967 Reinhardt & Gorka, p. 249, pl. 33, fig. 7, text-fig. 4.
1968 Stradner, Adamiker & Maresch, p. 39, pl. 34.

Comments: *Zygolithus litterarius* is distinguishable from other similar forms with x-shaped diagonal central structure by its rim, which consists of one layer of dextrally crystals plates mainly (distal view). The proximal side (pl. 41, fig. 4) may show a complicated bottom plate.

Appendix

The following newly-described Marthasterites does not come from the Maastrichtian, but from the *Paleocene* of Egypt!

Marthasterites spineus nov. spec.

(Text-figures 6 and 7 a—d)

Derivatio nominis: spineus = lat. "with spines".

Holotype: Prep. Ash/63/A (fig. 7 b, c).

Stratum typicum: Paleocene.

Locus typicus: Ash El-Mellaha range, Western Red Sea Coast, Egypt (Esna shale).

Diagnosis: An ortholithic nannofossil consisting of a pair of triradiate stars, which are united at their centre and shifted by 60 degrees to give the appearence of a regular sixradiate star with arms alternating at different focus. The arms wear spines directed towards each other at about the middle of their free length.

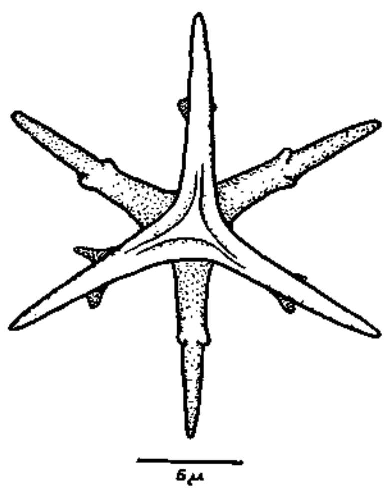

Fig. 6: *Marthasterites spineus* nov. spec. Schematized drawing; magnification app. × 3000. Ash El-Mellaha range, Western Red Sea Coast, Egypt.

Comments: A species of Marthasterites, which in its general appearance is similar to *M. reginus*, from which it differs however by the following features:

a) The spine-like bifurcation of the six free arms is not at their ends, but at about half of their free length and not very regular. Their is mostly only one spine, sometimes there are two.

b) the curving of the arms is very slight, the coiling is reversed as compared to *M. reginus*.

c) the ornamentation of the central field consists of three ridges, which are uniting at the centre enclosing angles of 120 degrees. These ridges are in the same direction as the arms and not shifted 60 degrees as in *M. reginus*.

Fig. 7: *Marthasterites spineus* nov. spec.; different specimens in axial view and in side view. Holotype from Prep. Ash 63/a at higher focus (fig. b) and at lower focus (fig. c). Sample: Ash El-Mellaha range, Esna shale, Western Red Sea Coast, Egypt.

10. Conclusions

The results reached by the authors in this study are presented in brief in the following.

1. A nannoplankton zonation is recognised for the uppermost Cretaceous and the early Tertiary of the Gulf of Suez region and the Red Sea coast, Egypt. The biozones met with are:

top a) *Discoaster binodosus* zone
b) *Marthasterites contortus* zone
c) *Marthasterites spineus* zone
d) *Discoaster multiradiatus* zone
e) *Heliolithus riedeli* zone

2. The lithostratigraphic units assigned to the Upper Cretaceous-Lower Tertiary exposed along the western side of the Gulf of Suez and the Red Sea are proved here to become younger toward the south. This is well demonstrated by the Tarawan Chalk rock unit: while it has a nannoplankton assemblage typical for the Upper Maastrichtian in the north at Gebel Tarbouli, its nannofossil content in the south at Gebel Duwi gives a Lower Landenian age.

3. A hiatus is recorded and represents the missing of the whole Danian and most of the Landenian in Gebel Tarbouli at the contact between the Tarawan Chalk and the Esna Shale, though field observations of this contact suggest that the sedimentation was unintermittent. This break in Sedimentation may explain the reduced thickness of the Esna Shale (10 m.) at the Gebel Tarbouli.

4. A list of the nannoplankton species of the Tarawan Chalk of Gebel Tarbouli is given together with a documentation of their microphotographs in addition to those of the Russian material (plates 1 to 50).

5. It is found that the Russian and the Egyptian Upper Maastrichtian could be easily correlated by means of their coccolith contents, in spite of the wide geographical separation of the two localities.

6. It has been established that the Egyptian section Gebel Tarbouli lies outside the *Nephrolithus frequens* domain, while the Russian locality falls within the high latitudes of *Nephrolithus frequens* domain (compare MARTINI, 1970).

7. The genus *Pontosphaera*, so far not known older than the Eocene, is recorded here for the first time in the Upper Maastrichtian of the Gebel Tarbouli, Egypt.

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PLATE 1

Watznaueria barnesae (Black) Perch-Nielsen
1 Distal view (USSR) **)
2 Proximal view (USSR)
3 Oblique distal view (USSR)
4 Distal view (UAR) *)
5 Proximal view (UAR)

*) (UAR) stands for Gebel Tarbouli, Gulf of Suez Region, Egypt.

**) (USSR) stands for Sinev-Shuravnin Deep Drilling, Dnjepr-Donetz Region, USSR (core at 278—279 meter). Sample from the collection of the Oceanographic Institute at Moscow.

PLATE 2

Biscutum constans (Gorka) Black
1 Distal view (USSR)
2 Proximal view (USSR)
3 Oblique proximal view (USSR)
4 Two distal views (UAR)

PLATE 3

Biscutum testudinarium Black
1 Distal view (USSR)
2 Proximal view (USSR)

Markalius inversus (Deflandre) Bramlette & Martini
3 Distal view (USSR)
4 Proximal view (USSR)

PLATE 4

Biscutum testudinarium Black
1 Fragmentary coccosphere, internal view (USSR)

Watznaueria barnesae (Black) Perch-Nielsen
2 Complete coccosphere (USSR)

PLATE 5

Arkhangelskiella cymbiformis Vekshina
1 Distal view (UAR)
2 Marginal rim, proximal side (UAR)
3 Pores of central area (UAR)

PLATE 6

Arkhangelskiella cymbiformis Vekshina
1 Distal view (USSR)
2 Proximal view (USSR)

PLATE 7

Arkhangelskiella cymbiformis Vekshina
1 Oblique proximal view (USSR)
2 Oblique proximal view (USSR)

PLATE 8

Kamptnerius magnificus Deflandre
1 Distal view (USSR)
2 Proximal view (USSR)

PLATE 9

Kamptnerius magnificus Deflandre
1 Distal view of coccolith with open central area (USSR)
2 Proximal view of similar specimen (USSR)

PLATE 10

Kamptnerius magnificus Deflandre
1 Oblique proximal view (USSR)
2 Oblique proximal view (USSR)

PLATE 11

Kamptnerius magnificus Deflandre
1 Oblique distal view (USSR)
Kamptnerius percivalii Bukry
2 Distal view (UAR)

PLATE 12

Polypodorhabdus crenulatus (Bramlette & Martini) nov. comb.
1 Distal view (USSR)
2 Distal view (USSR)

PLATE 13

Polypodorhabdus crenulatus (Bramlette & Martini) nov. comb.
1—3 Distal views (USSR)
4 Proximal view (UAR)

PLATE 14

Polypodorhabdus pienaari nov. spec.
1 Distal view (UAR)
2 Oblique distal view (UAR)
3 Distal view (UAR)
4 Distal view of holotype (UAR)

PLATE 15

Polypodorhabdus schizobrachiatus (Gartner) nov. comb.
1—3 Distal views (UAR)

PLATE 16

Podorhabdus granulatus (Reinhardt) Bukry
1—3 Distal views (UAR)

PLATE 17

Podorhabdus dietzmanni (Reinhardt) Reinhardt
1 Oblique distal view (UAR)
2 Proximal view (UAR)

PLATE 18

Prediscosphaera cretacea (Arkhangelsky) Gartner
1 Distal view (USSR)
2 Proximal view (USSR)
4 Oblique distal view (USSR)
Prediscosphaera sp.
3 Distal view (UAR)

PLATE 19

Transitional forms between *Prediscosphaera cretacea* (Arkhangelsky) Gartner and *P. spinosa* (Bramlette & Martini) Bukry
1 Distal view (USSR)
2 Distal view (USSR)
Prediscosphaera cretacea (Arkhangelsky) Gartner
3—4 Side views (USSR)

PLATE 20

Prediscosphaera spinosa (Bramlette & Martini) Bukry
1—2 Distal views (USSR)
3—4 Proximal views (USSR)

PLATE 21

Prediscosphaera sp.
1 Distal view (USSR)
2—4 Distal views (UAR)

PLATE 22

Prediscosphaera stoveri Perch-Nielsen
1 Distal view (USSR)
Prediscosphaera honjoi Bukry
2 Distal view (UAR)
3 Distal view (UAR)
4 Proximal view (UAR)

PLATE 23

Ahmuellerella octoradiata (Gorka) Reinhardt
1 Distal view (USSR)
2 Distal view (USSR)
3 Oblique distal view (USSR)
4 Proximal view (USSR)

PLATE 24

Reinhardtites mirabilis Perch-Nielsen
1—3 Distal views (USSR)
4 Distal view (UAR)

PLATE 25

Reinhardtites mirabilis Perch-Nielsen
1—2 Oblique proximal views (USSR)
3—4 Proximal views (USSR)

PLATE 26

Rhagodiscus plebeius Perch-Nielsen
1—2 Distal views (USSR)
3—4 Proximal views (USSR)

PLATE 27

Rhagodiscus plebeius Perch-Nielsen
1—2 Distal views (USSR)
Rhagodiscus sp.
3 Distal view (UAR)
4 Proximal view (USSR)

PLATE 28

Nephrolithus frequens Gorka
1—3 Distal views (USSR)

PLATE 29

Nephrolithus frequens Gorka
1—3 Proximal views (USSR)

PLATE 30

Cribrosphaerella laughtoni (Black) Bukry
1 Distal view (USSR)
2 Centre of same specimen in larger magnification (USSR)
3 Distal view (USSR)
4 Same specimen, close-up of central area (USSR)

PLATE 31

Cribrosphaerella laughtoni (Black) Bukry
1 Distal view (USSR)
2—3 Proximal views (USSR)
4 Oblique proximal view (USSR)

PLATE 32

Cribrosphaerella numerosa (GORKA) REINHARDT & GORKA
1 Distal view (UAR)
2 Central area of same specimen in higher magnification (UAR)
Rhabdolithina splendens (DEFLANDRE) REINHARDT
3 Proximal view (UAR)
4 Side view of shaft (UAR)

PLATE 33

Zygodiscus spiralis BRAMLETTE & MARTINI
1 Distal view (USSR)
2 Distal view (UAR)
3—4 Proximal views (USSR)

PLATE 34

Zygodiscus sisyphus GARTNER
1—3 Distal views (USSR)
4 Proximal view (USSR)

PLATE 35

Zygodiscus theta (BLACK) BUKRY
1 Distal view (USSR)
2 Oblique distal view (USSR)
Zygolithus erectus DEFLANDRE
3 Distal view (UAR)
Zygolithus cf. *diplogrammus* DEFLANDRE
4 Proximal view (USSR)

PLATE 36

Zygodiscus acanthus (REINHARDT) REINHARDT
1—3 Distal views (USSR)
4 Proximal view (USSR)

PLATE 37

Zygodiscus tarboulensis nov. spec.
1 Distal view (paratype) (UAR)
2 Distal view (holotype) (UAR)
3 Distal view (paratype) (UAR)
4 Distal view of partly inversed specimen (UAR)

PLATE 38

Vekshinella elliptica GARTNER
1 Distal view (?) (UAR)
2—4 Proximal views (UAR)

PLATE 39

Vekshinella crux (DEFLANDRE & FERT) nov. comb.
1—2 Distal views (UAR)
3—4 Proximal views (UAR)

PLATE 40

Vekshinella cruciata (NOEL) nov. comb.
1 Distal view (USSR)
4 Proximal view (USSR)
Vekshinella aachena BUKRY
2—3 Distal views (USSR)

PLATE 41

Zygolithus litterarius (GORKA) REINHARDT & GORKA
1—3 Distal views (UAR)
4 Proximal view (UAR)

PLATE 42

Eiffellithus sp. Heavily fossilized specimens
1 Distal view (UAR)
2 Distal view (USSR)
3—4 Proximal views (USSR)

PLATE 43

Eiffellithus trabeculatus (GORKA) REINHARDT & GORKA
2 Distal view (USSR)
Eiffellithus anceps (GORKA) REINHARDT & GORKA
1 and 4 Distal views (USSR)
3 Distal view with double carbon coating in rim area (USSR)

PLATE 44

Eiffellithus anceps (GORKA) REINHARDT & GORKA
1—2 Distal views (USSR)
3 Proximal view (USSR)
4 Oblique distal view (USSR)

PLATE 45

Cylindralithus serratus BRAMLETTE & MARTINI
1—4 Axial views (UAR)

PLATE 46

Corollithion exiguum STRADNER
1 and 4 Distal views (UAR)
2 and 3 Proximal views (UAR)

PLATE 47

Corollithion exiguum STRADNER
1 Distal view (UAR)
Stephanolithion laffitei NOEL
2 Proximal view (UAR)
Corollithion rhombicum (STRADNER & ADAMIKER) BUKRY
3 Distal view (UAR)

PLATE 48

1 Unidentified globular body with pore (UAR)
Pontosphaera multicarinata (GARTNER) nov. comb.
2 Plan view in light microscope, crossed nicols (UAR)
3 Distal side with spiral sutures (electronmicrograph) (UAR)

PLATE 49

Lithraphidites quadratus BRAMLETTE & MARTINI
1—2 Side views (UAR)
3 Side view (USSR)

PLATE 50

Micula staurophora (GARDET) STRADNER
1—4 Oblique views of more or less tilted specimens (UAR)

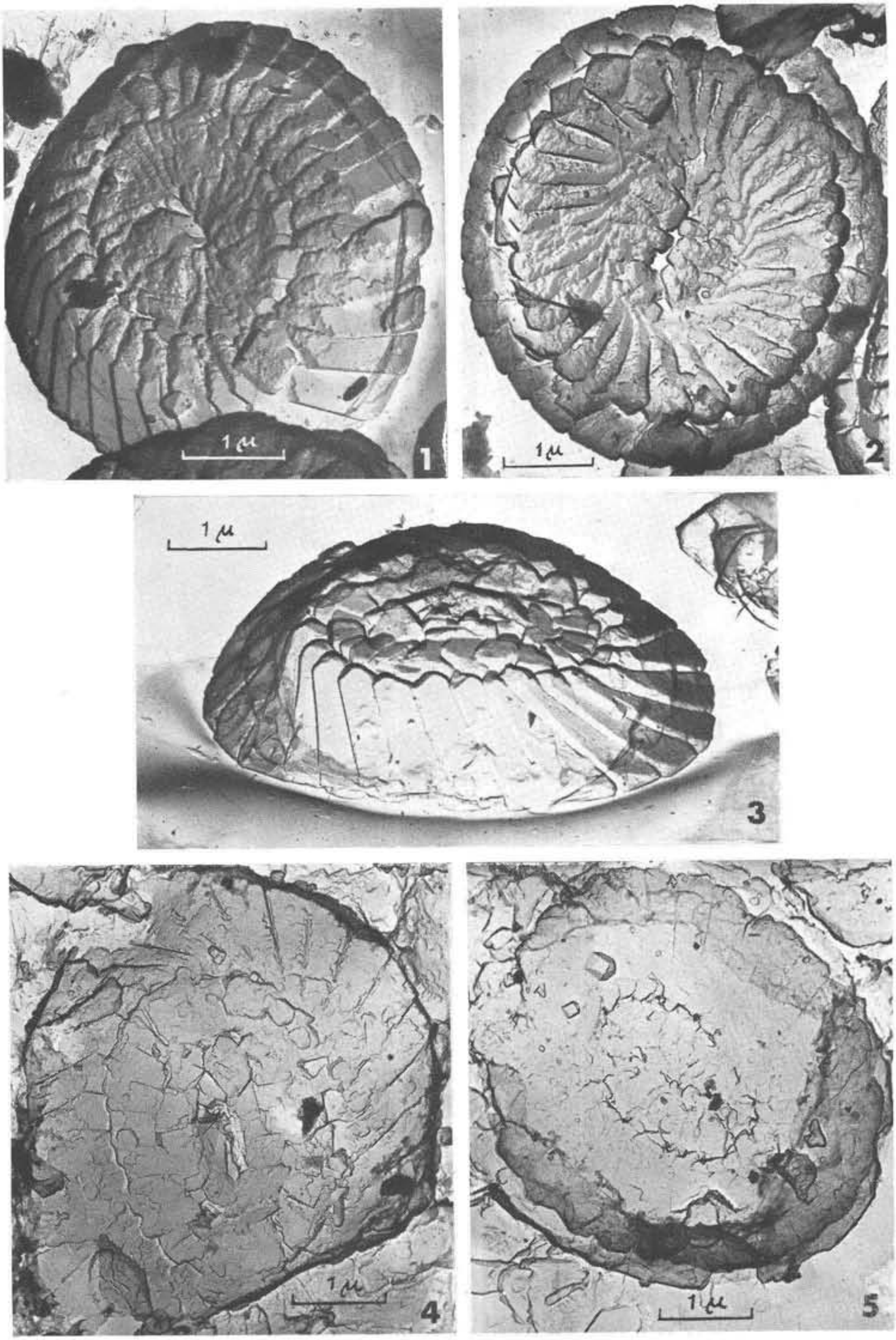
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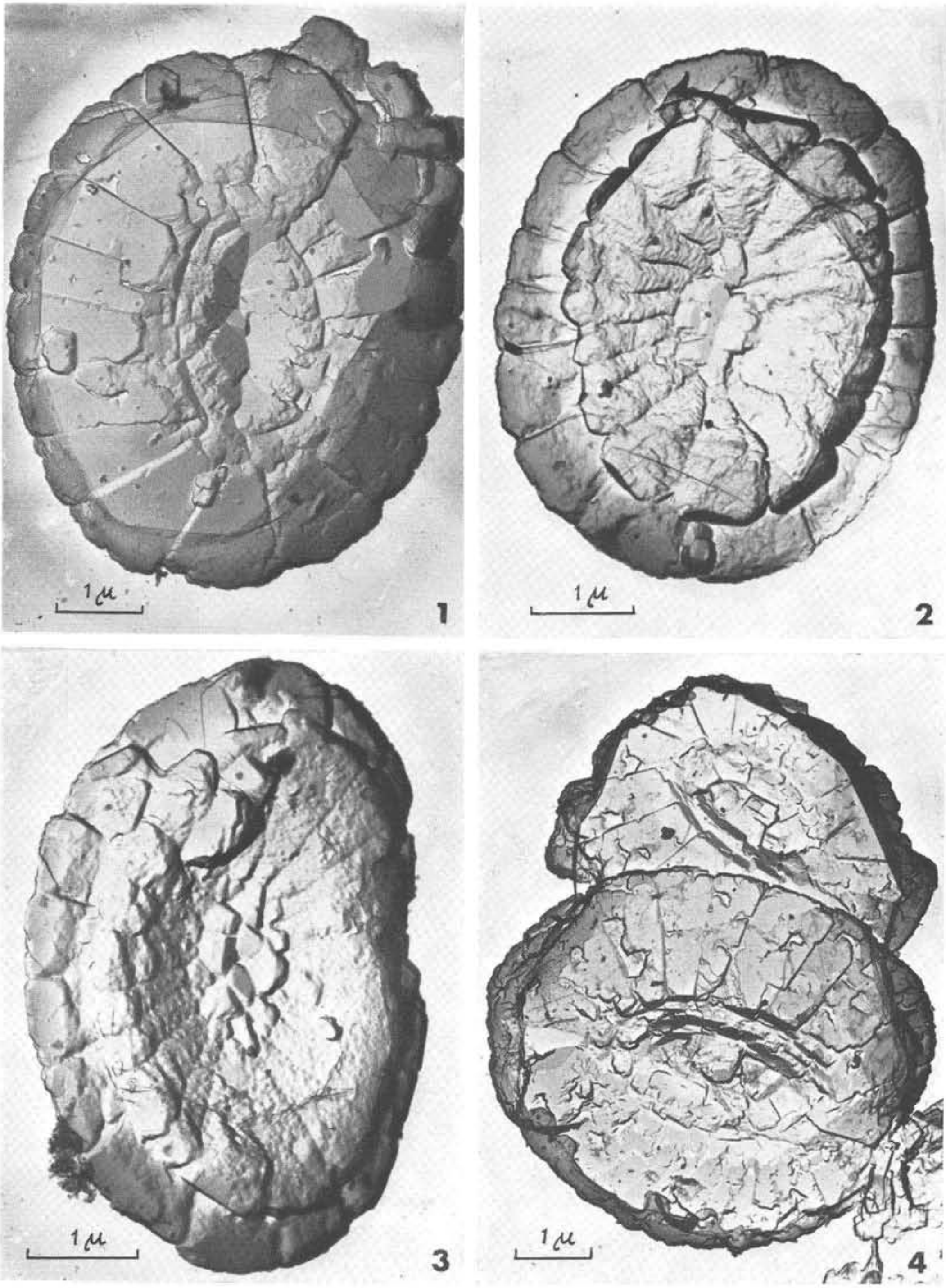
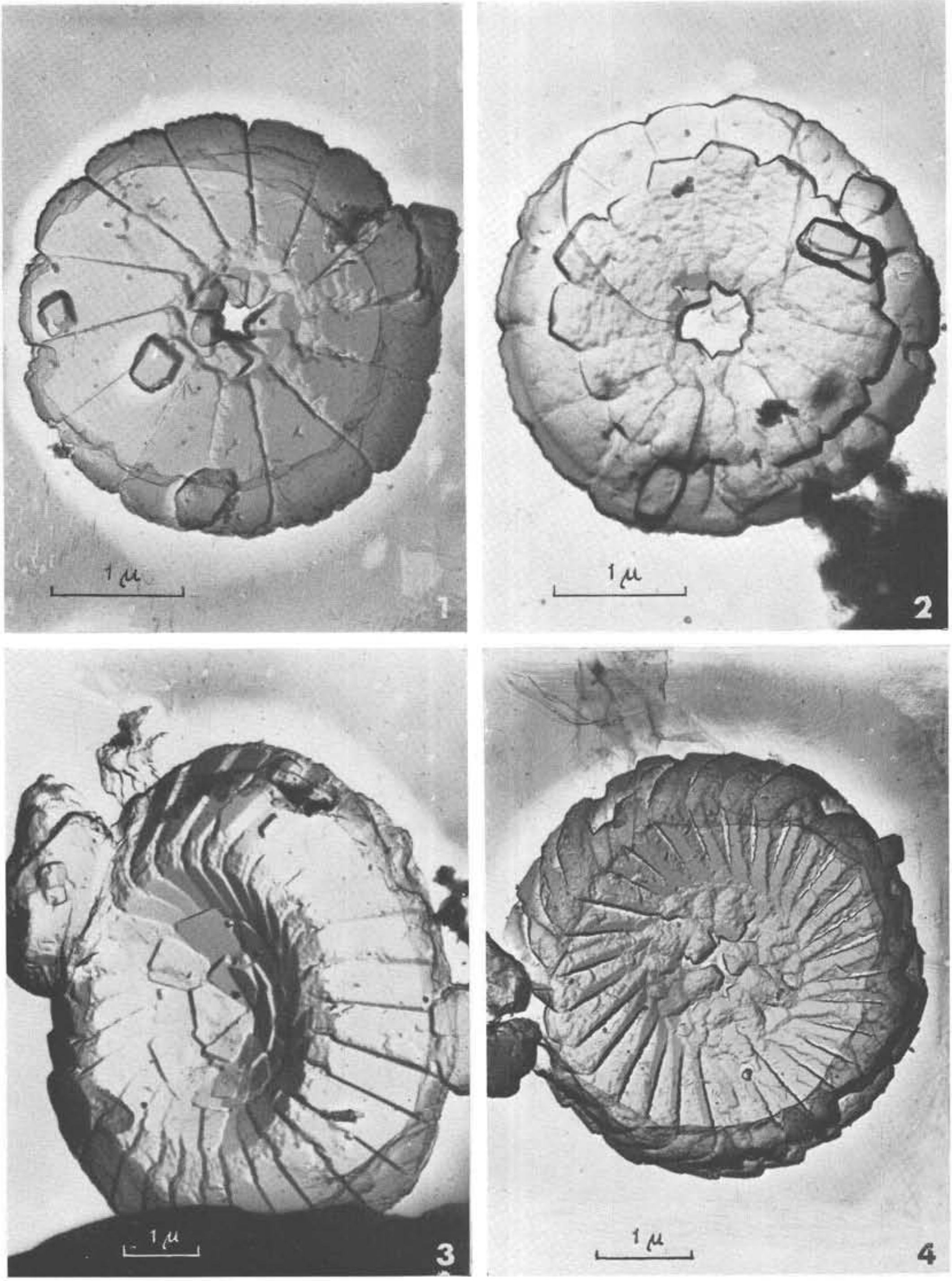
PLATE 2

