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THE NANNOFOSSILS OF THE EOCENE FLYSCH IN THE HAGENBACH VALLEY (NORTHERN VIENNA WOODS), AUSTRIA

(Pl. LXXX—LXXXIX, 4 Figs.)

Nannofossilien vom Eozän Flysch im Hagenbach Tal (Wienerwald) Österreich

(Taf. LXXX—LXXXIX, 4 Fig.)

A b s t r a c t: Assemblages of nannofossils (shell remains of marine calcareous phytoflagellates) occurring in the Eocene flysch of the Hagenbach Valley in the Northern Vienna Woods, Austria, were analysed and their occurrence listed. Besides 46 nannofossil species of Tertiary age, also reworked nannofossils from Lower and Upper Cretaceous were recorded. The nannofossil assemblages were found to be typical for the „Marthasterites tribrachiatus-Zone" and are considered to be of Lower Eocene age. Two new subzones, the „*Scyphosphaera columella* Subzone" (lower Lower Eocene) and the „*Scyphosphaera tubicena* Subzone" (middle Lower Eocene) are proposed on account of two species of the genus *Scyphosphaera*, which are described as new to science. The nannoplankton zonation of flysch sediments from the Paleocene and Eocene of Austria, Czechoslovakia, Poland and Switzerland is discussed and correlated.

PREFACE

„Nannofossil" is a general term used for describing very small calcareous shell elements occurring in marine sediments from Jurassic to Recent and measuring no more than 3—40 microns. The majority of nannofossils is produced by phytoflagellates (Coccolithineae), who inside their plasmatic cell-body secrete the elliptical or circular plates or rings, tubes or polygonal elements. Besides the coccoliths, the shell elements of the Coccolithineae, also the discoasters, star-or rosette-shaped elements derived from calcareous flagellates, can be used as guide-fossils for a detailed zonation of marine sediments.

This paper is intended to demonstrate once more, that flysch sediments of many places are very rich in fossils, not in mega- nor in microfossils, but in nannofossils. This statement, which is considered to be a positive addition to our traditional view of the flysch as a sediment poor in bodily preserved fossils, might be of interest not only to paleontologists and paleo-ecologists, but also for stratigraphers and petroleum geologists.

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Already back in 1873 Gümbel proved that some Eocene marls contain „800 billions of coccoliths per cubic meter!" (his exclamation mark). For literature and data on nannofossils in Eocene marls of the Central European Flysch sediments the reader may refer to the following papers: Benesova & Hanzlikova (1962), Brix (1961), Bystrická (1963, 1964, 1965), Hay (1964), Hay & Schaub (1960), Radomski (1967, 1968), Stradner (1961, 1962, 1964).

On the Geology of the Hagenbach Valley

The Valley of the Hagenbach is situated in the northern part of the Vienna Sandstone Zone or Flyschzone (Küpper, 1962, 1965) and cuts through Upper Cretaceous and Lower Eocene sediments alternatively. Due to the erosion caused by the Hagenbach brook a deep creek exposes several natural outcrops along its course. The samples were taken from marly shales intercalating with flysch sandstones, dipping 40—70° SE to SSE in the middle part of the valley, where the Lower Eocene is exposed.

For more detailed information on the Geology of the Flysch of the Vienna Woods the reader is referred to „Geologie von Wien" (H. Küpper 1965) and to R. Grill 1968 and the literature quoted therein; for more information on the outcrops of the Hagenbach Valley and their lithology turn to the preceeding paper by F. Brix (same volume, p. 455), in which also a map with the position of the outcrops is shown (fig. 2).

The main bulk of fossils within the Flysch sediments exposed in the Hagenbach Valley are calcareous nannofossils. There are also arenaceous foraminifera, which are dealt with in the following paper by W. Grün (same volume, p. 305) and some nondescript planctonic Globigerinidae, which unfortunately are in a very poor state of preservation.

SYSTEMATIC DESCRIPTIONS

The following descriptions of calcareous nannofossils deal only with such forms that can be recognized and determined with the help of the light microscope. Smaller forms falling into the scope of electron microscopy are omitted.