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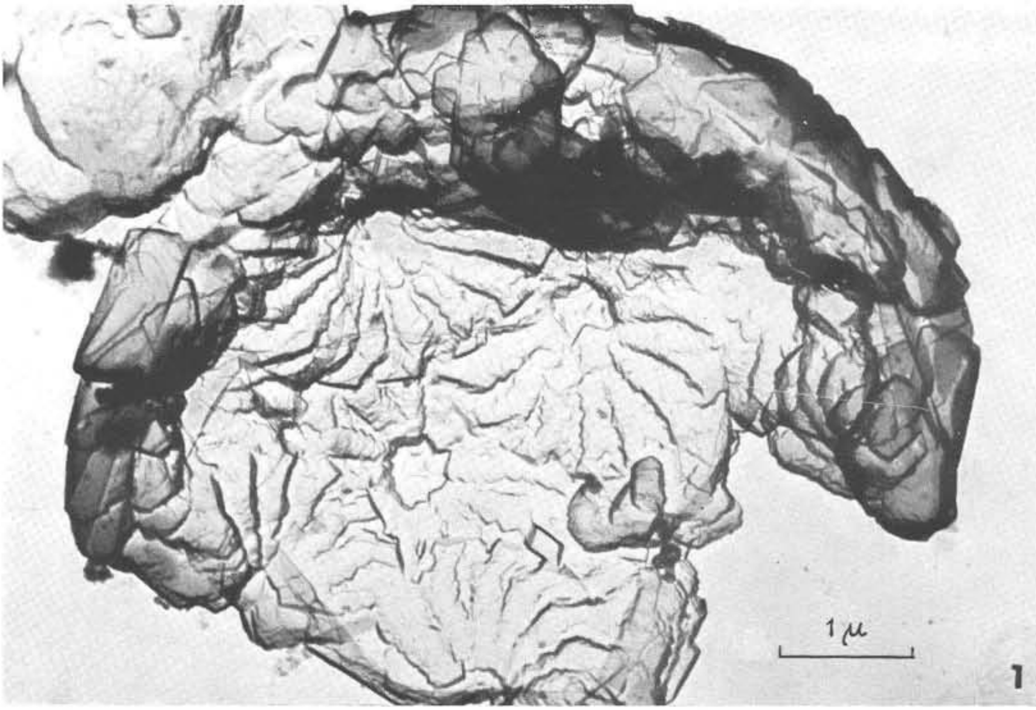
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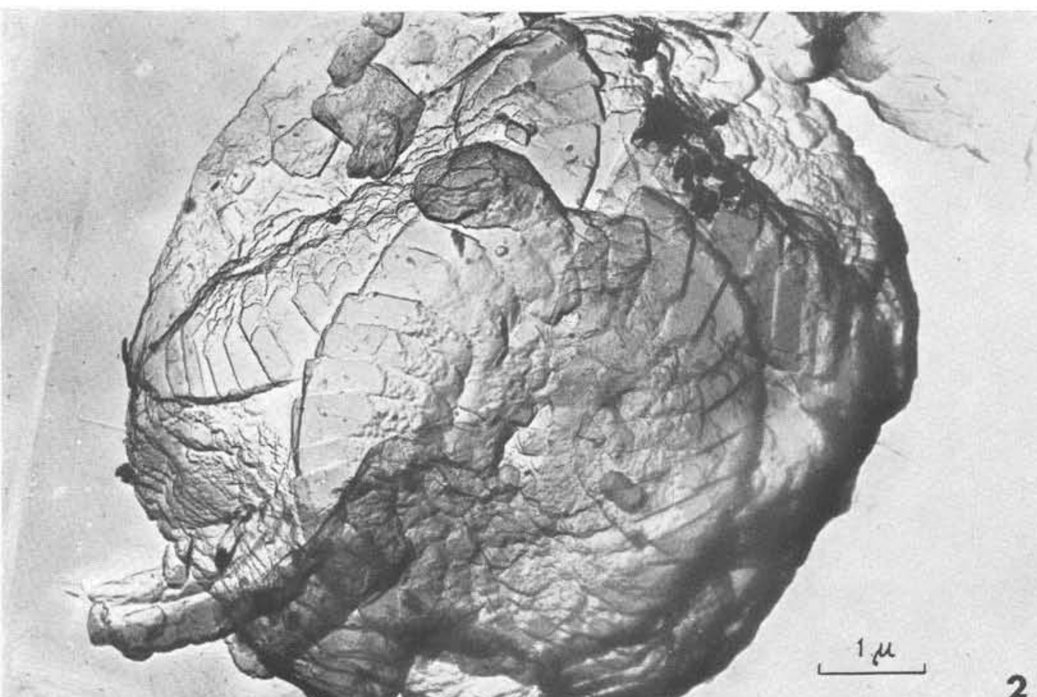
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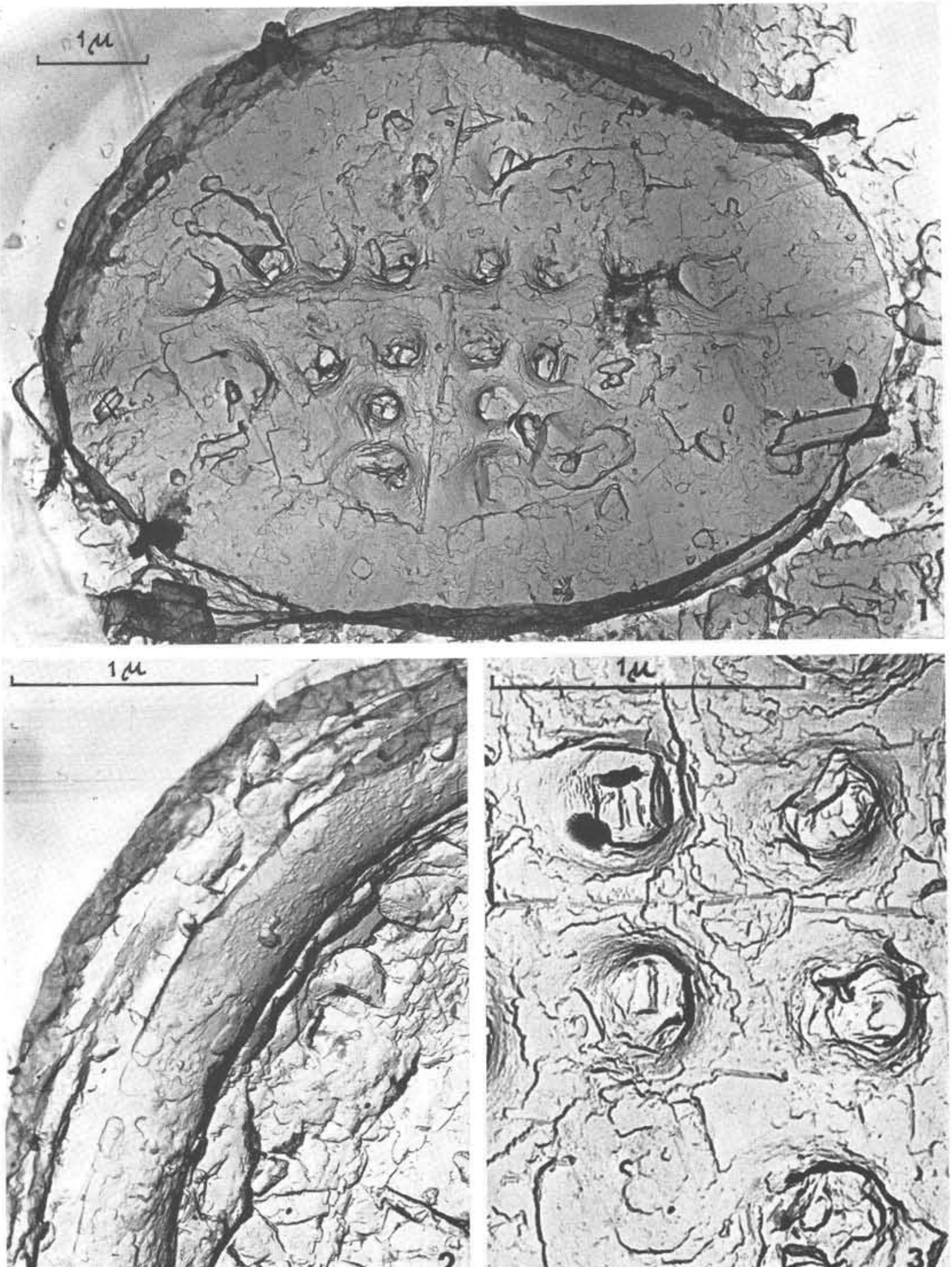
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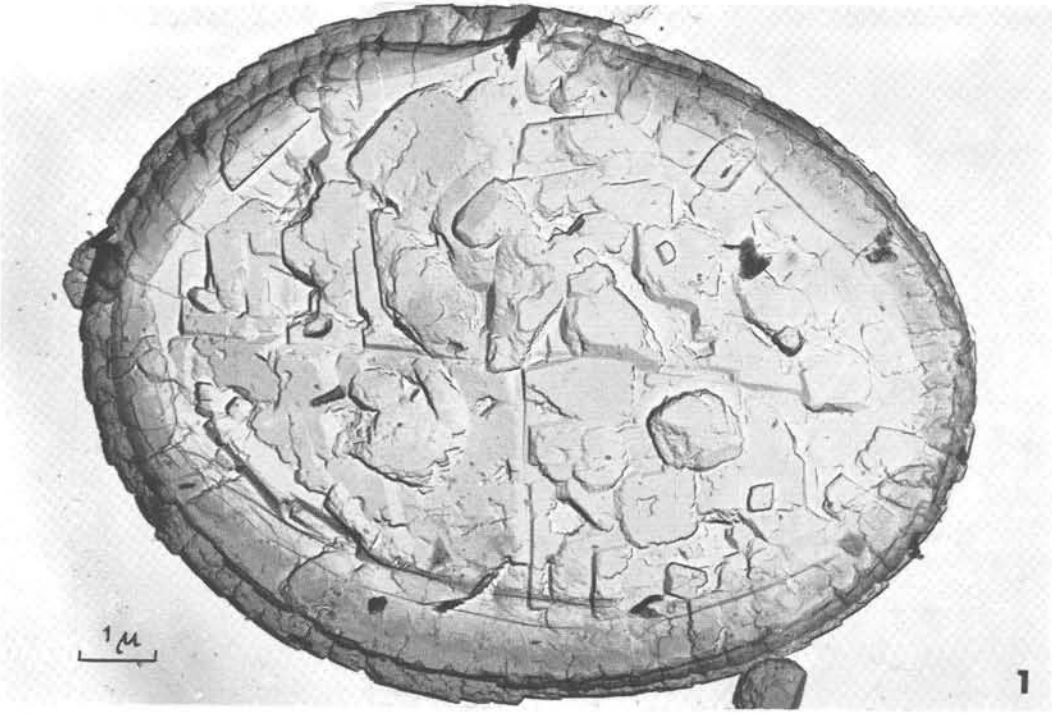
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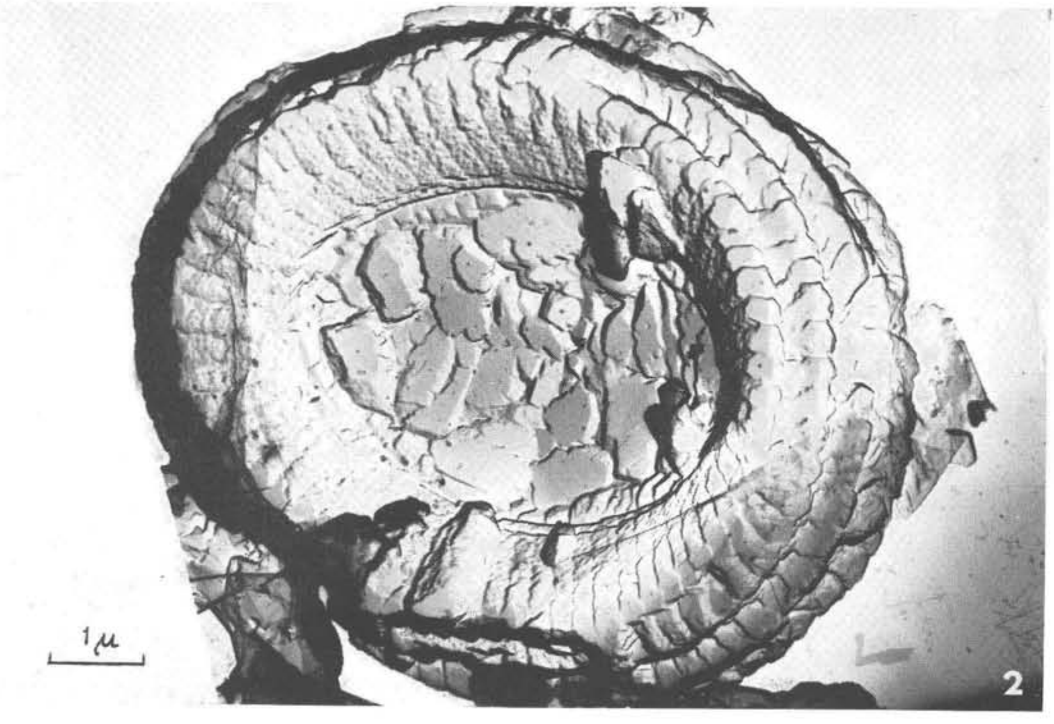
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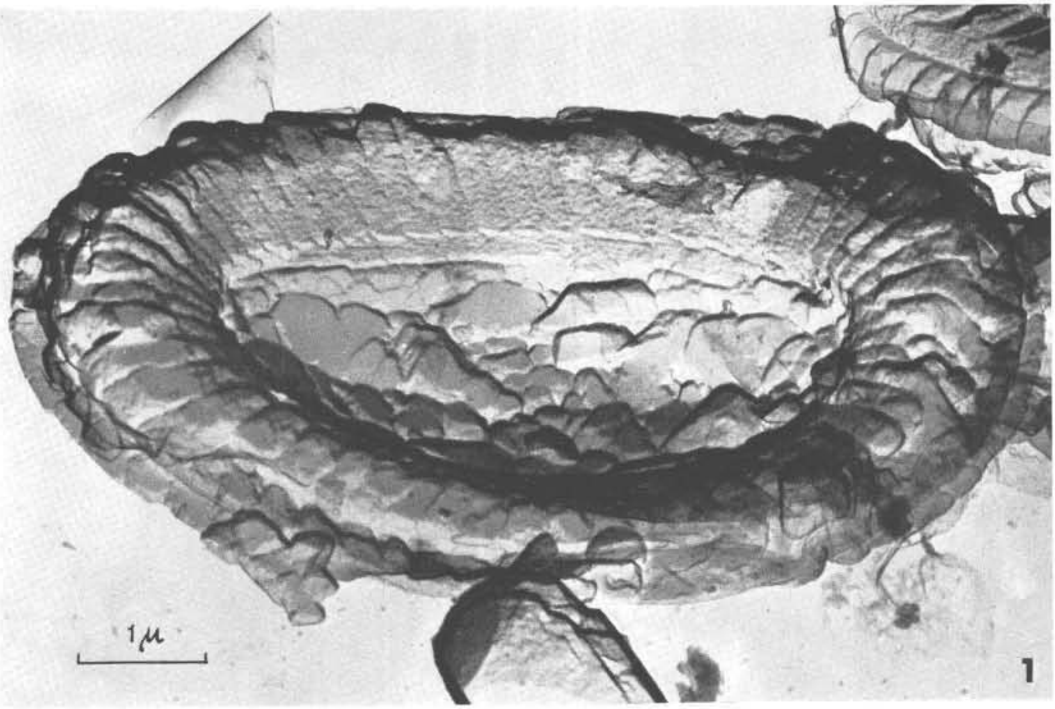
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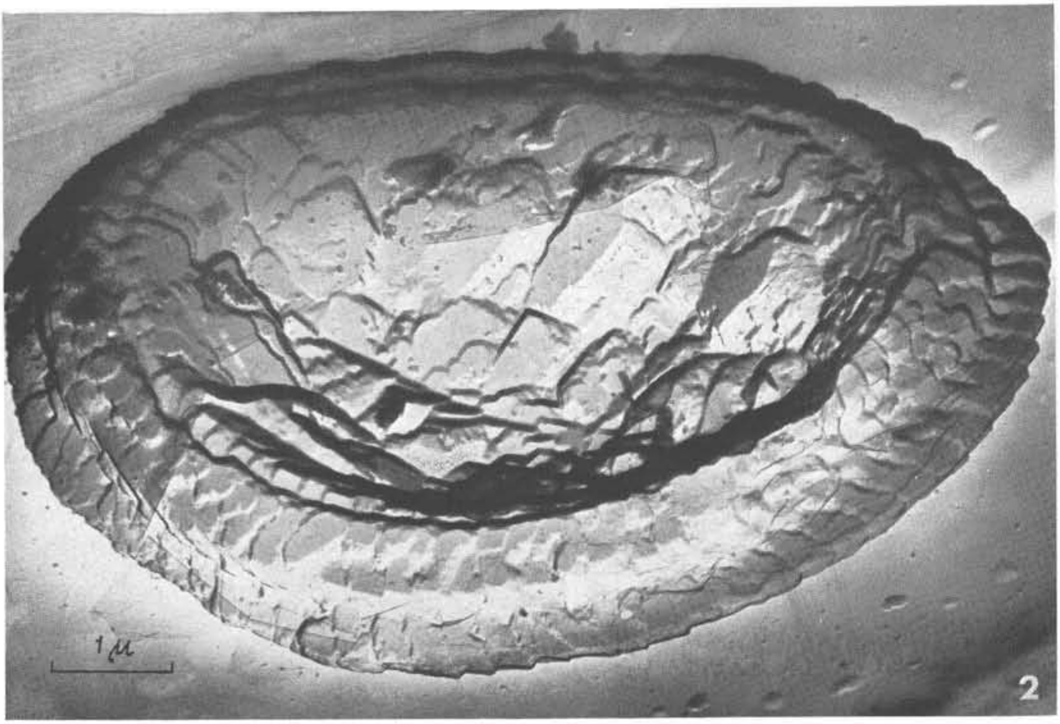
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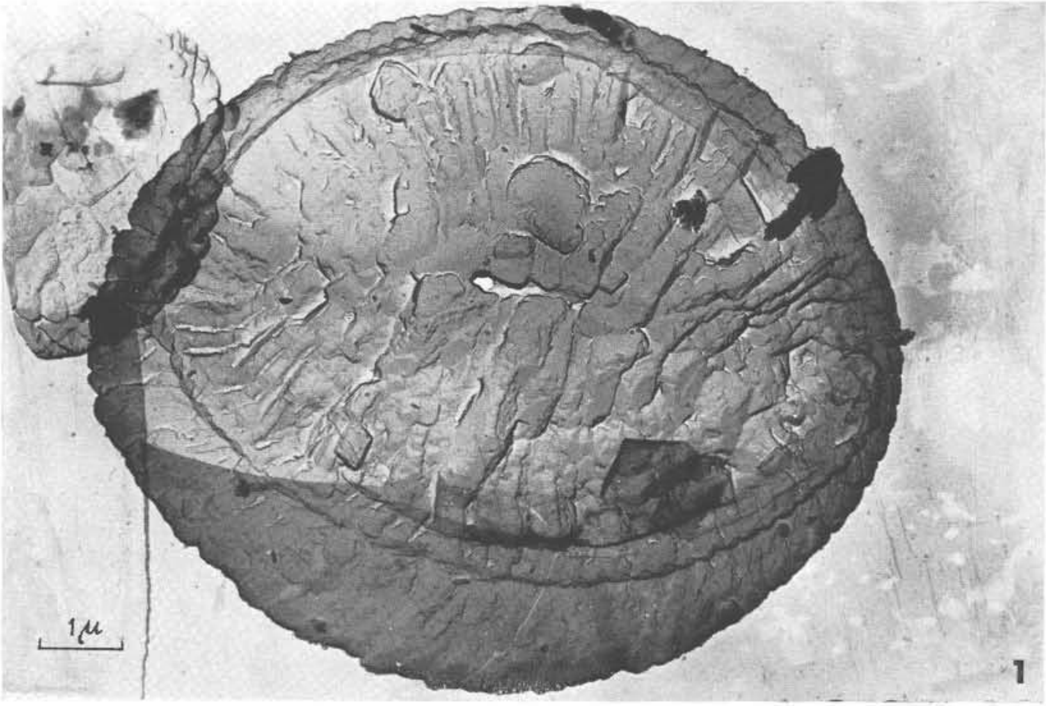
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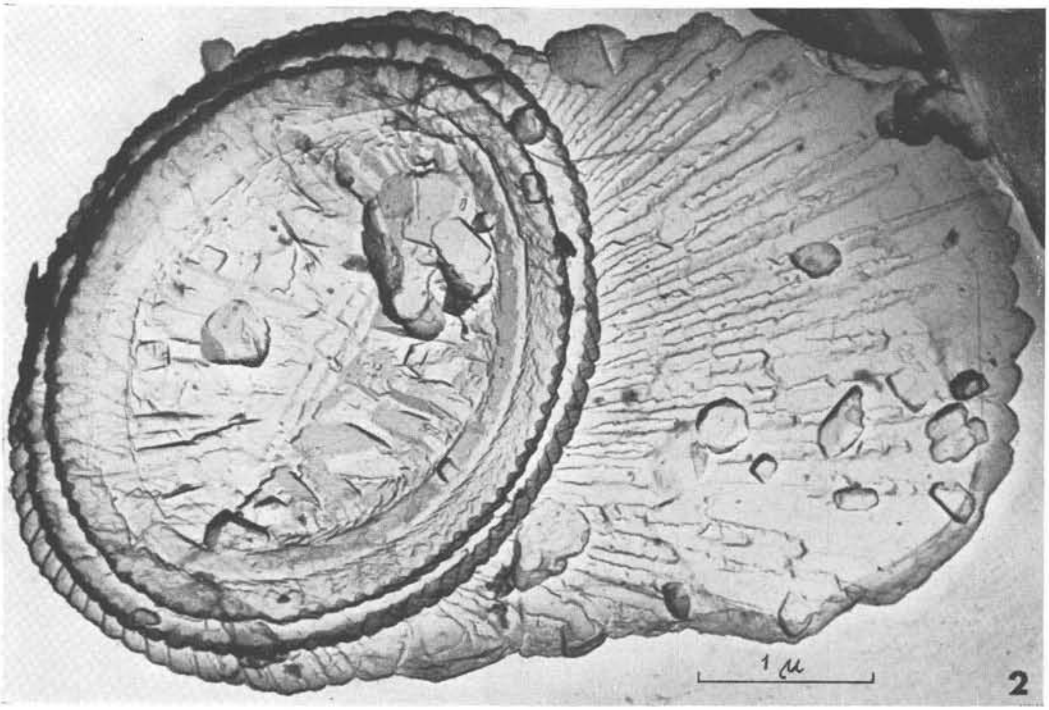
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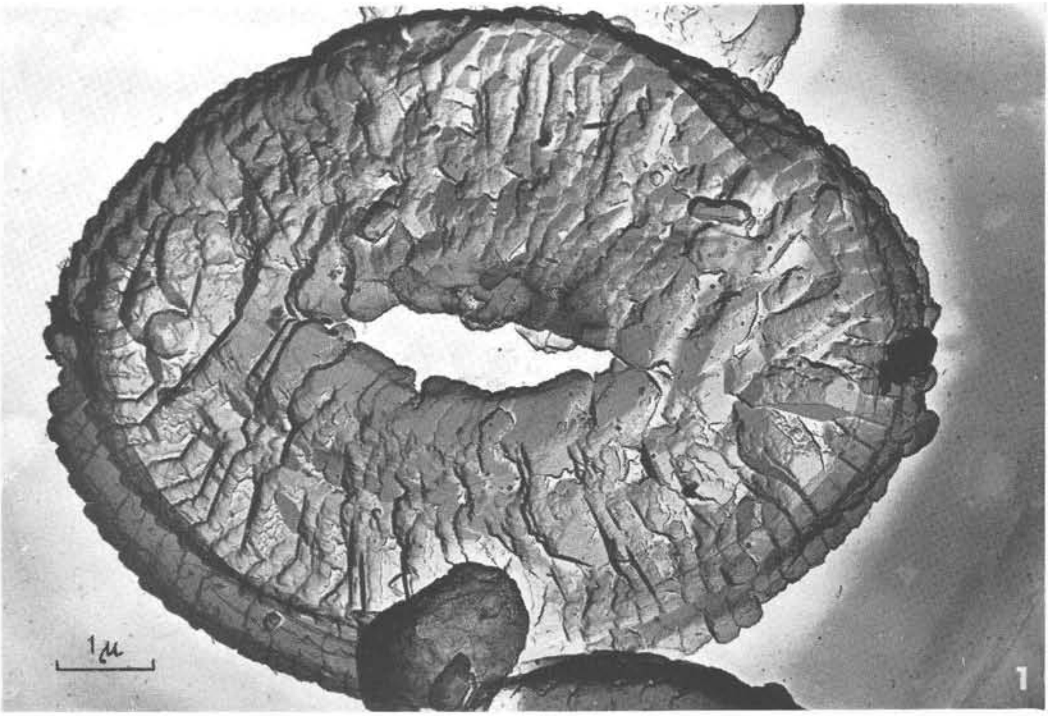
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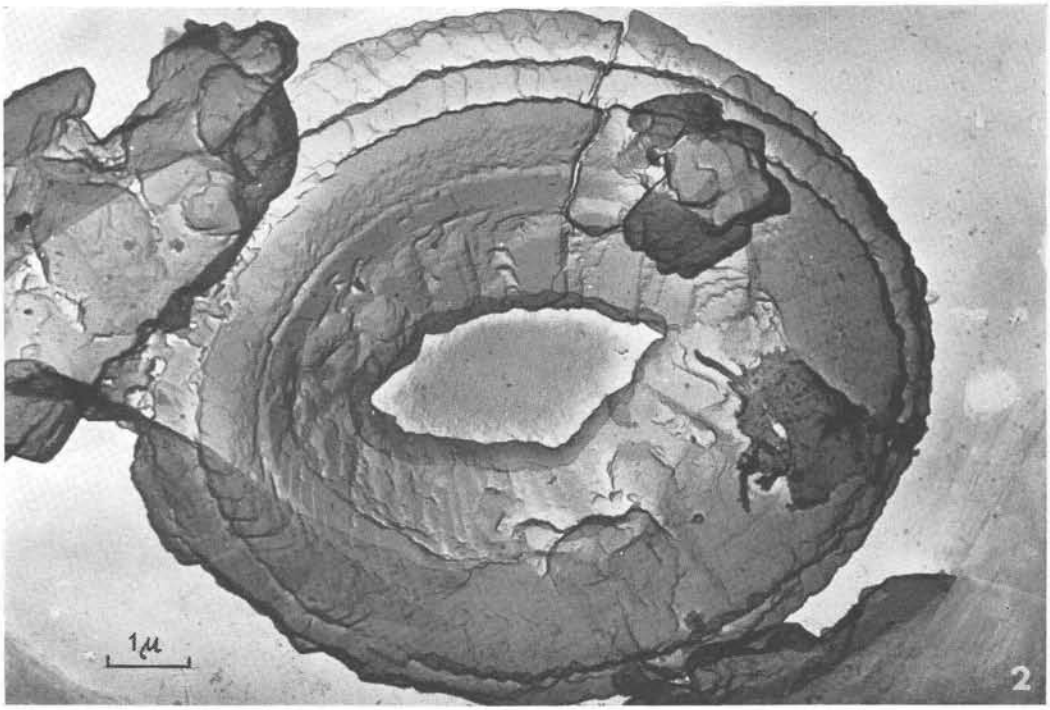
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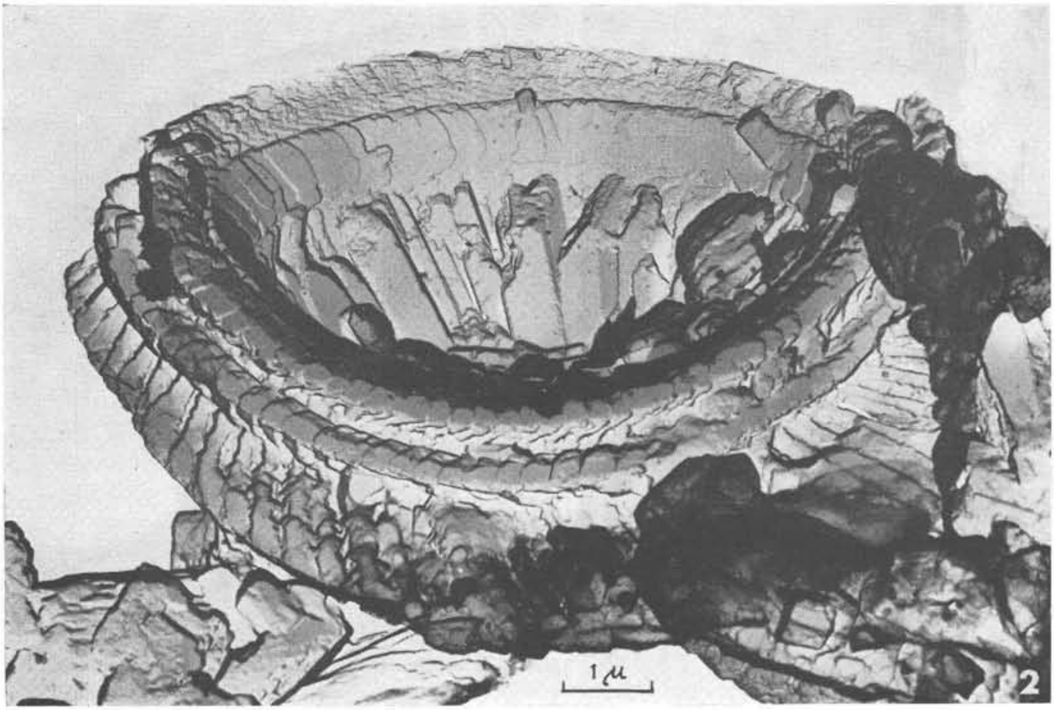
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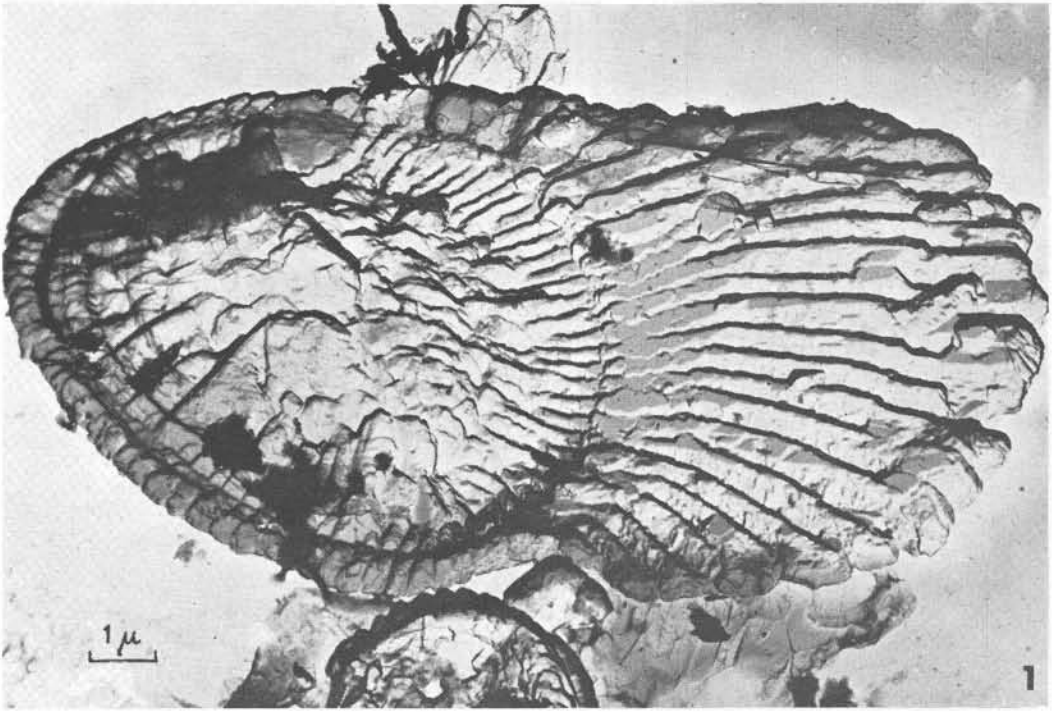

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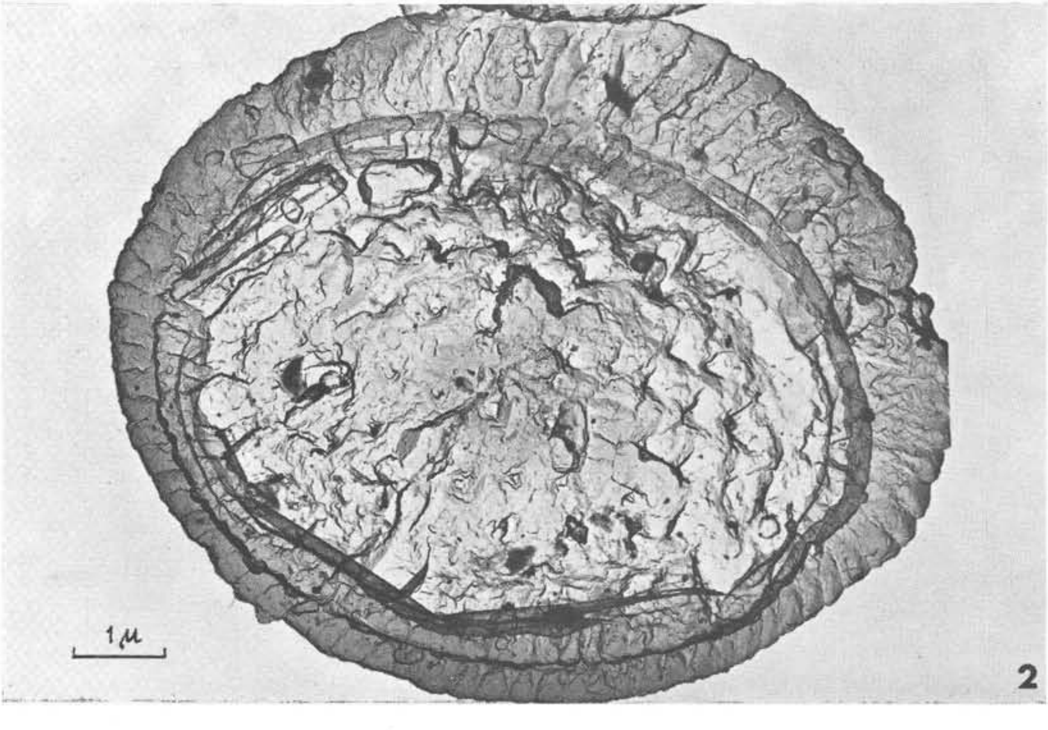

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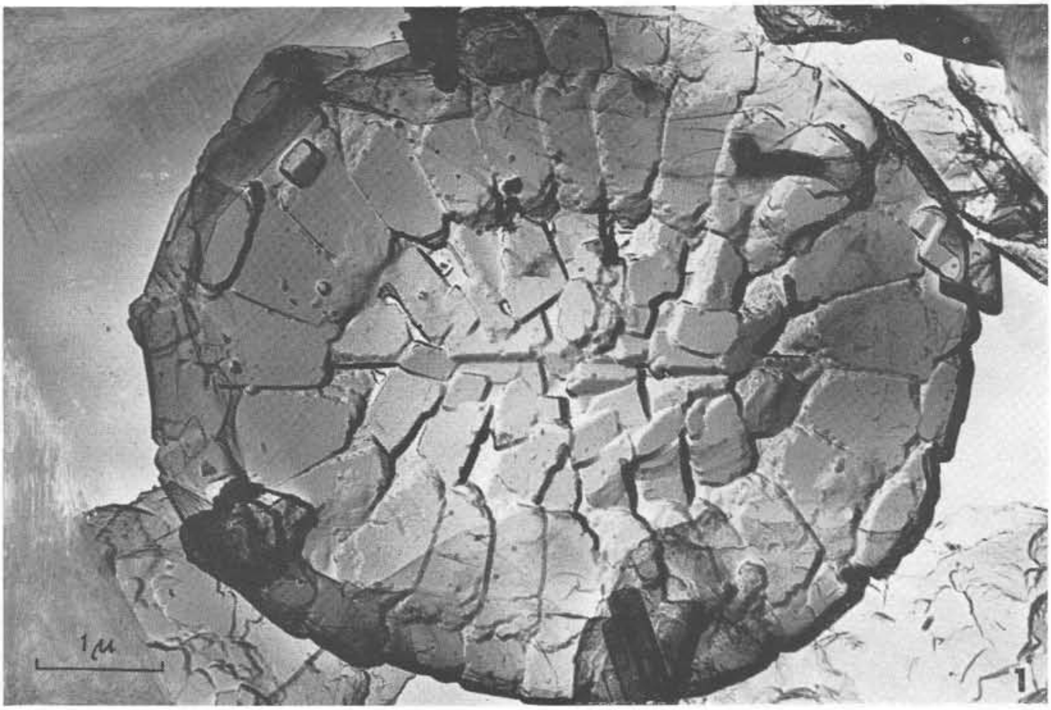
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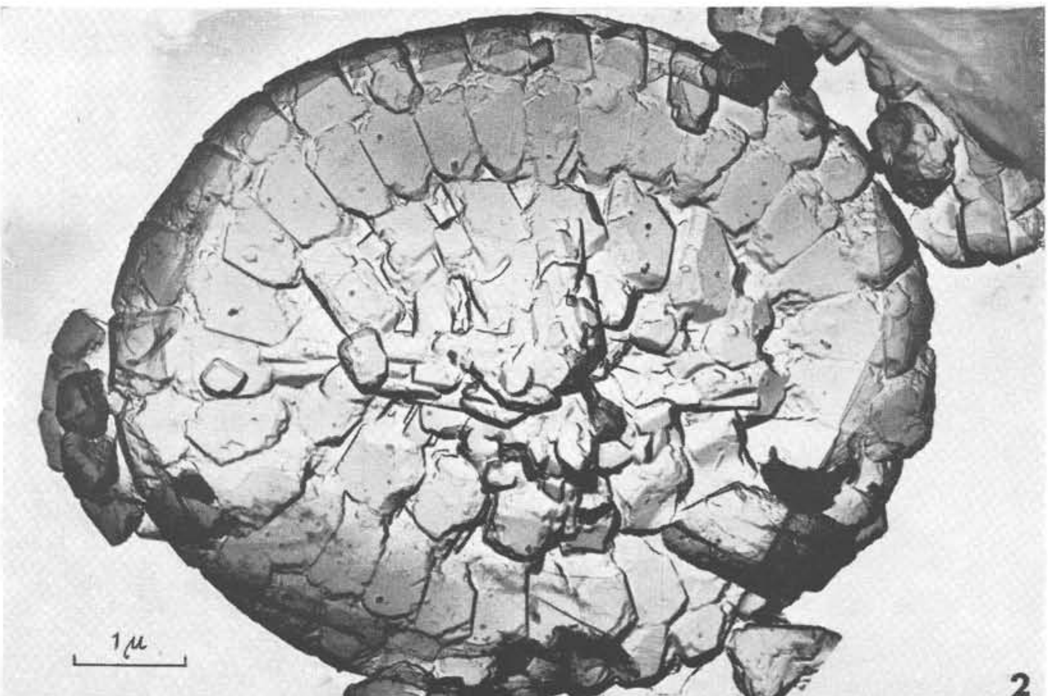
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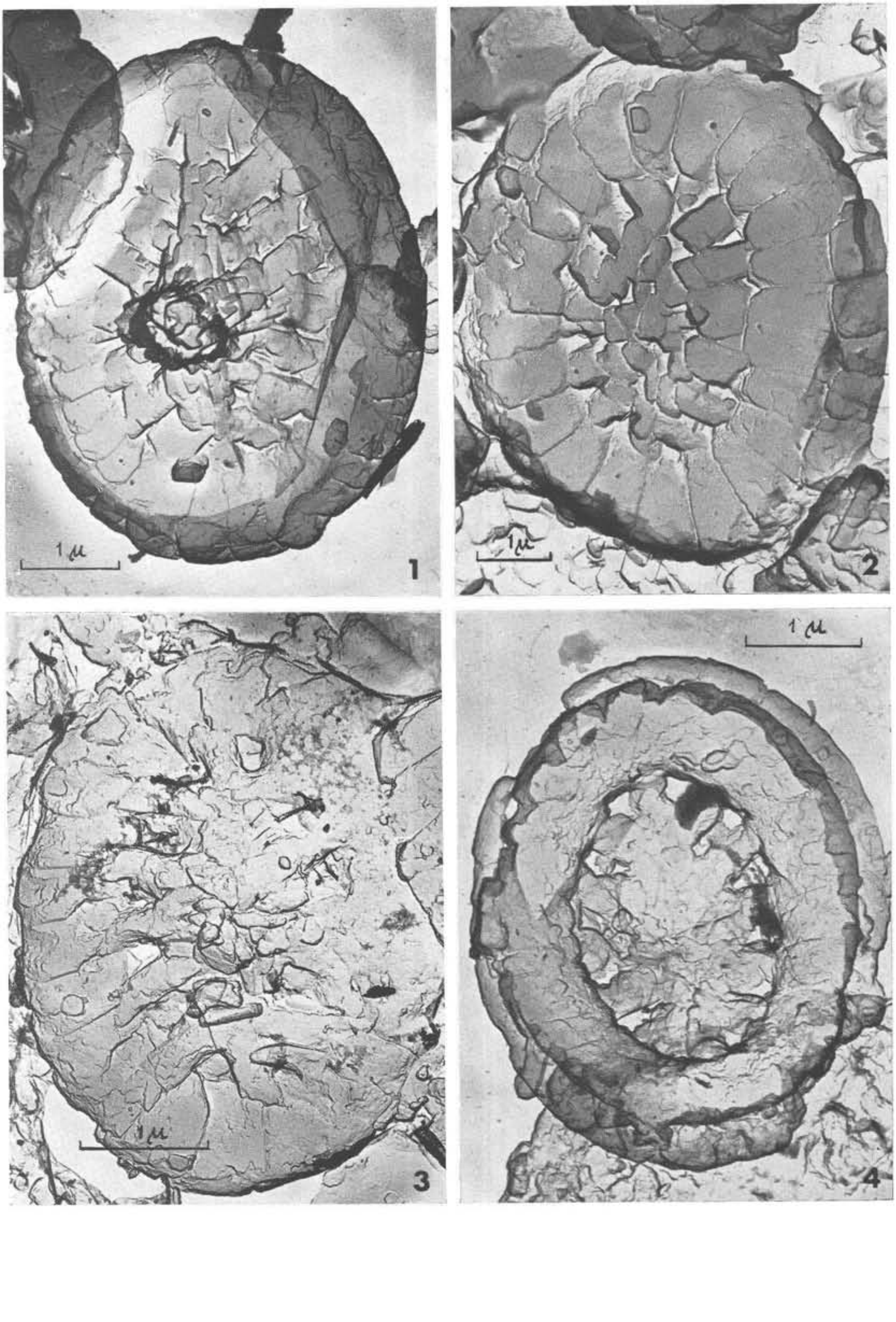
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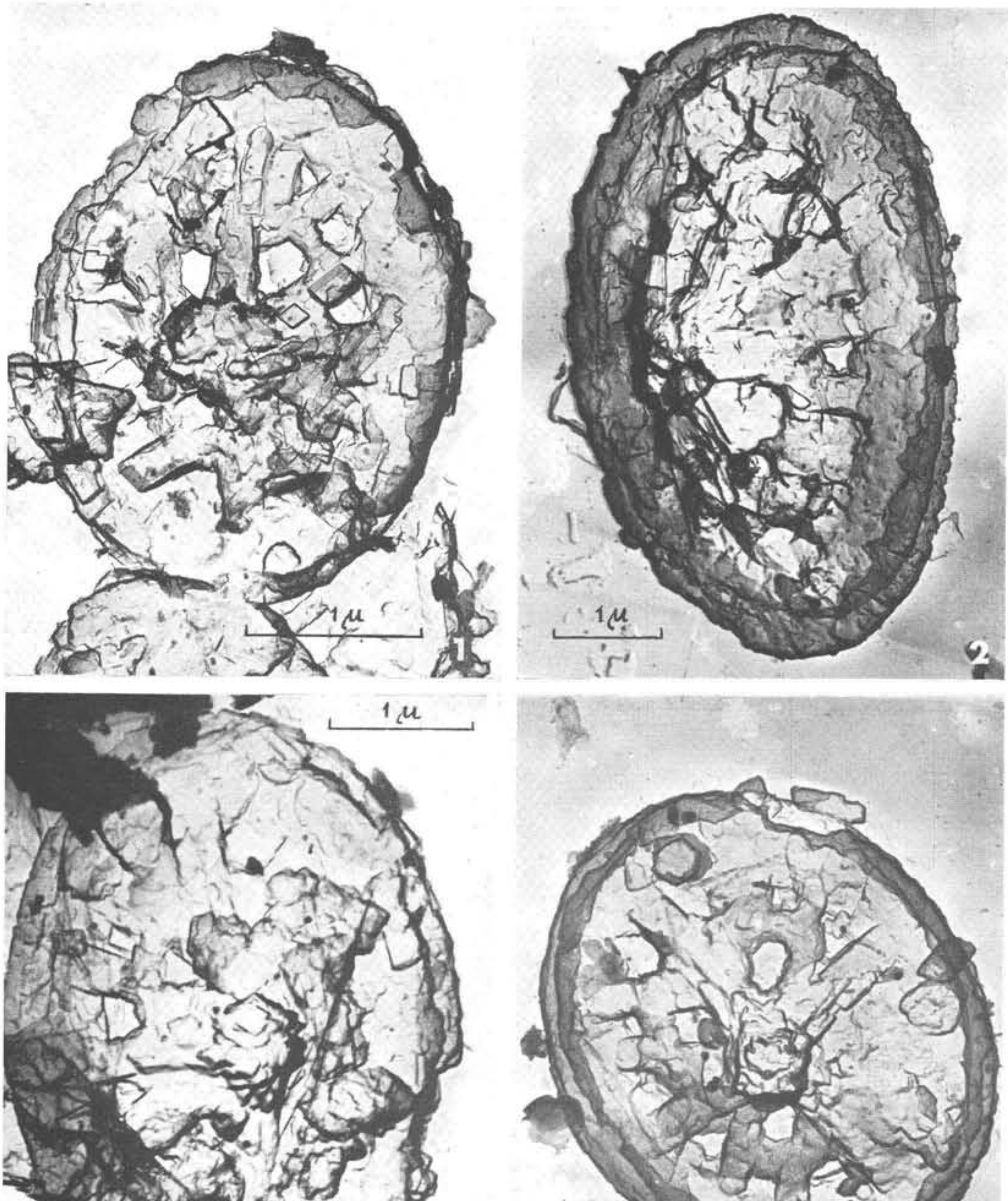
PLATE 14

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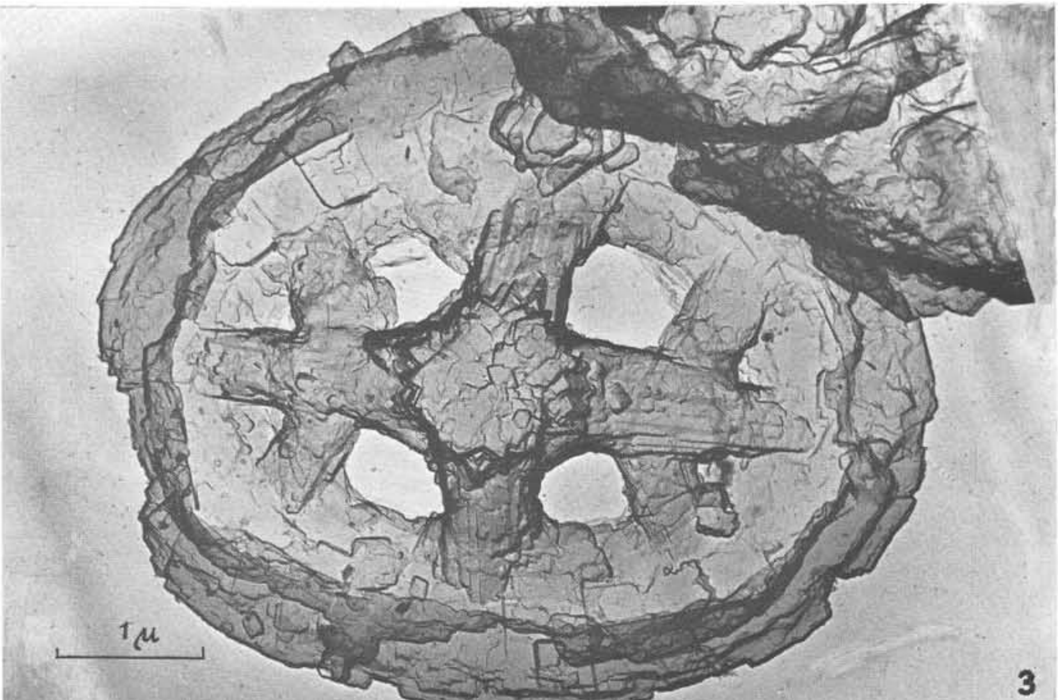
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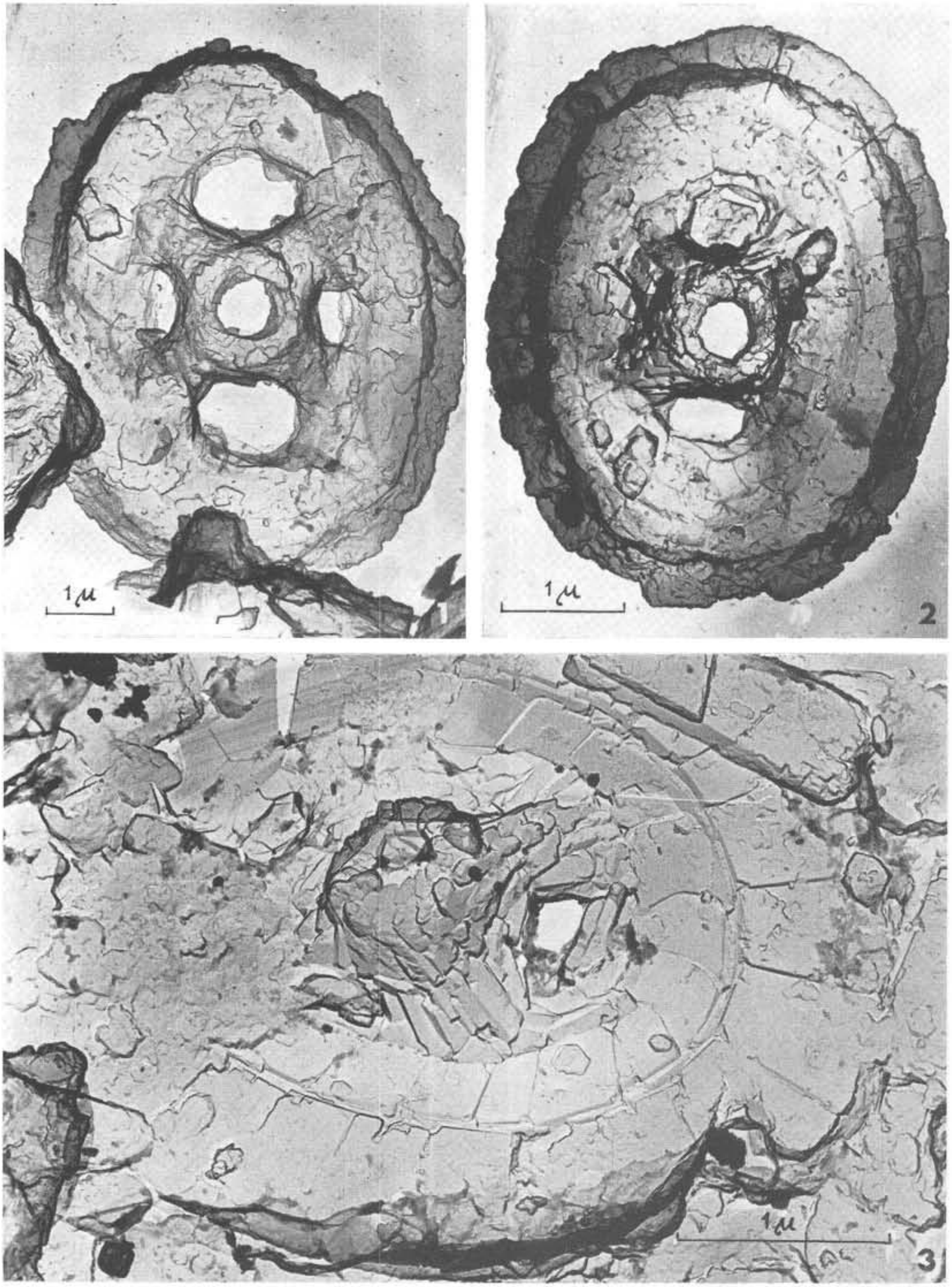
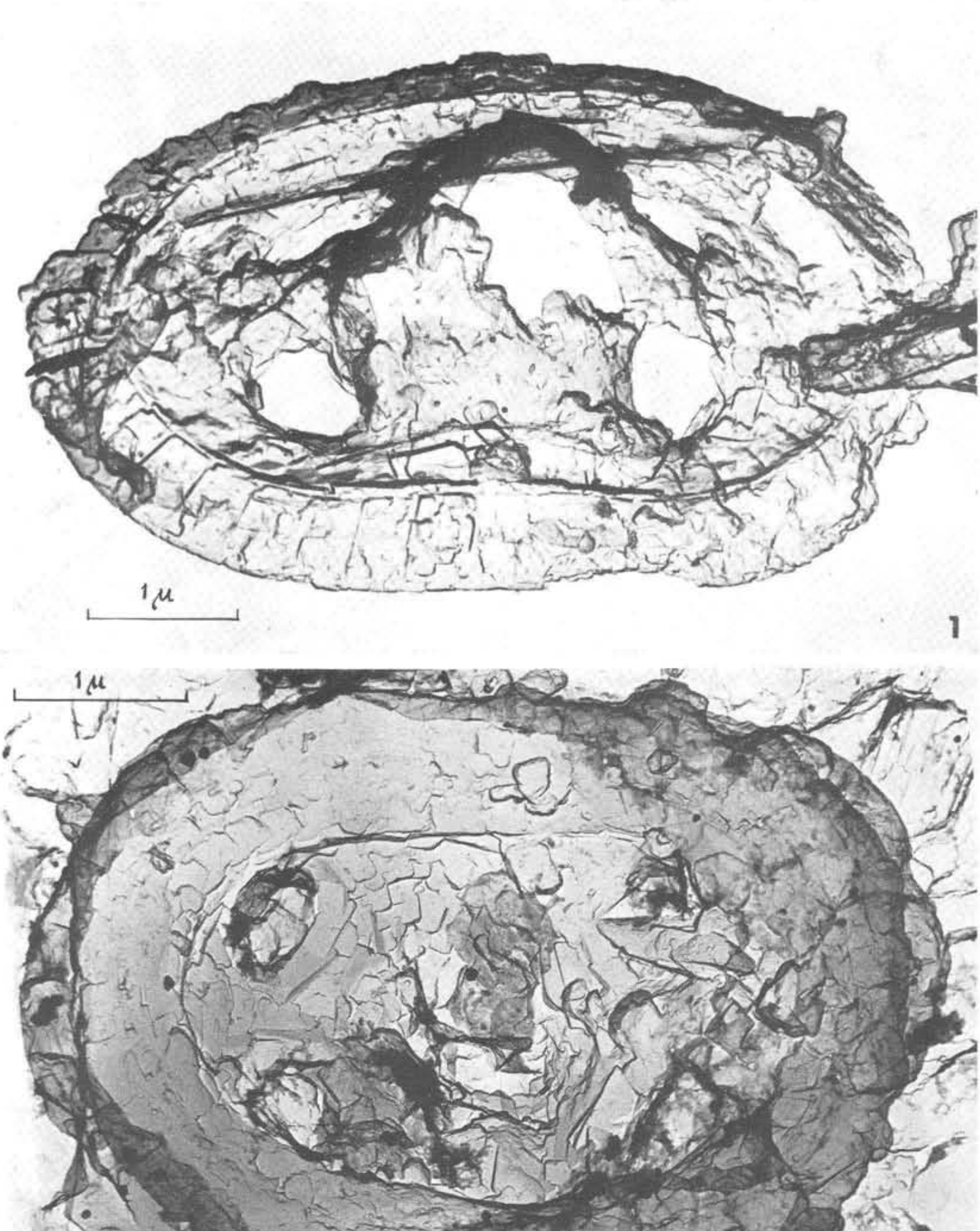
PLATE 16