Among the described forms two main groups can be discerned: 1) the star- and rosette-shaped discoasters, derived from heterotrophic marine unicellular calcareous flagellates, and 2) elliptical, round, rhombical, polygonal or tubular coccoliths, derived from phototrophic unicellular marine calcareous flagellates. The coccoliths can be sorted into two subgroups in respect to the life-cycle of the phytoflagellate, which produced them: the *holococcoliths,* derivates of the motile, flagellate phase and the *heterococcoliths,* derivates of the non-motile, aflagellate phase of the life-cycle.

Both groups of the discoaster- and coccolith-assemblage contain species of stratigraphic importance; some previously neglected species can be applied in addition to the recognized zone-markers as new guide-fossils or marker-fossils for a more detailed zonation of the Eocene.

LIST OF NANNOFOSSILS ENCOUNTERED IN THE „*MARTHASTERITES TRIBRACHIATUS* ZONE" OF THE HAGENBACH VALLEY, AUSTRIA

Ordo:	COCCOLITHOPHORALES Schiller 1926
Subordo:	*DISCOASTERINEAE* Kamptner 1967
Familia:	*Discoasteromonadaceae* Bursa 1965
	(= *Discoasteridae* Tan Sin Hok 1927)
Genus:	*Discoaster* Tan Sin Hok 1927
	D. binodosus
	D. elegans
	D. cf. *gemmifer*
	D. gemmeus
	D. kuepperi
	D. lenticularis
	D. lodoensis
	D. mirus
	D. multiradiatus
	D. salisburgensis
Genus:	*Marthasterites* Deflandre 1959
	M. tribrachiatus
Subordo:	*COCCOLITHINEAE* Kamptner 1928
Familia:	*Coccolithaceae* Kamptner 1928
Tribus:	*Coccolitheae* Kamptner 1958
Subtribus:	*Coccolithinae* Kamptner 1958
Genus:	*Campylosphaera* Kamptner 1963
	C. dela
Genus:	*Chiasmolithus* Hay, Mohler & Wade 1966
	C. bidens
	C. grandis
Genus:	*Coccolithus* Schwarz 1894
	C. bisulcus
	C. cribellum
	C. eopelagicus
	C. macellus
	C. pelagicus
	C. petrinus n. sp.
Genus:	*Reticulofenestra* Hay, Mohler & Wade 1966
	R. cf. *placomorpha*
Subtribus:	*Cyclococcolithinae* Kamptner 1958
Genus:	*Cyclococcolithus* Kamptner 1954
	C. gammation
Genus:	*Cyclolithella* Loeblich & Tappan 1963
	C. robusta
Subtribus:	*Rhabdosphaerinae* Stradner 1968+
Genus:	*Rhabdosphaera* Haeckel 1894
	R. herculea n. sp.
	R. cf. *pinguis*
	R. truncata
Genus:	*Blackites* Hay & Towe 1962
	B. creber
Subtribus:	*Syracosphaerinae* Kamptner 1958
Genus:	*Scyphosphaera* Lohmann 1902

S. apsteini
S. cf. *galeana*
S. columella n. sp.
S. tubicena n. sp.
Tribus: *Zygosphaereae* Kamptner 1958
Subtribus: *Zygolithinae* Stradner 1968 ++
Genus: *Heliorthus* Brönniman & Stradner 1960
H. concinnus
H. junctus
H. fallax
Genus: *Neococcolithes* Sujkowski 1931
N. dubius
Subtribus: *Zygosphaerinae* Kamptner 1958
Genus: *Zygrhablithus* Deflandre 1959
Z. bijugatus
Tribus: *Pontosphaereae* Hay 1966+++
Genus: *Discolithina* Loeblich & Tappan 1963
D. plana
D. pulchra
D. pulcheroides
Genus: *Helicopontosphaera* Hay & Mohler 1967
H. seminulum
Tribus: *Calciosolenieae* Kamptner 1958
Genus: *Scapholithus* Deflandre 1954
S. fossilis
Familia: *Braarudosphaeraceae* Deflandre 1947
Genus: *Braarudosphaera* Deflandre 1947
B. bigelowi
Genus: *Micrantholithus* Deflandre 1954
M. vesper
Familia: *Sphenolithaceae* Vekshina 1959
Genus: *Sphenolithus* Deflandre 1952
S. radians
Familia: *Thoracosphaeraceae* Schiller 1930
Genus: *Thoracosphaera* Kamptner 1927
T. deflandrei
Incertae sedis: Genus *Clathrolithus* Deflandre 1954
C. ellipticus