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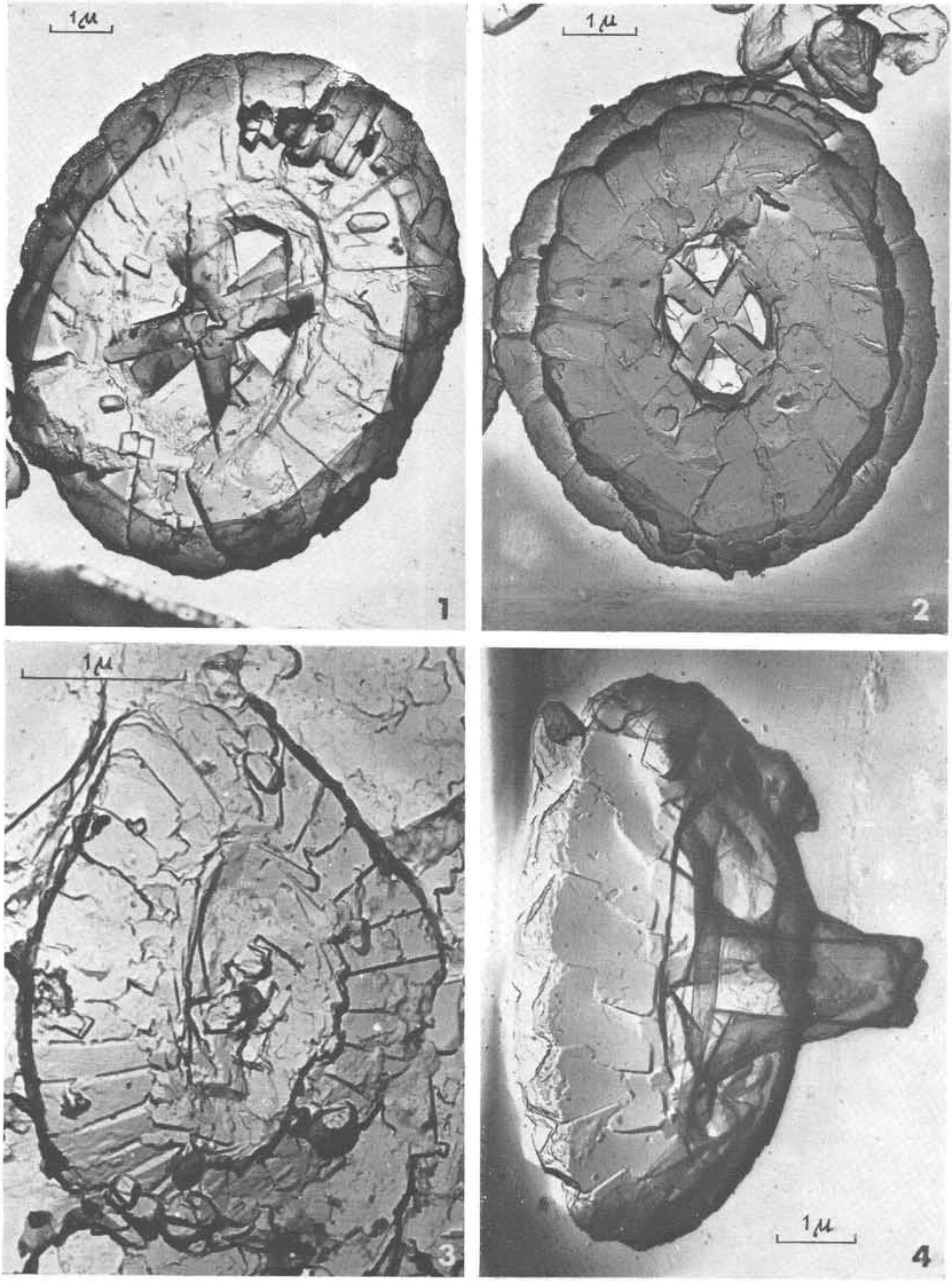
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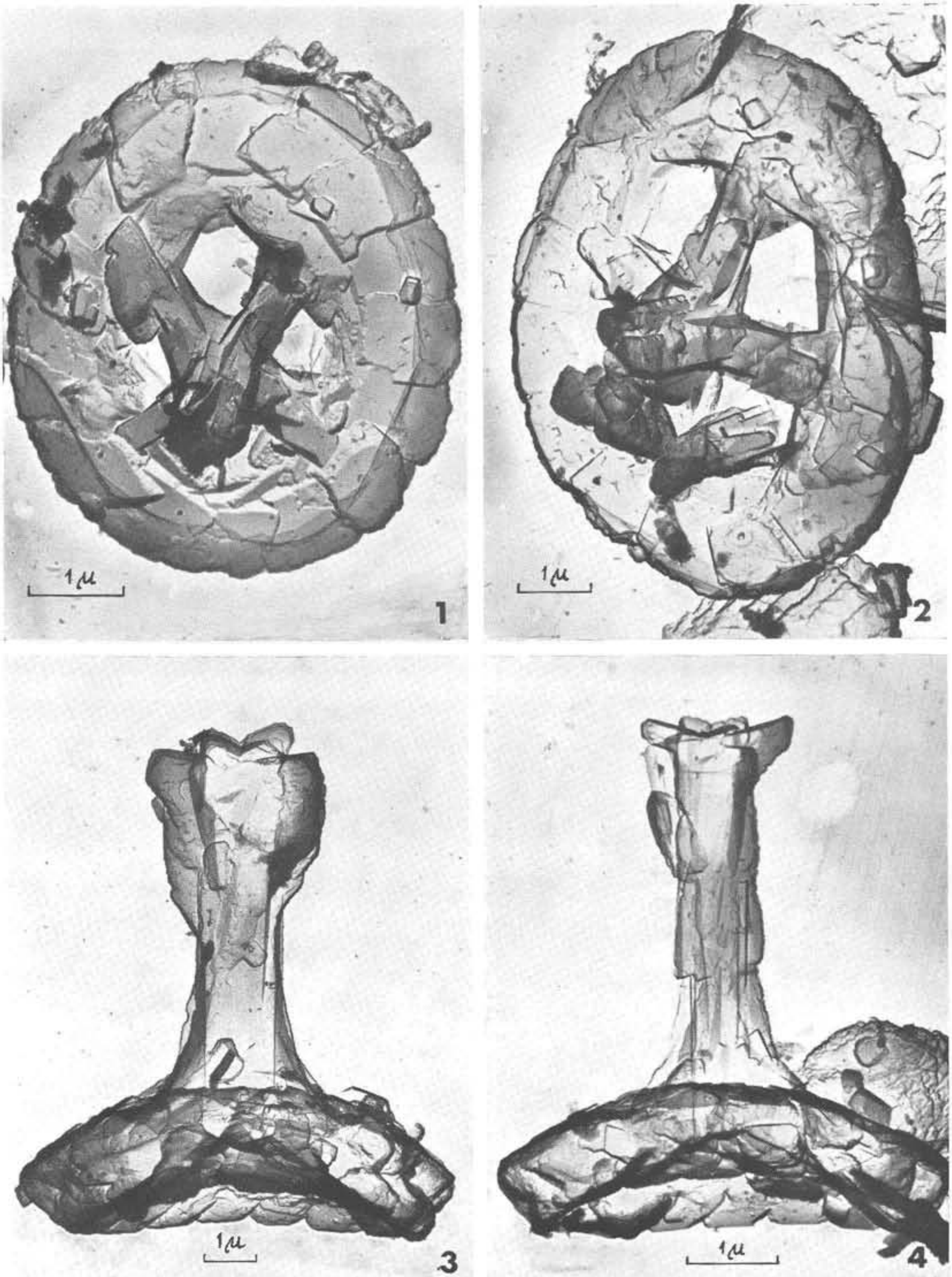

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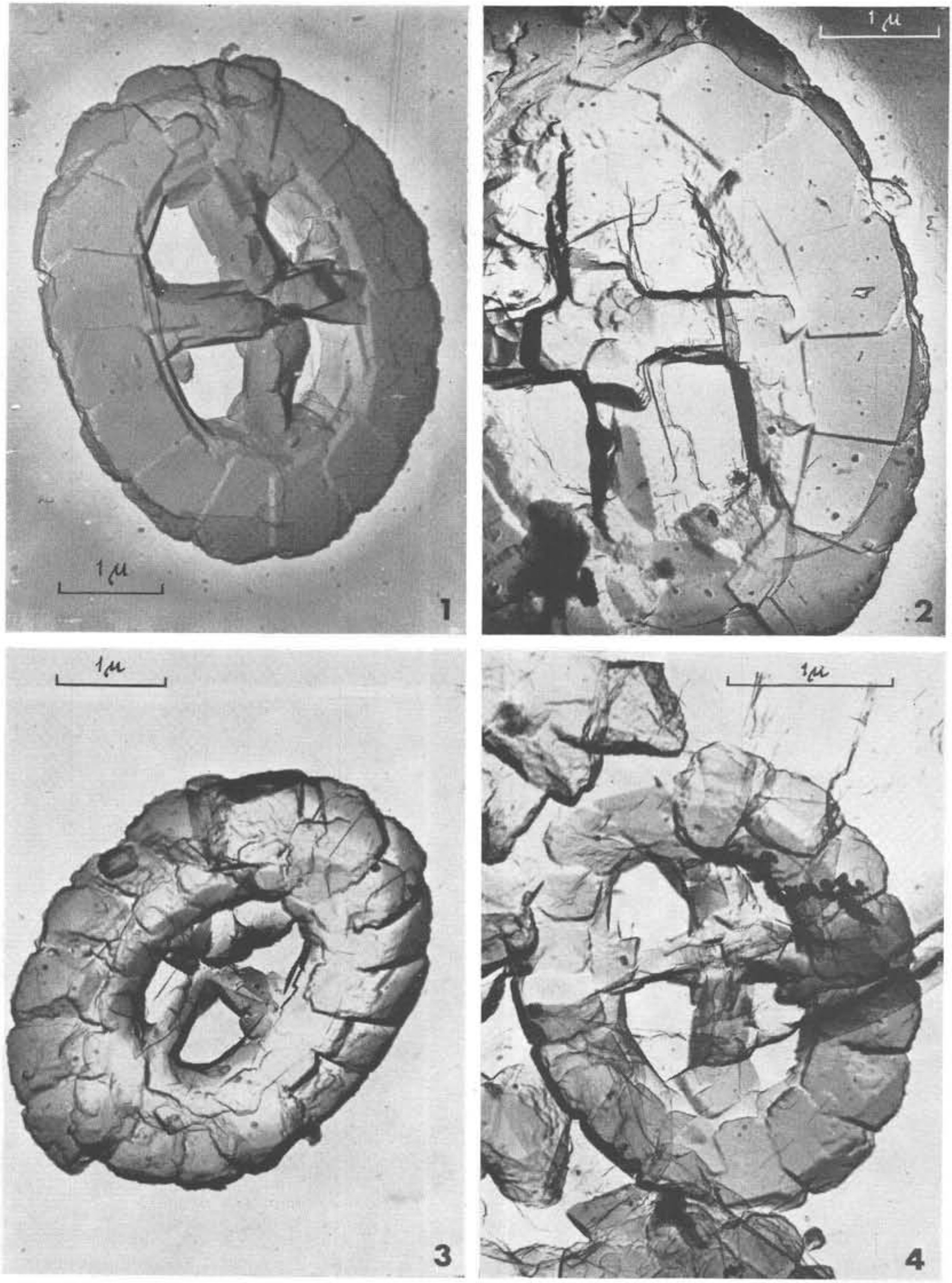

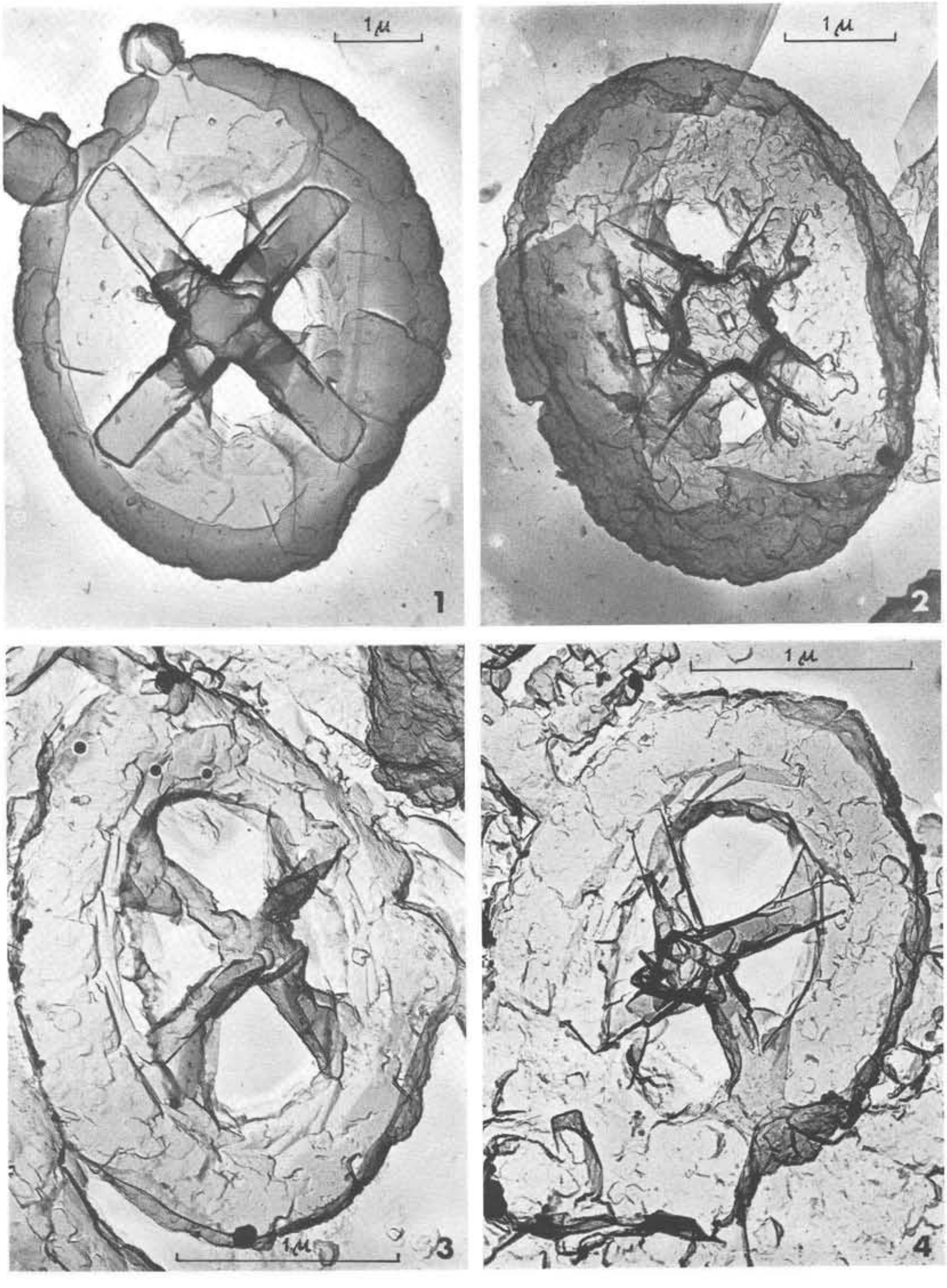
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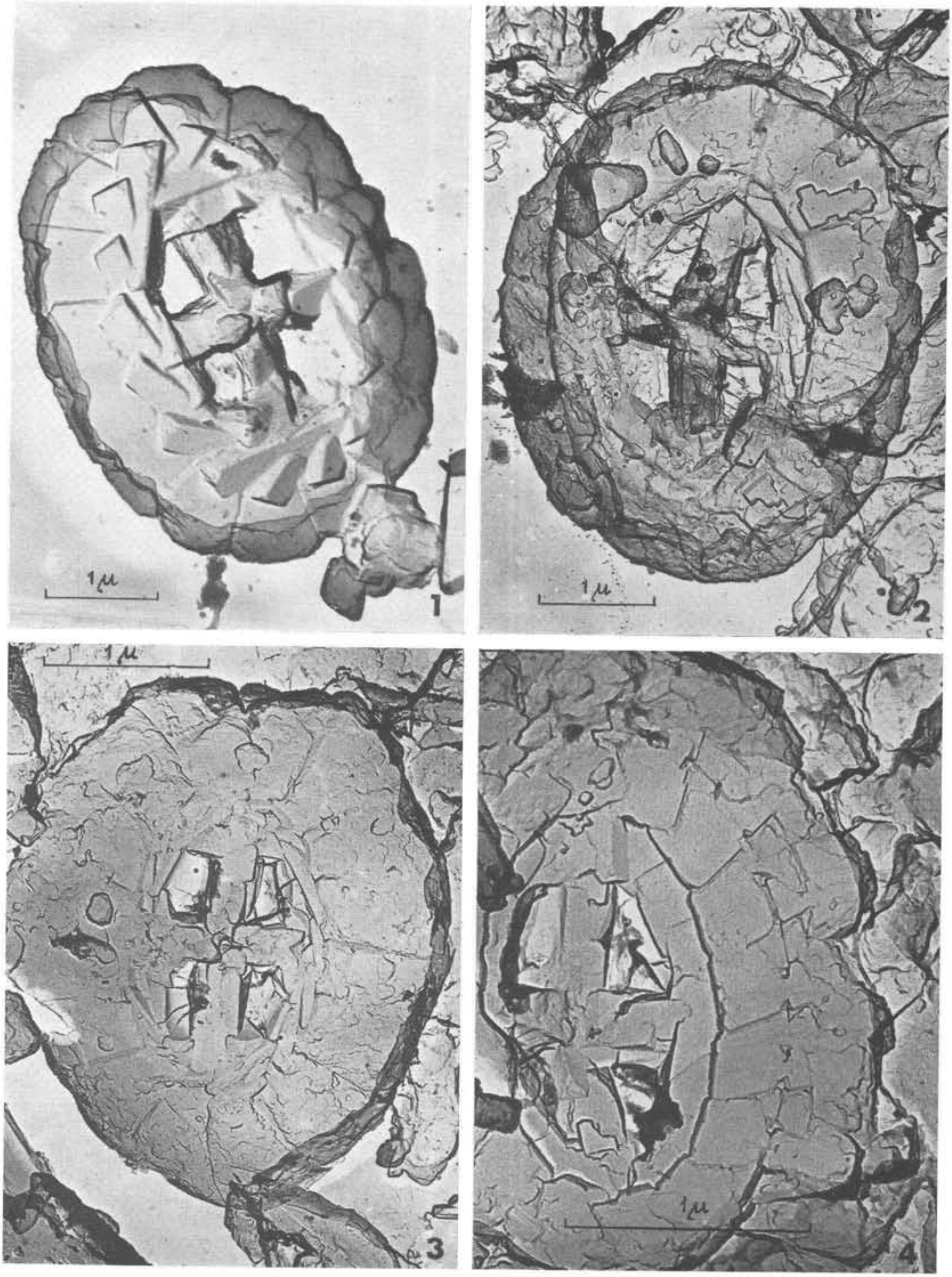

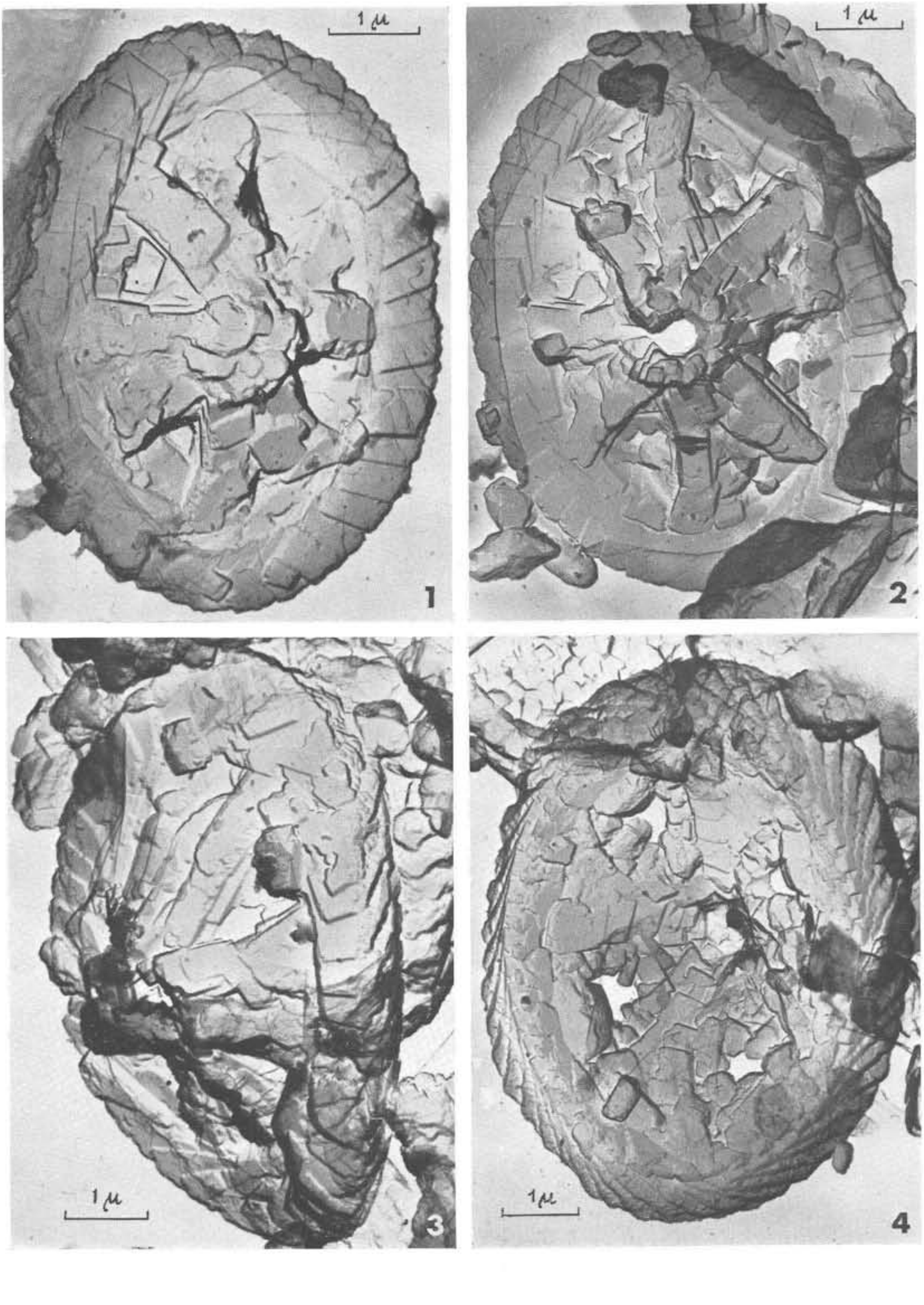
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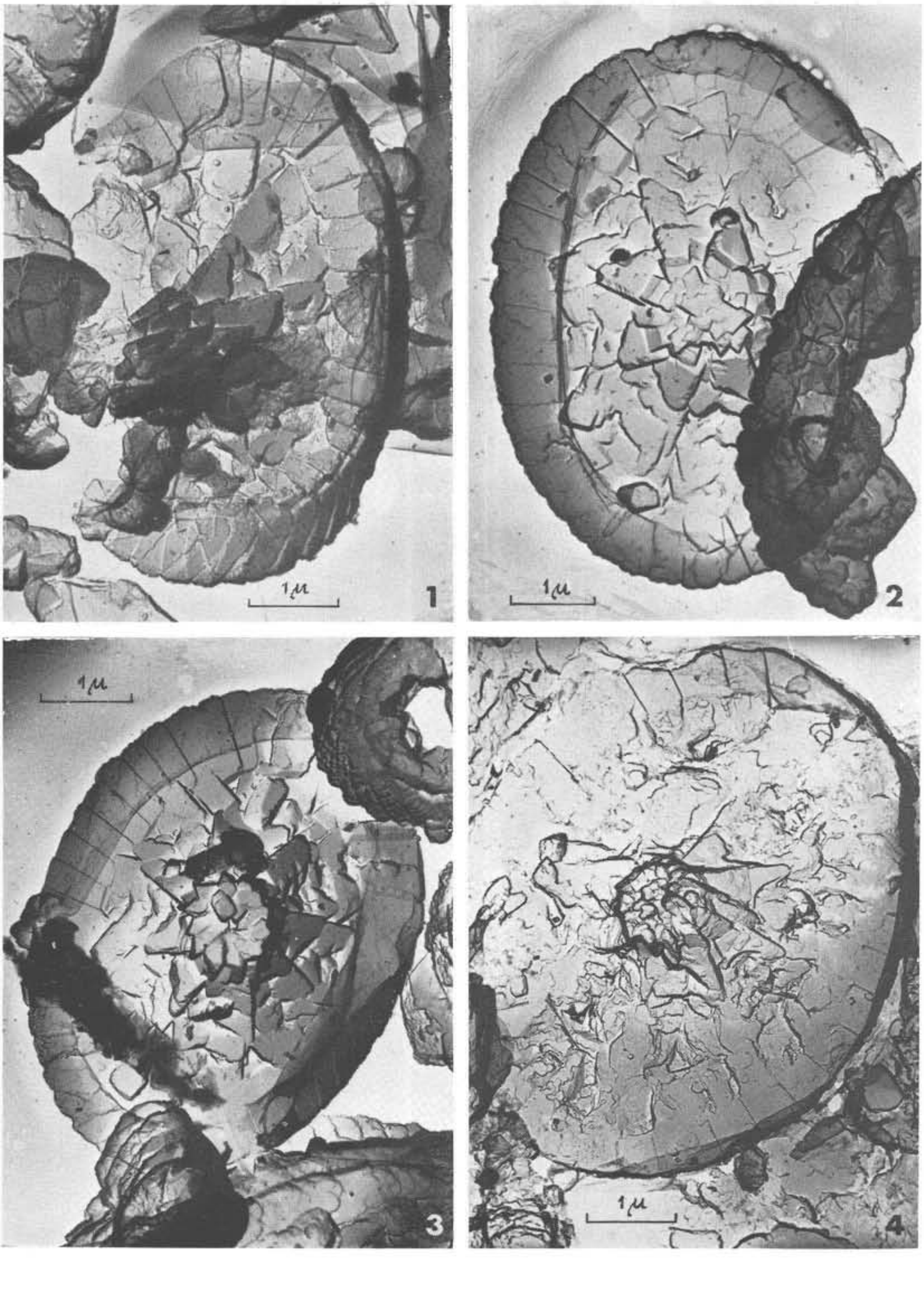

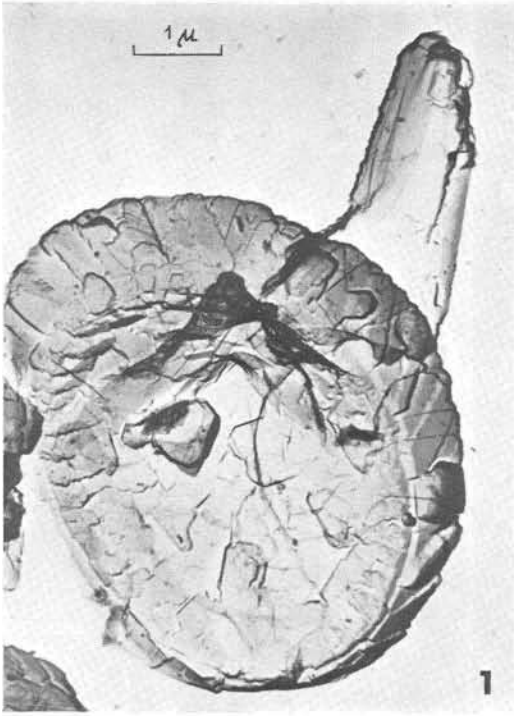
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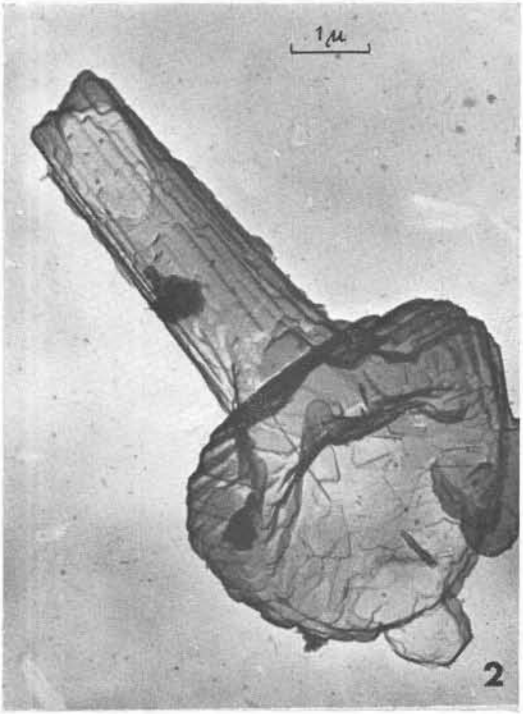
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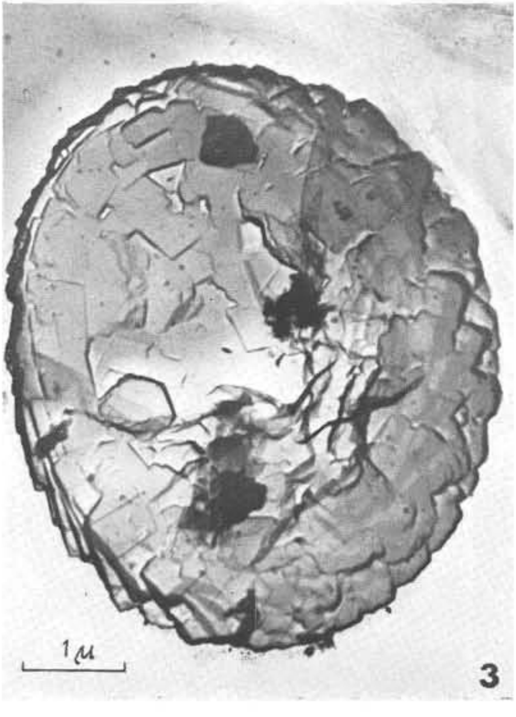
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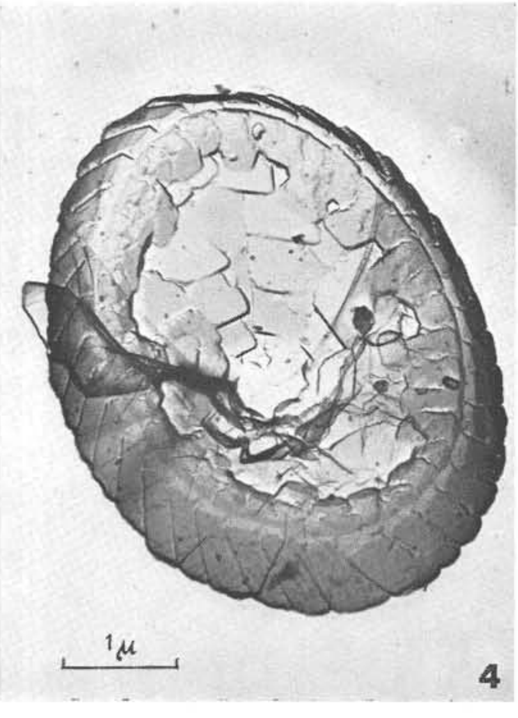
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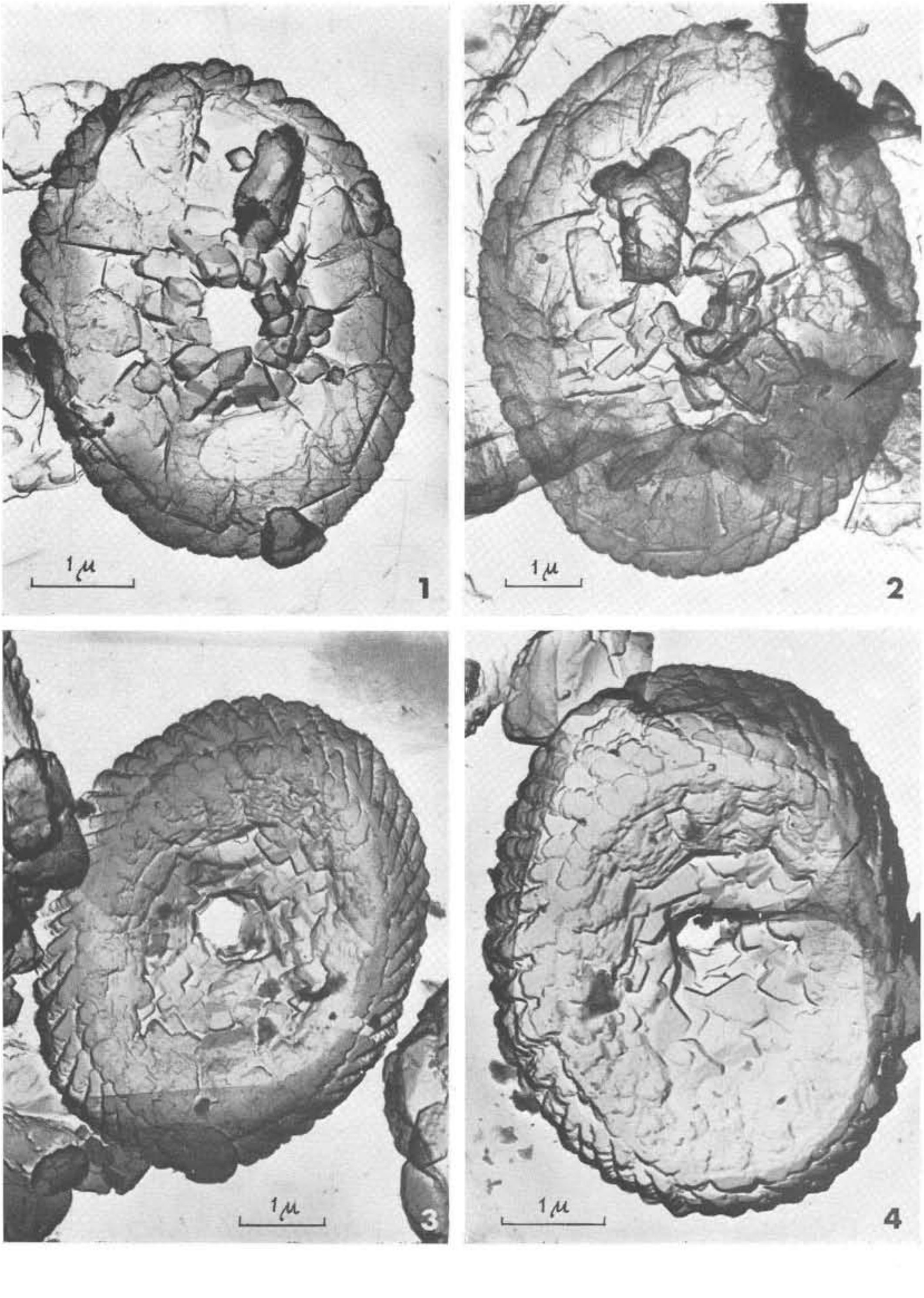
PLATE 26



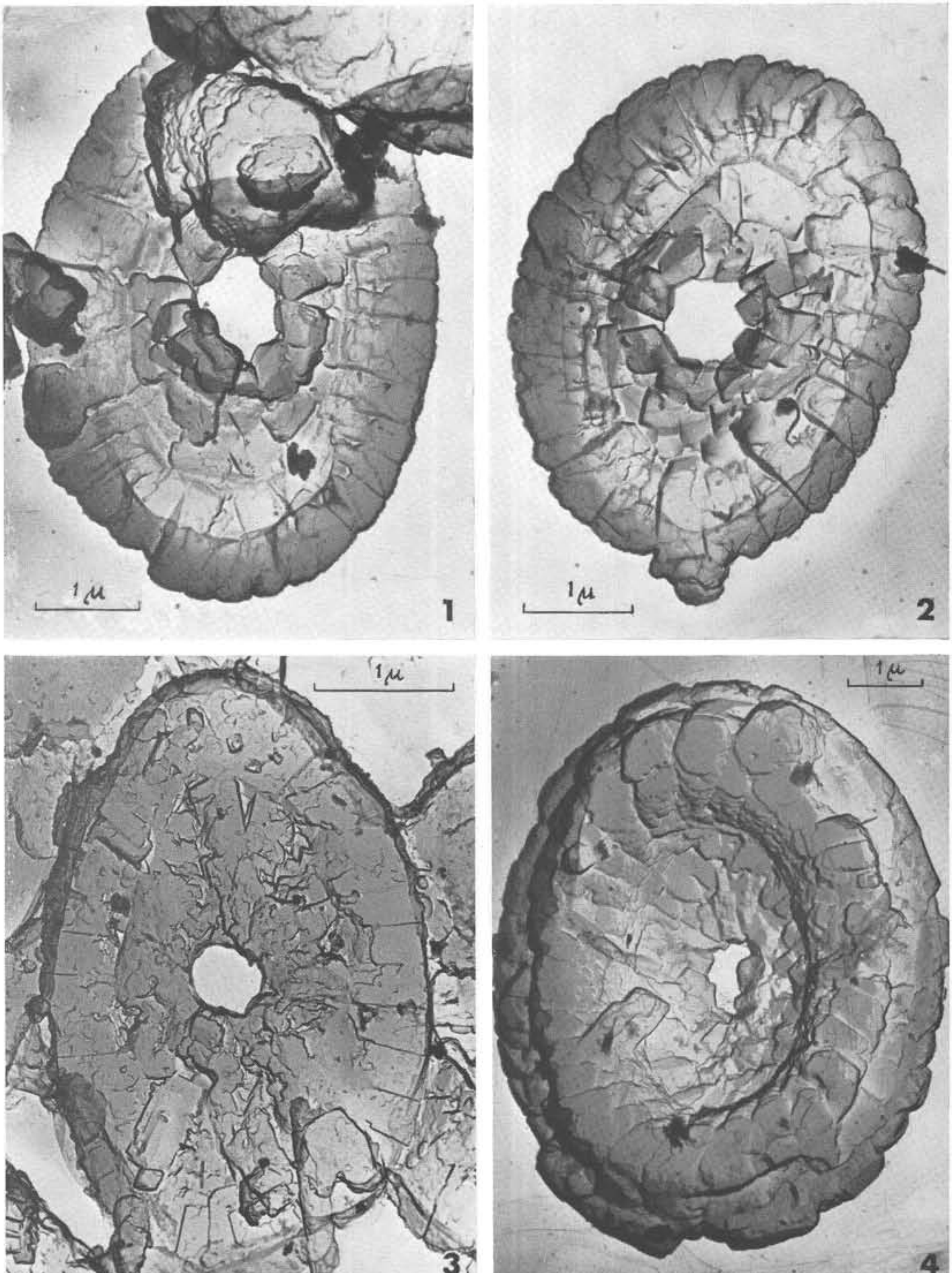

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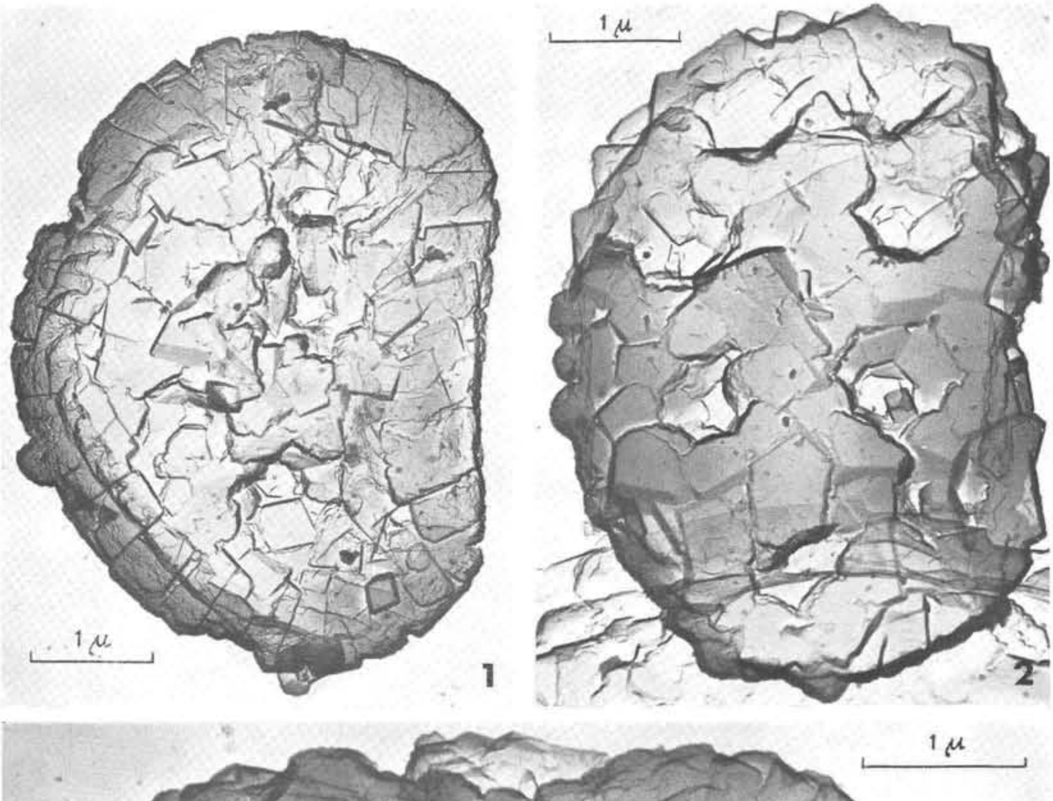
PLATE 28



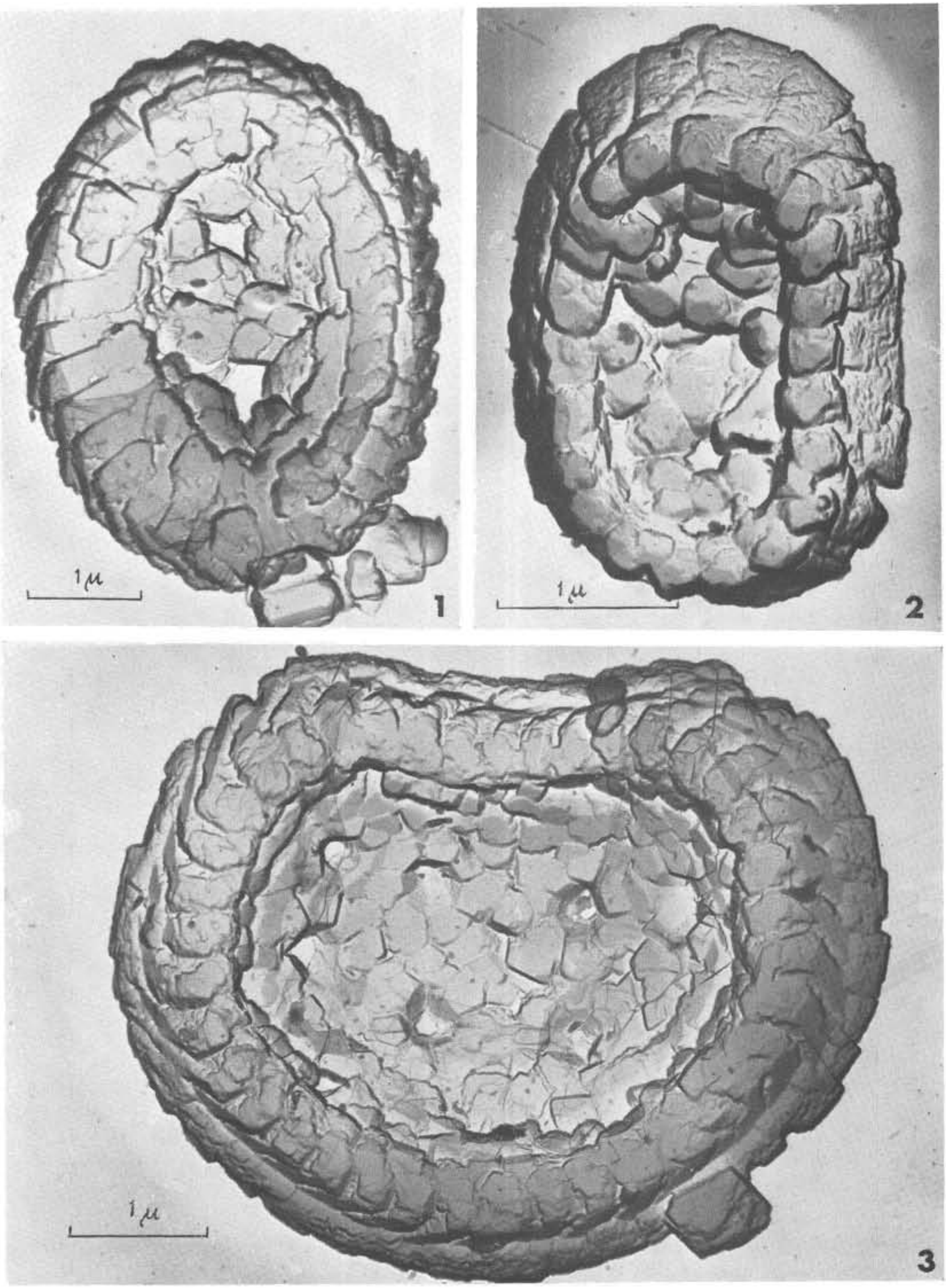

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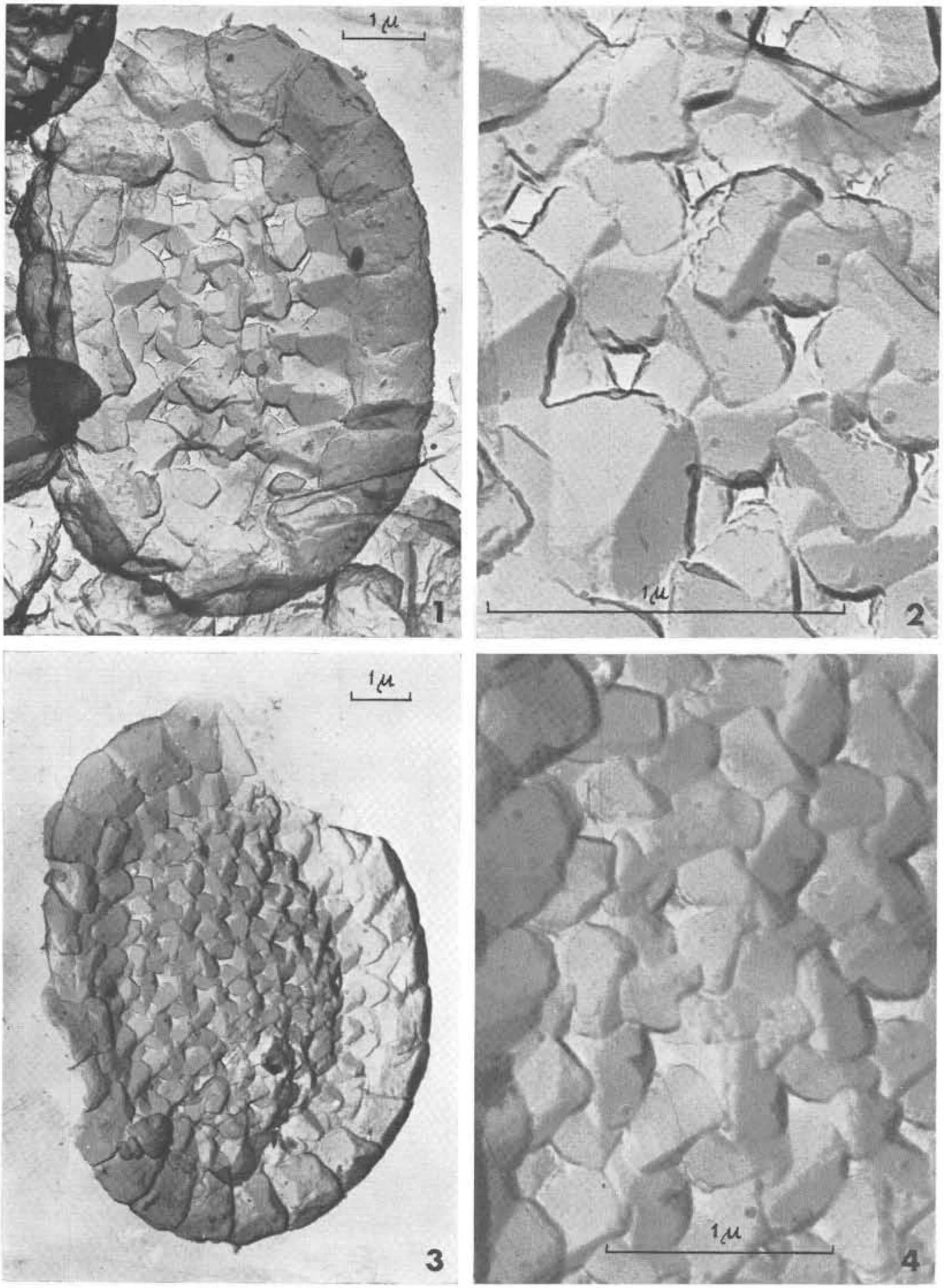
PLATE 30



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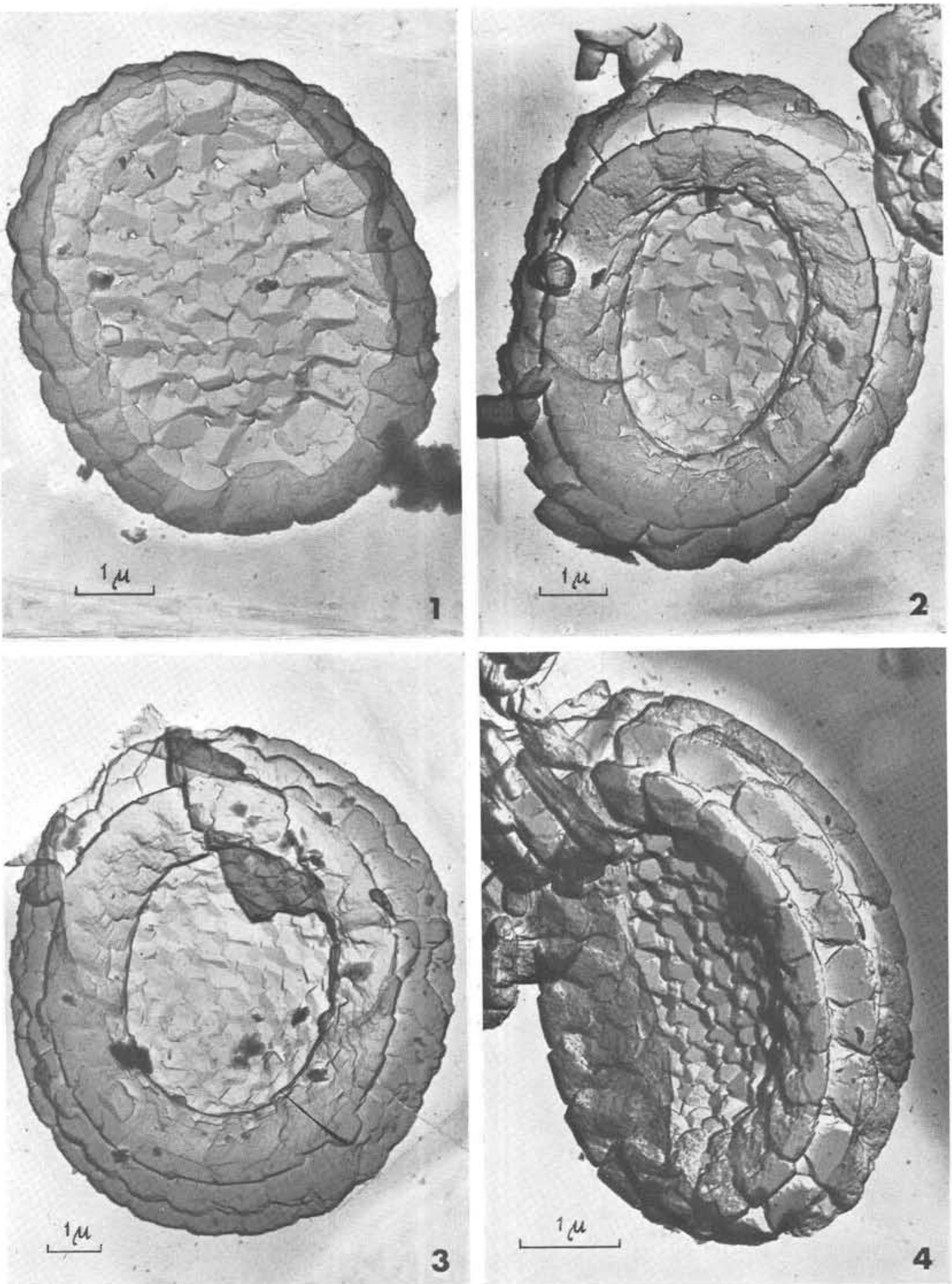

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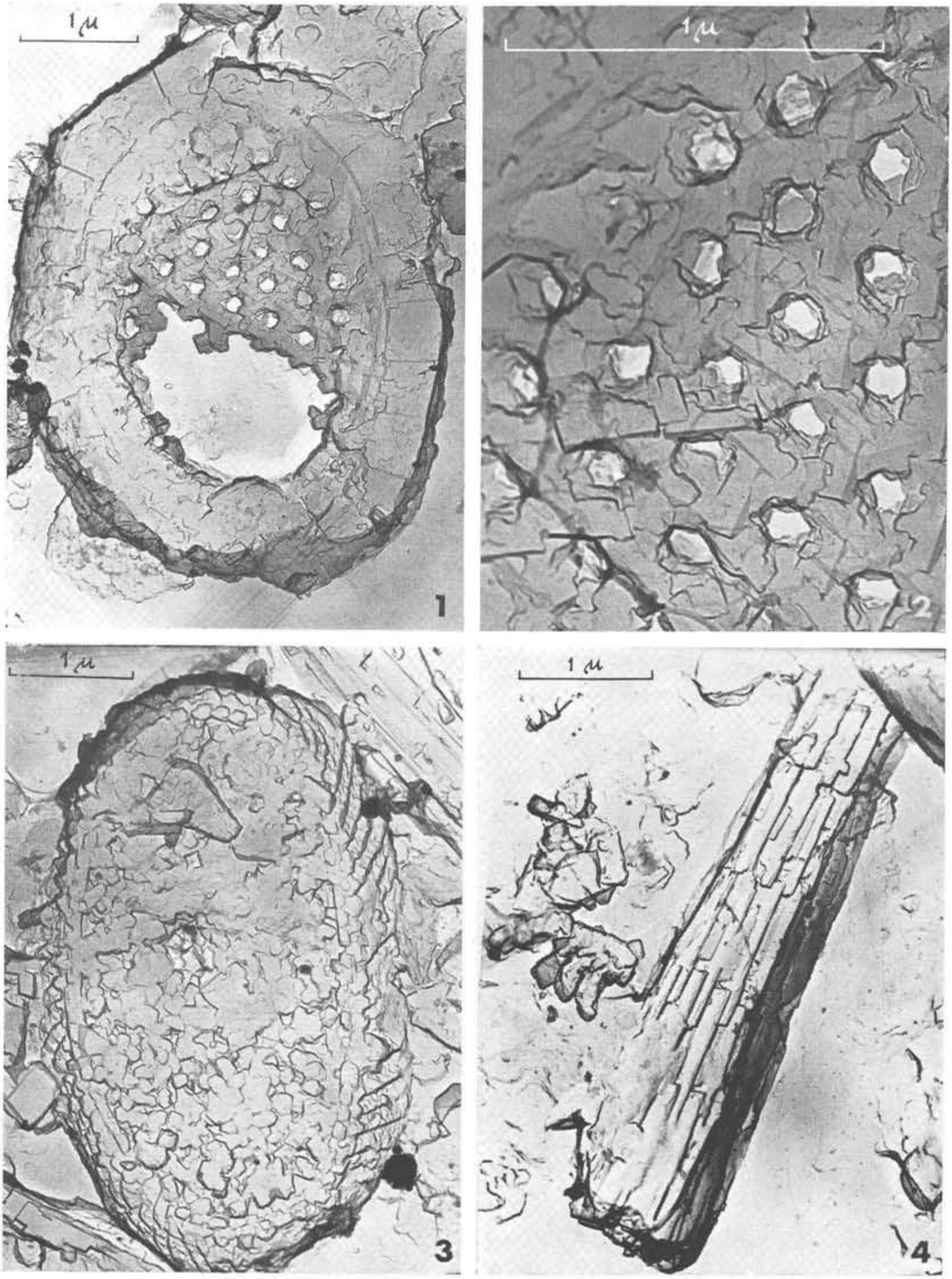


PLATE 33

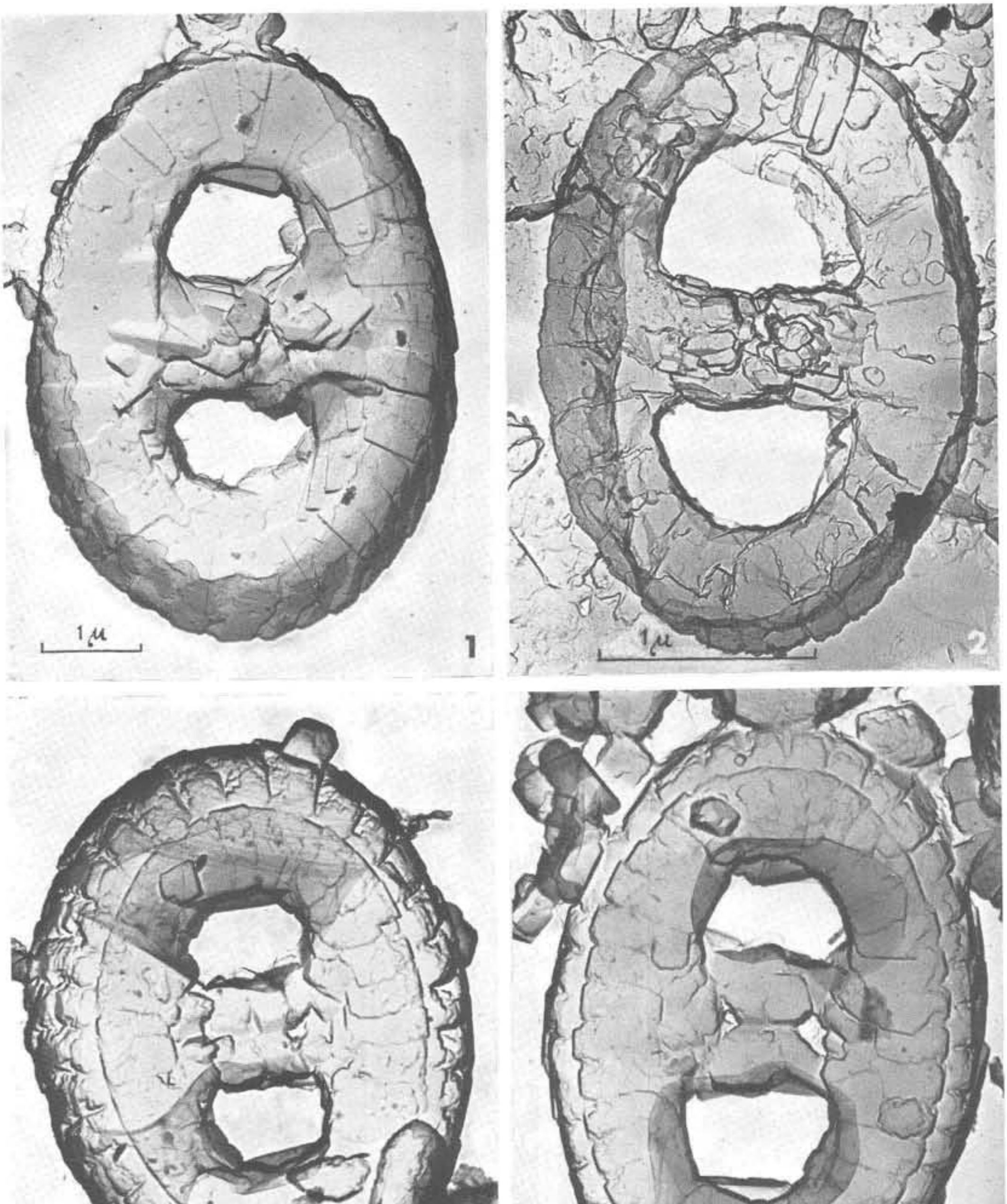
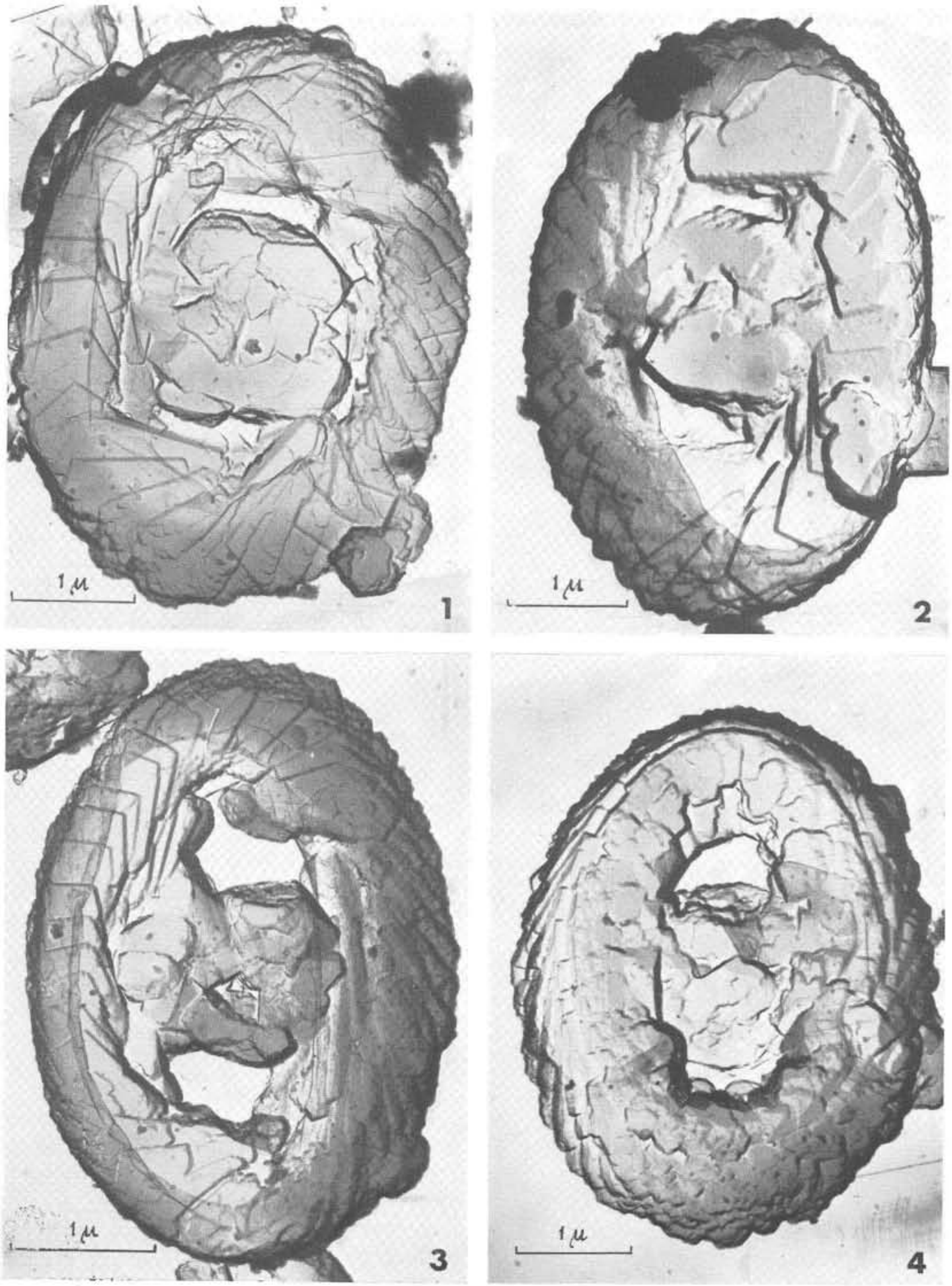
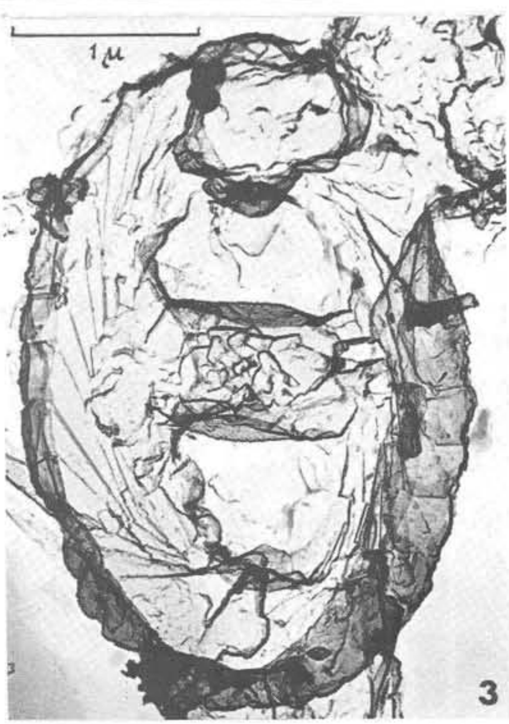


PLATE 34




1μ
1


1μ
2


1μ
3

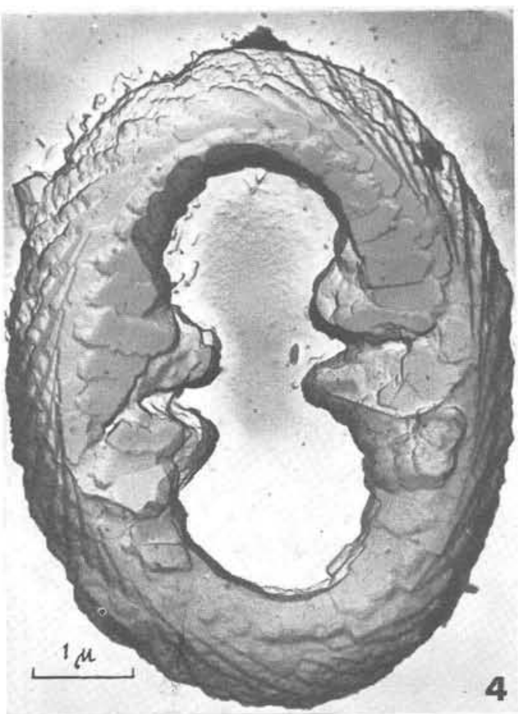
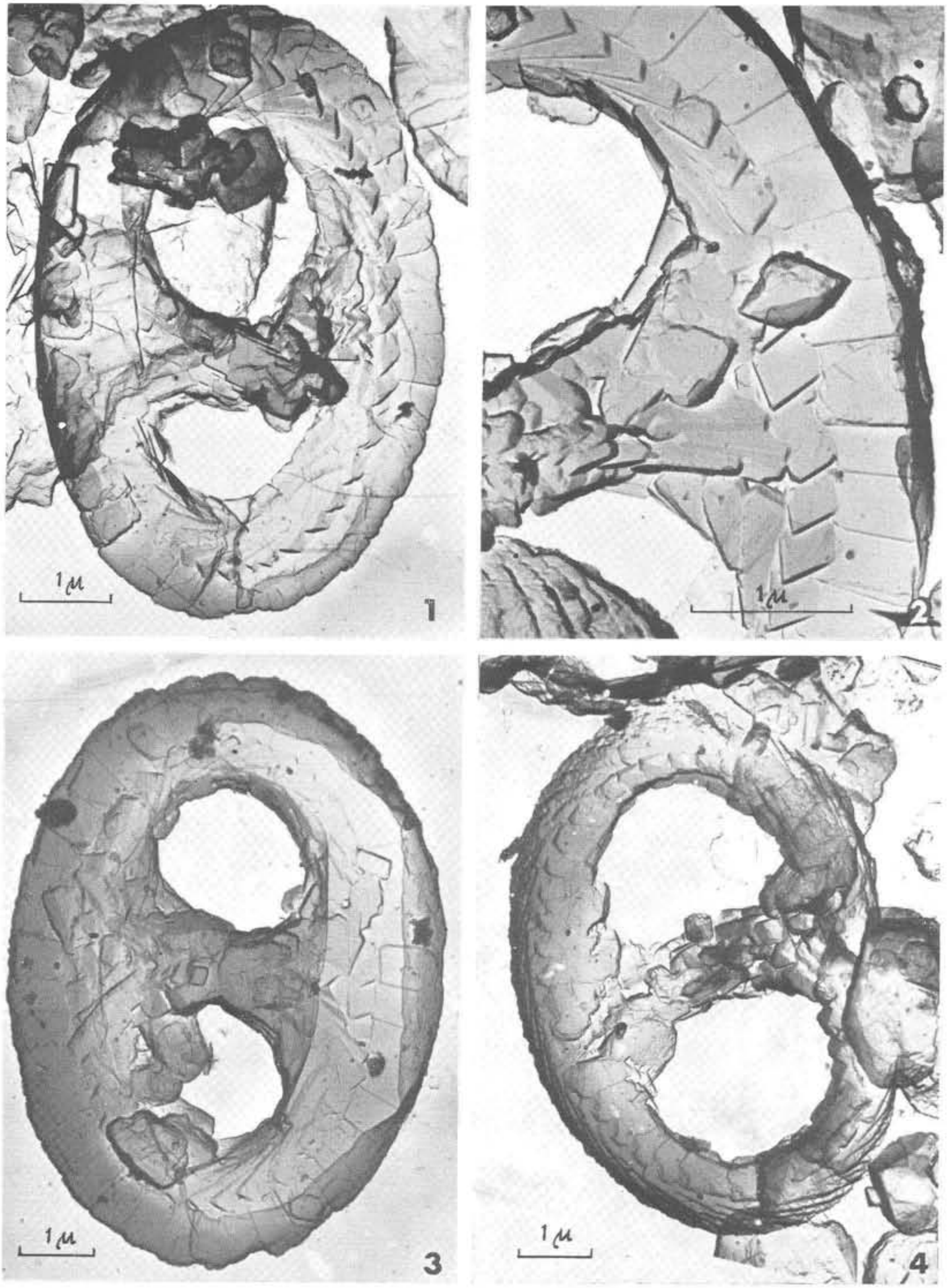
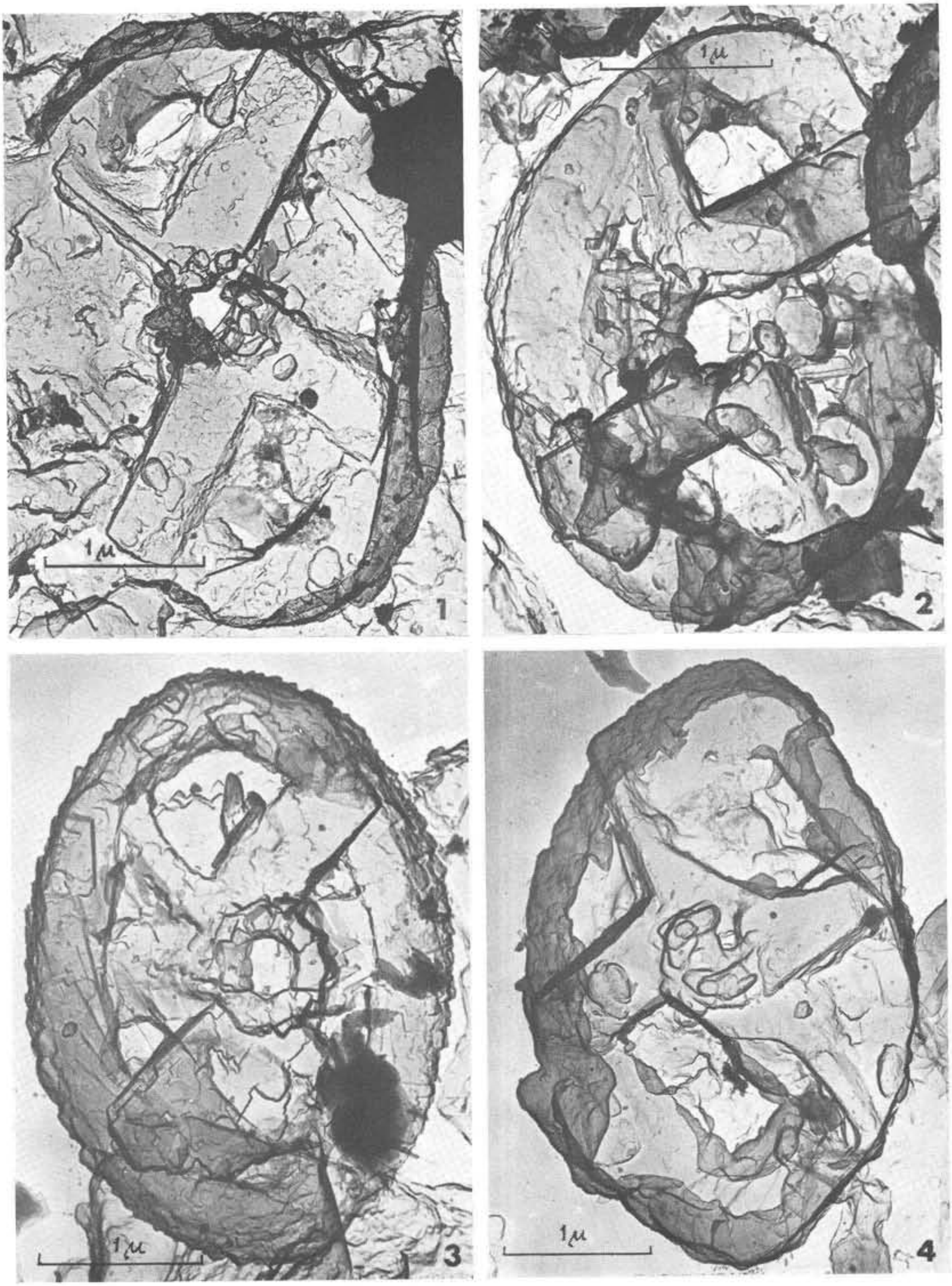
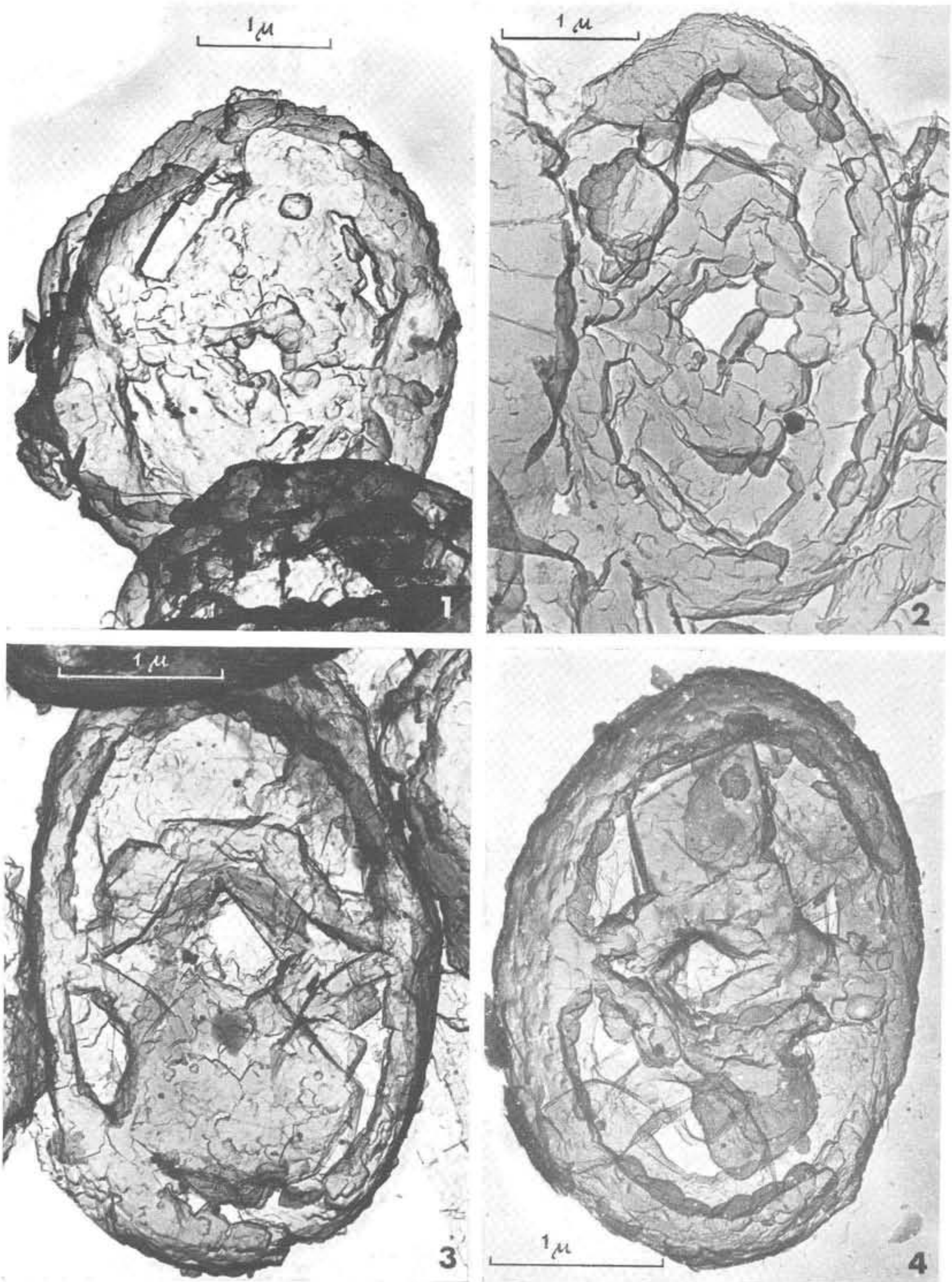

1μ
4

PLATE 36




1μ
1
1μ
2
1μ
3
1μ
4


1 μ
1
1 μ
2
1 μ
3
1 μ
4

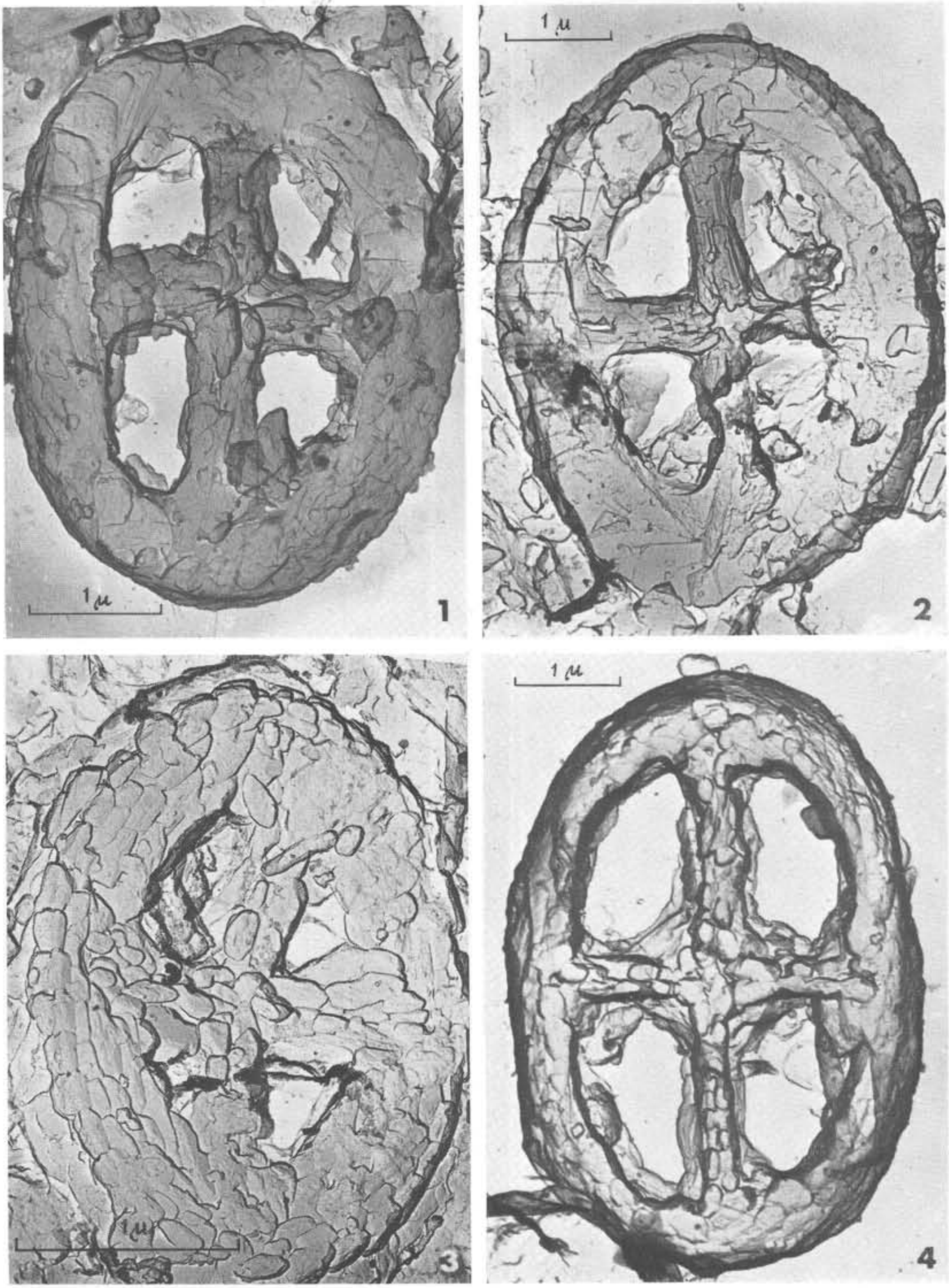

1 μ
1
1 μ
2
1 μ
3
1 μ
4

PLATE 40

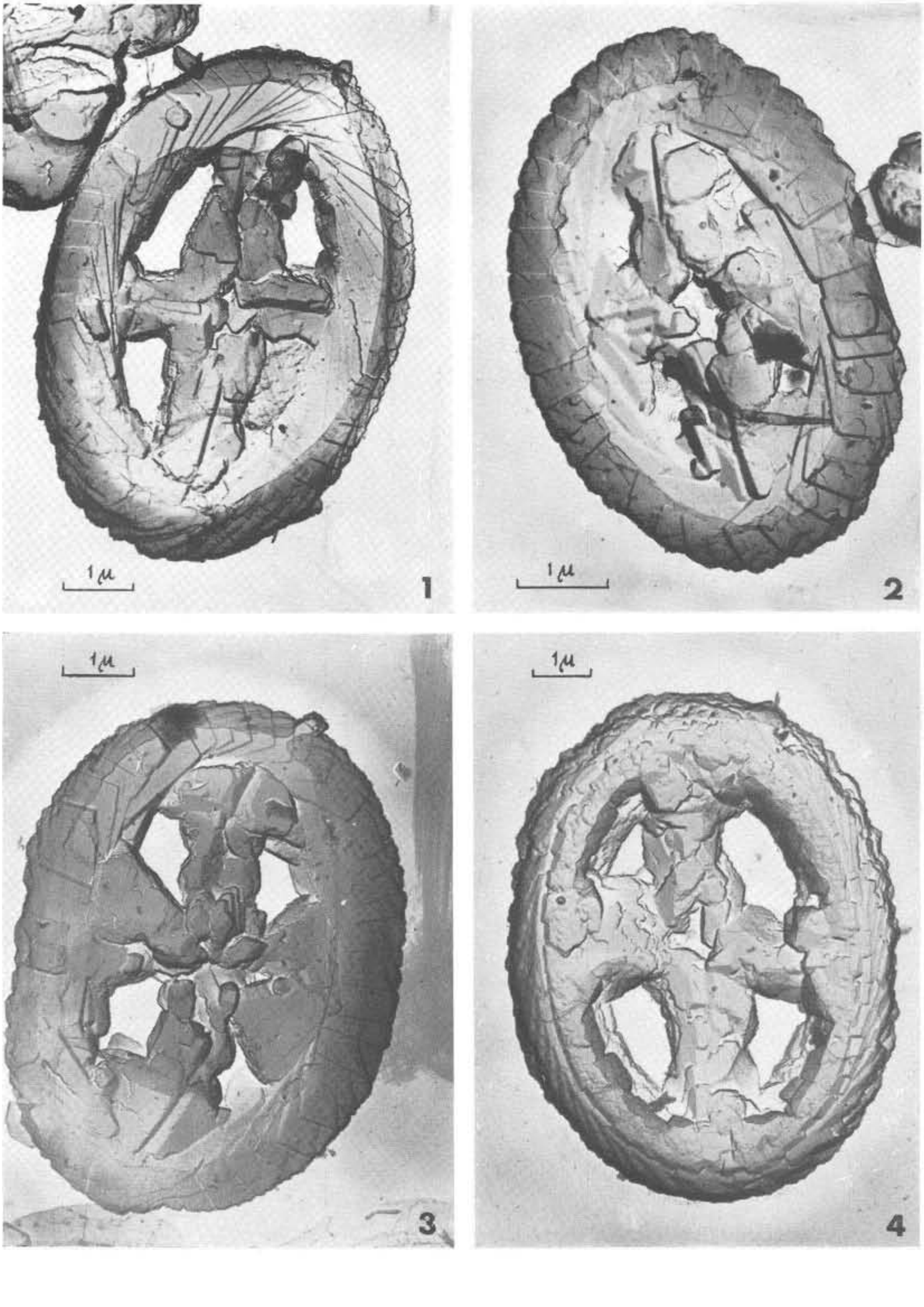


PLATE 41

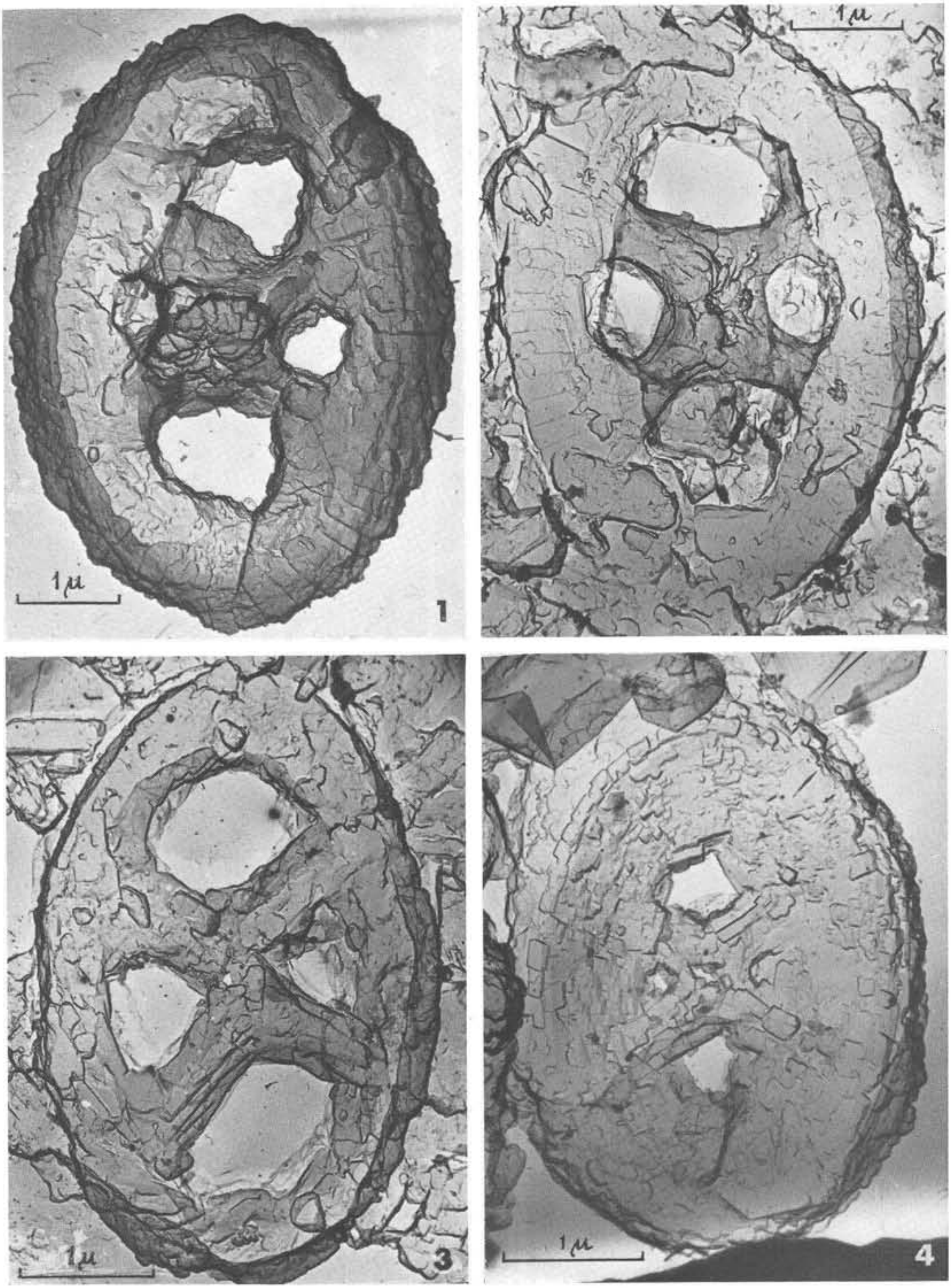
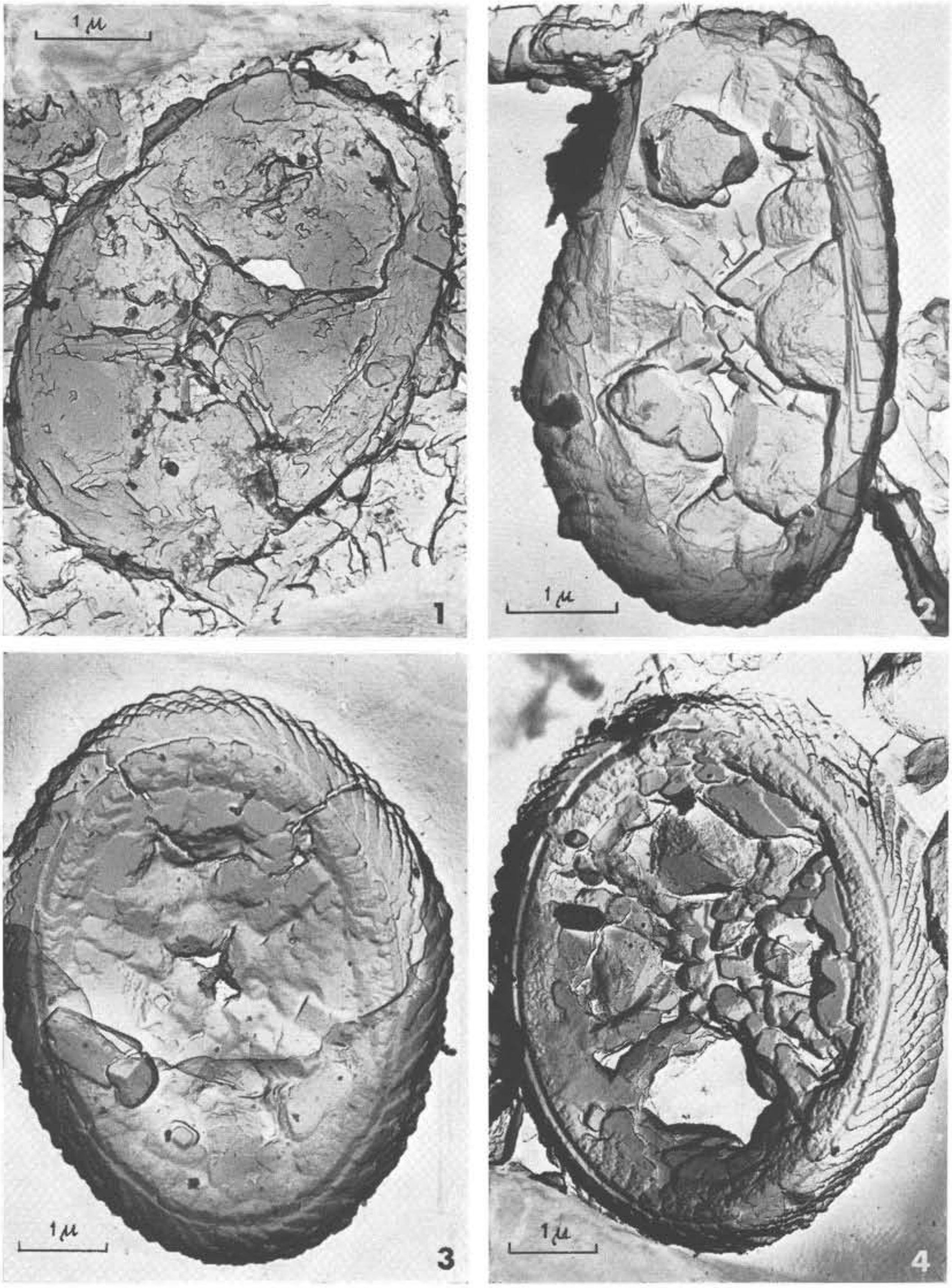


PLATE 42



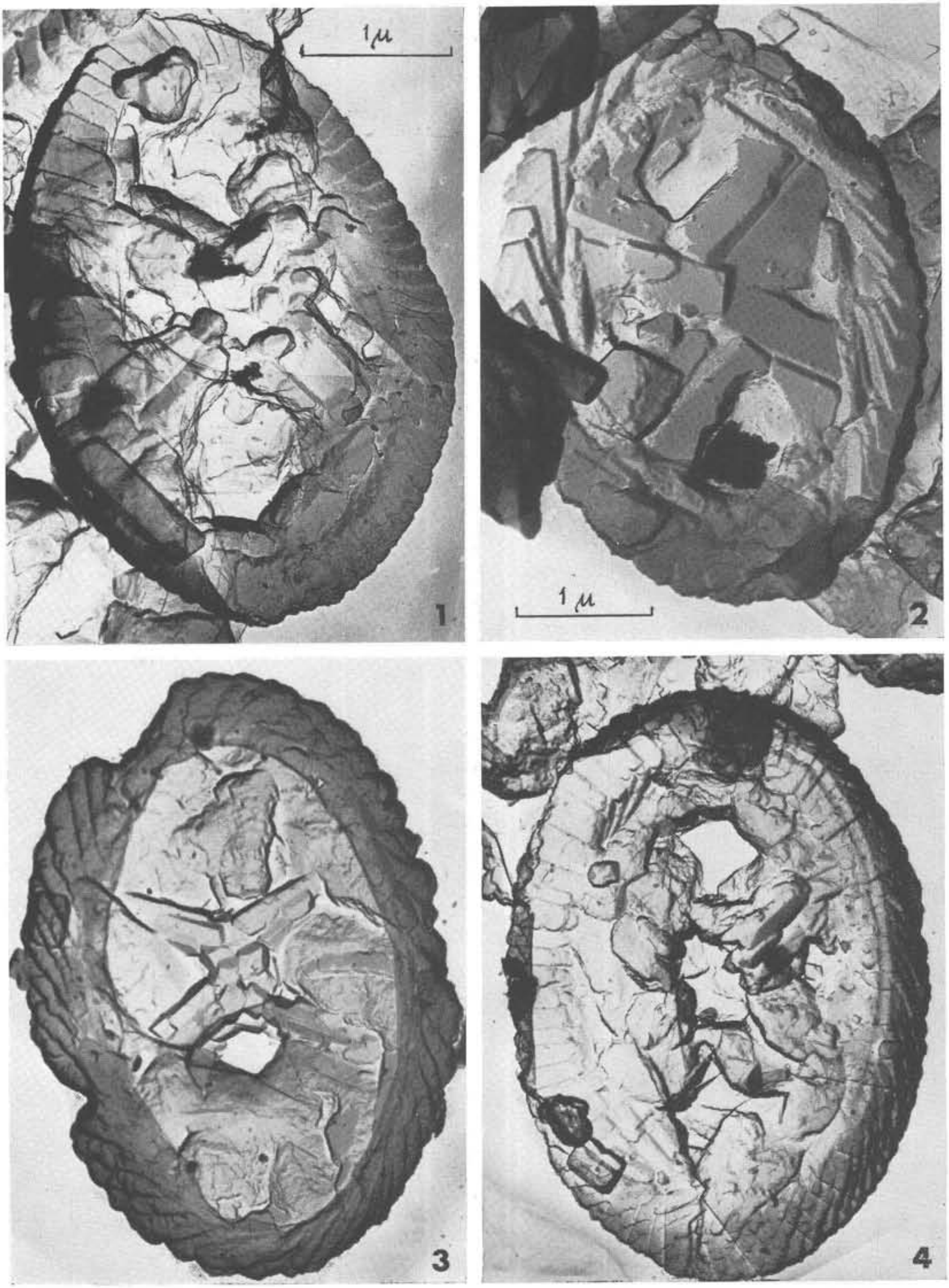
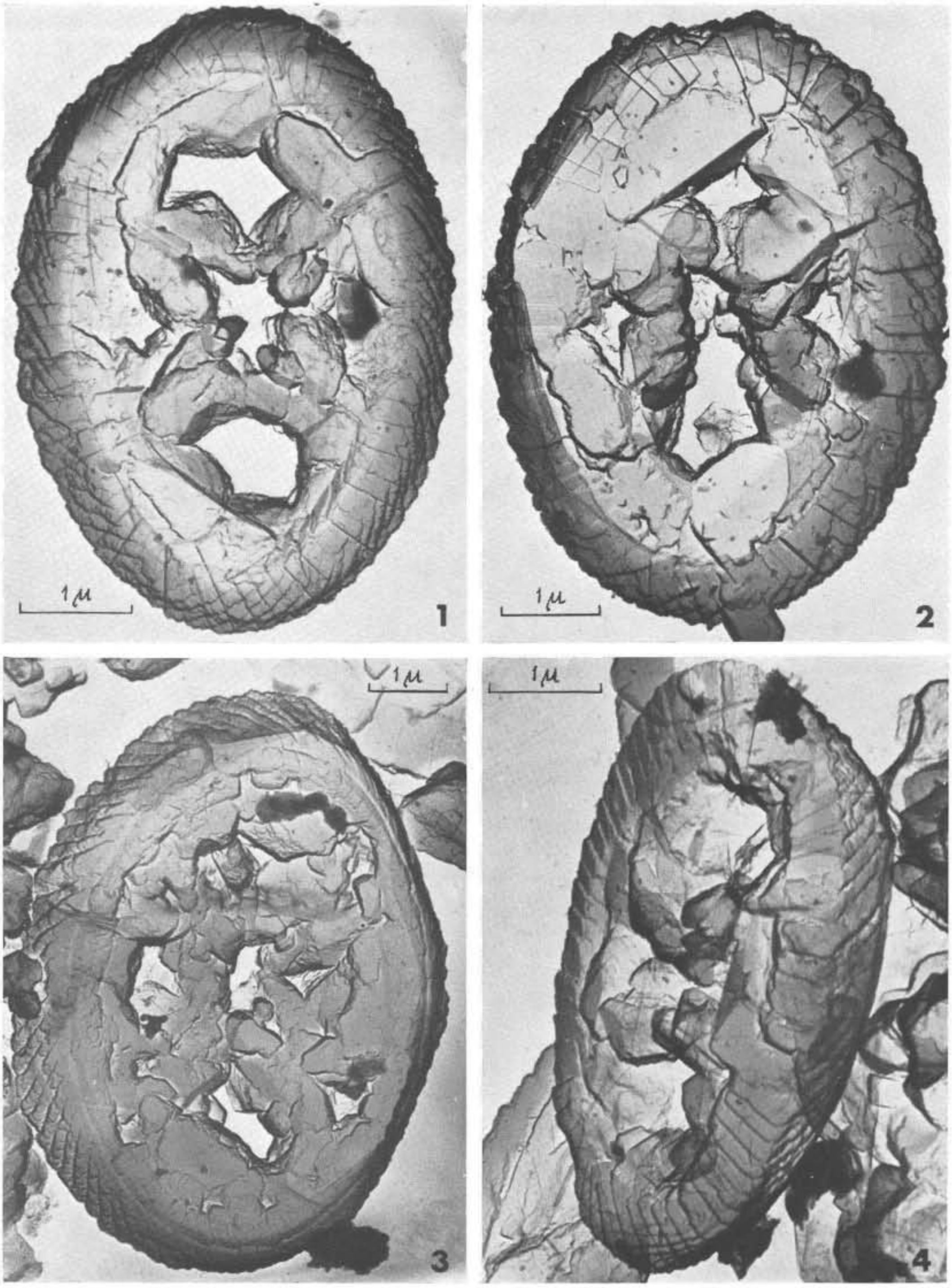

1 μ
1
1 μ
2
3
4

PLATE 44



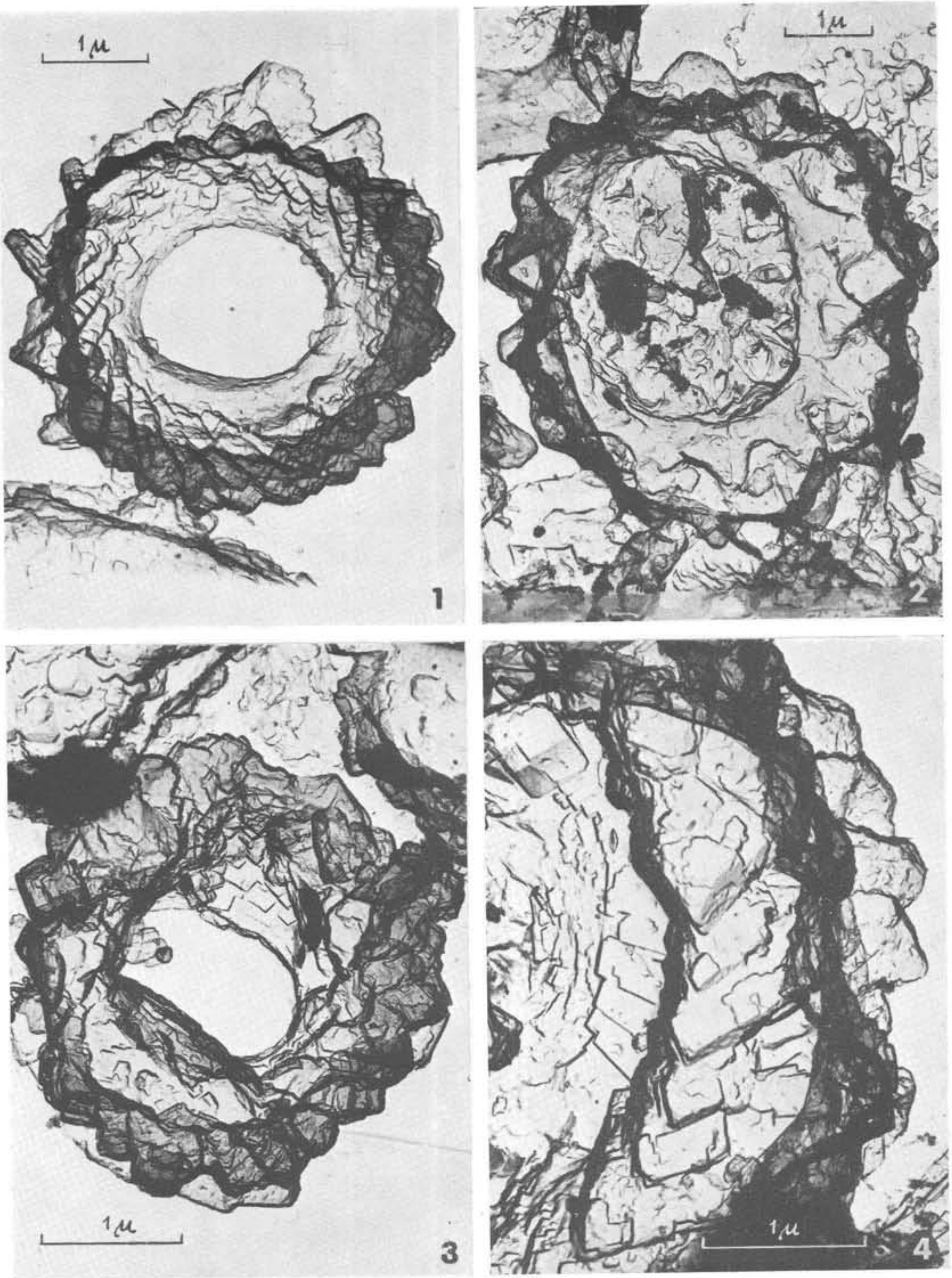
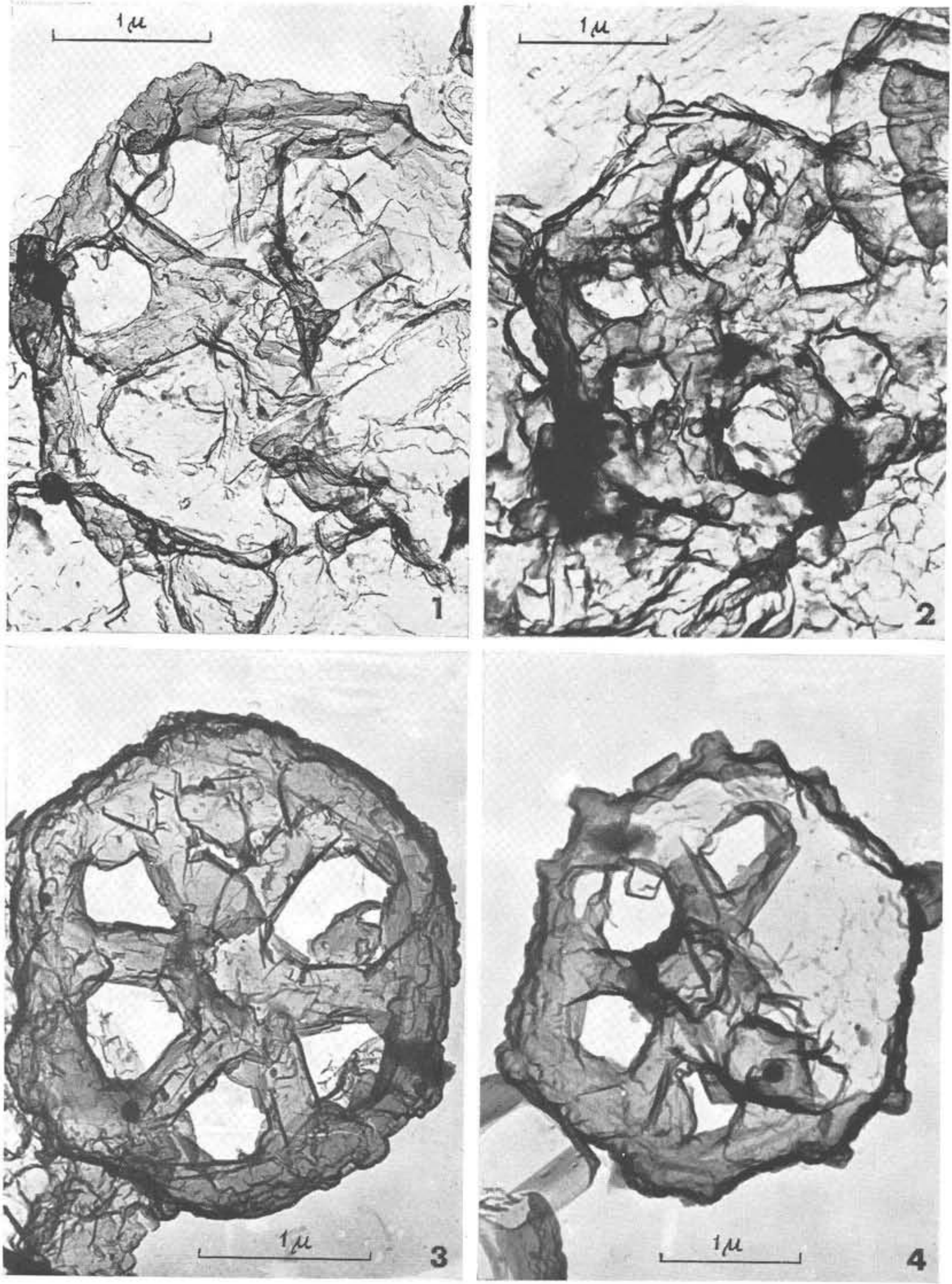
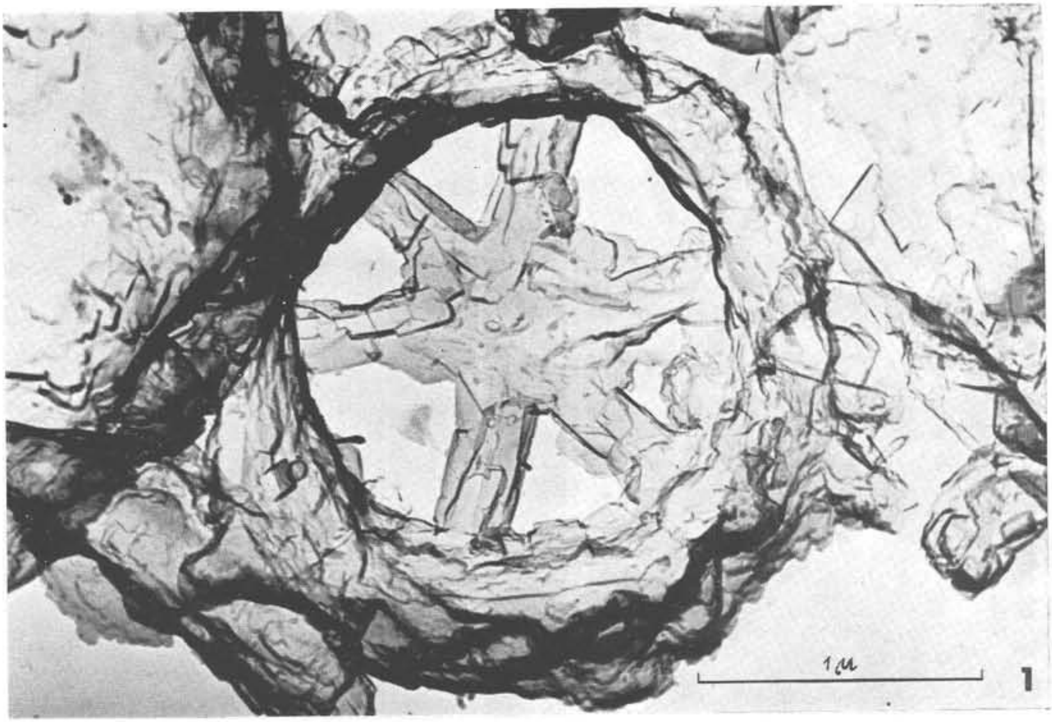
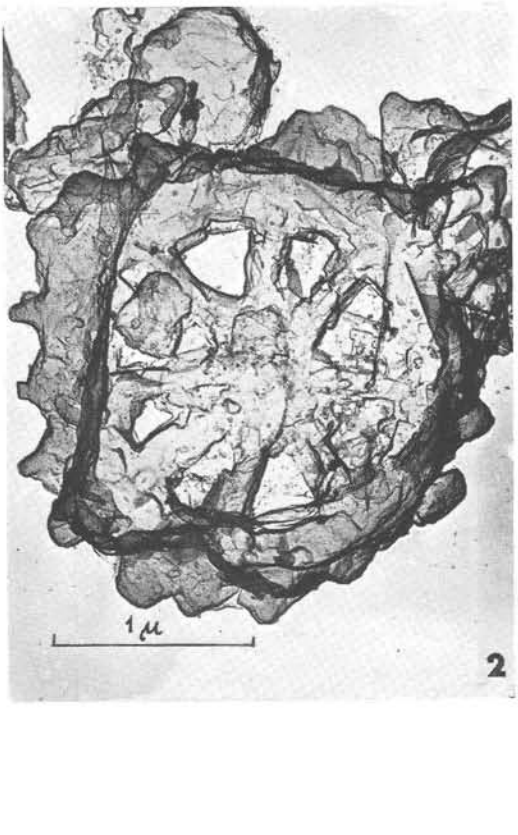

1 μ
1
1 μ
2
1 μ
3
1 μ
4

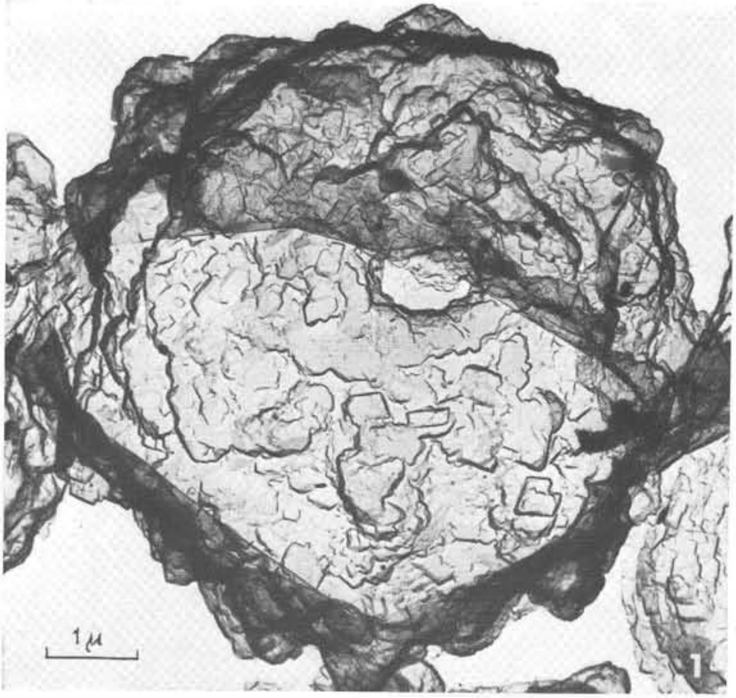
PLATE 46



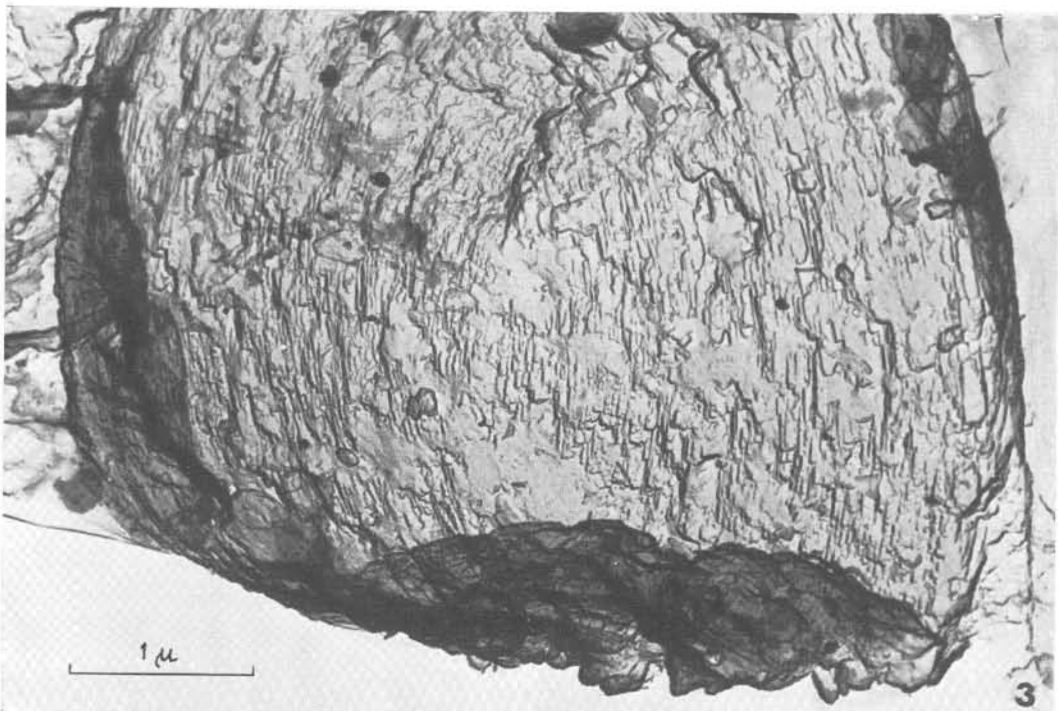

1 μ
1

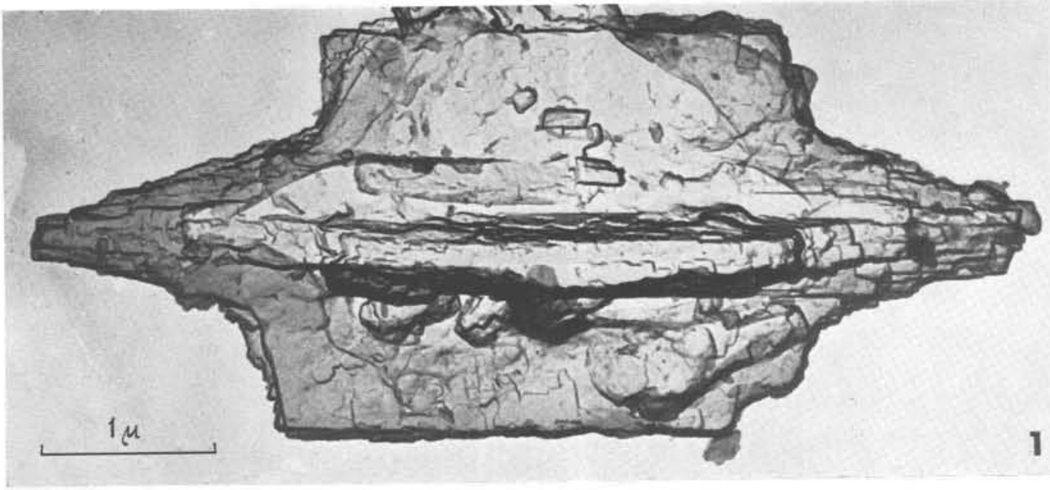

1 μ
2

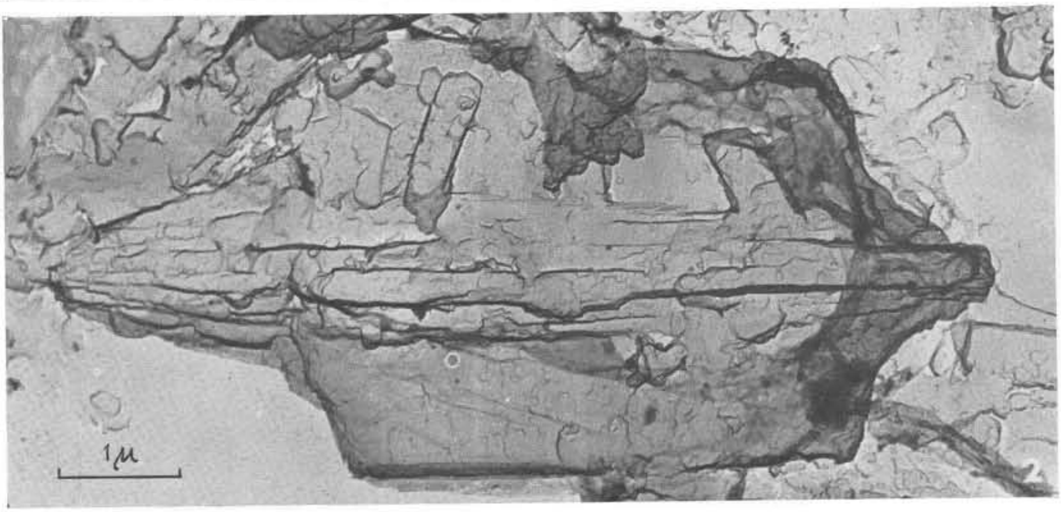

1 μ
3

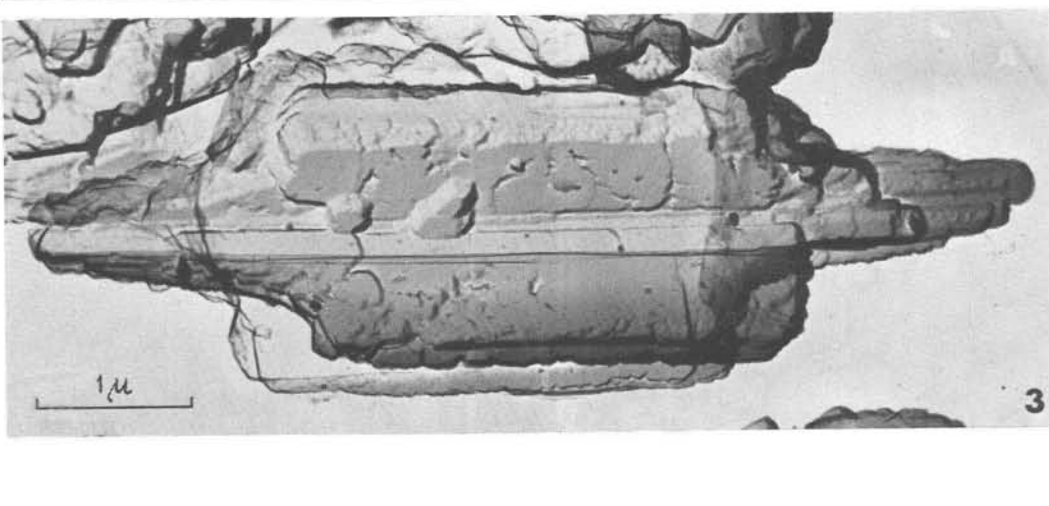

1 μ
1

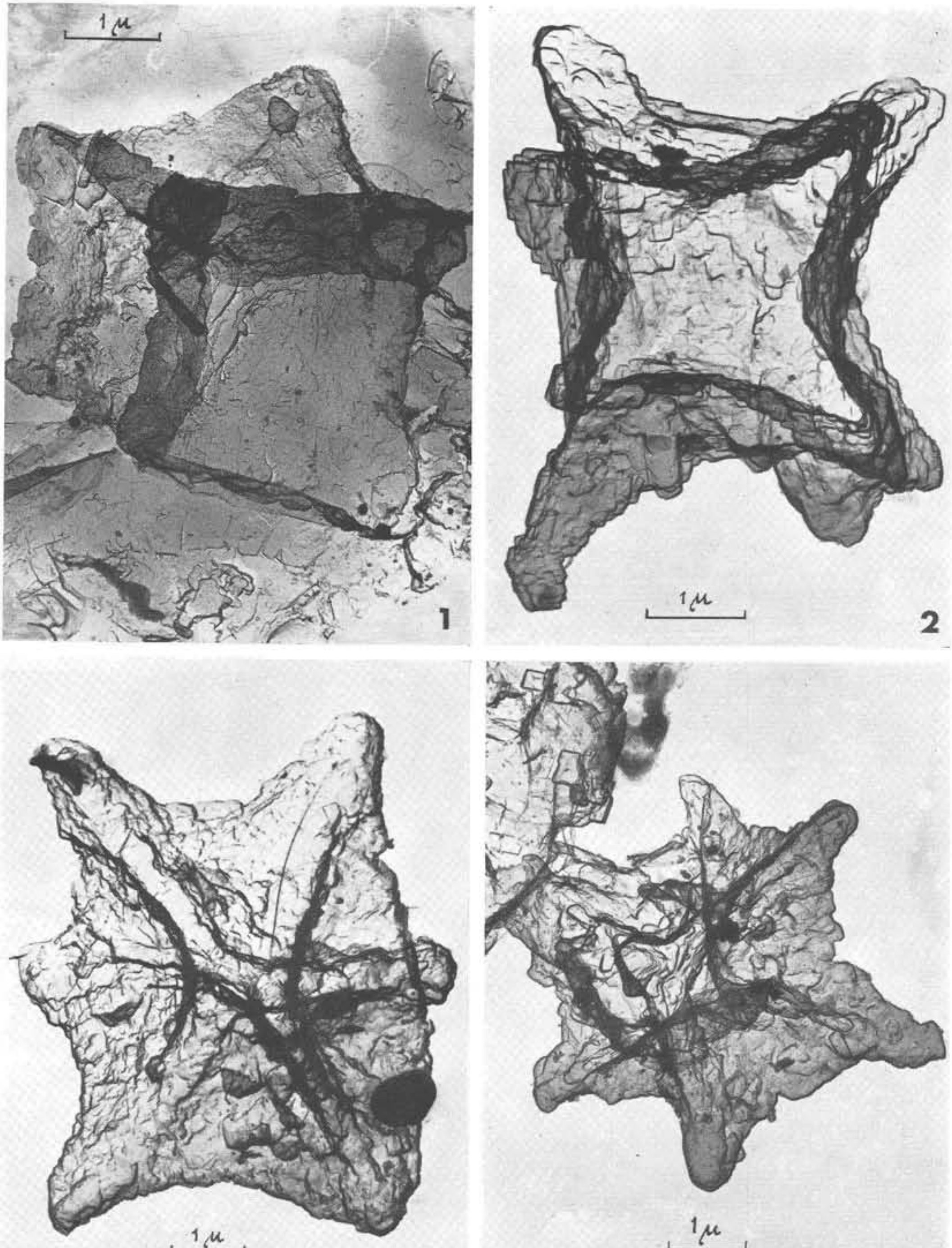

2


1 μ
3


1μ
1


1μ
2


1μ
3


1 μ
1
1 μ
2
1 μ
3
1 μ
4

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Zoologisch-Botanische Datenbank/Zoological-Botanical Database

Digitale Literatur/Digital Literature

Zeitschrift/Journal: Jahrbuch der Geologischen Bundesanstalt Sonderbände

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