\+ Type genus: *Blackites* Black & Towe 1962
++ Type genus: *Neococcolithes* Sujkowski 1931
+++ Type genus: *Pontosphaera* Lohmann 1902

Due to the new informations on the nannofossil ultrastructure made available since the application of electron microscopy and scanning microscopy the systematics of the nannofossils has been brought into a state of turmoil. Of some species the electron microscopical documentation is rather complete, of others only partial information is available (for example: proximal view known, distal view unknown), of others only light microscopical photographs or drawings are published. Therefore the older systems of nannofossils, based on fragmentary evidence, just the same as the system offered here, can be considered as „tentative" merely, because it has become clear, that the ultrastructure visible in the electron microscope alone will furnish reliable criteria for a natural system of nannofossils, especially of the coccoliths.

After the pioneering work by Kamptner since 1944 and by Deflandre & Fert since 1952 and Deflandre & Durrieu 1957 many instructive electron micrographs showing the ultrastructure of nannofossils have been published (Adamiker, Be, Bernheim, Black, Braarud, Bramlette, Cohen, Deflandre, Durrieu, Edwards, Farinacci, Flügel, Fert, Gaarder, Gartner, Grunau, Halldal, Hay, Honjo, Kamptner, Lecal, Markali, Martini, Maresch, McIntyre, Mohler, Noel, Parke, Reinhardt, Shumenko, Stradner, Towe, Vekshina, Wade, Watabe, Wilbur, et al.).

For systematic work in this group of fossils the following books are very useful:

Deflandre & Deflandre-Rigaud: Fichier Micropaléontologique Général — Series 17 et 18: Nannofossiles calcaires I & II, Editions du C.N.R.S. Paris.

Loeblich & Tappan: Annotated Index and Bibliography of the Calcareous Nannoplankton; *Phycologia*, vol. 5, nr 2 & 3, 1966.

For practical work in the paleontological laboratory the light microscope also in future times will take the main share of work to solve stratigraphical and paleoecological problems. From this point of view pictures and descriptions of nannofossil-assemblages based on light microscopical observation only, just as the ones offered here, seem to be justified even after so much progress in electron microscopy. Thus, if the following pages are of help in routine work on the stratigraphy of marine sediments in general and on flysch stratigraphy in special, they have served their purpose.

Discoaster binodosus Martini

Plate LXXXII, fig. 1, 4

1958 *Discoaster binodosus* Martini; p. 362, pl. 4, figs. 18a, b.
1961 *Discoaster binodosus* Martini; Stradner & Papp, p. 66, p. 4, figs. 1, 7, pl. 5, figs. 1—6, text-fig. 8/4.
1963 *Discoaster binodosus* Martini; Bystrická, p. 275, pl. 2, figs. 5—6.
1965 *Discoaster binodosus* Martini; Bystrická, p. 8.
1967 *Discoaster binodosus* Martini; Radomski, p. 388.
1967 *Discoaster binodosus* Martini; Hay & Mohler, p. 1538.
1968 *Discoaster binodosus* Martini; Samuel & Bystrická, p. 122, 124.

Asteroliths with 5 to 9 rays with pointed or nodged tips, which are flanked by two lateral nodes.

Common from Upper Paleocene („*Discoaster multiradiatus* Zone") to Eocene. Very similar to *Discoaster tani nodifer*, which might have been mistaken for *Discoaster binodosus* in Upper Eocene sediments by some authors. Therefore the upper limit of the occurrence of *Discoaster binodosus* is still uncertain.

Discoaster elegans Bramlette & Sullivan

Plate LXXX, figs. 7, 8, 10; text-fig. 1/4

1961 *Discoaster stradneri* Martini, p. 10, pl. 2, fig. 22, pl. 5, fig. 52 (non *D. stradneri* Noel 1960).

1961 *Discoaster elegans* Bramlette & Sullivan, p. 159, pl. 11, figs. 16a, b.
1963 *Discoaster elegans* Bramlette & Sullivan, Bystrická, p. 277, pl. 3, figs. 2—6.
1964 *Discoaster elegans* Bramlette & Sullivan; Bystrická, p. 215, pl. 5, fig. 7.
1967 *Discoaster elegans* Bramlette & Sullivan; Radomski, p. 389.
1968 *Discoaster elegans* Bramlette & Sullivan; Samuel & Bystrická, p. 122, 126.

Asteroliths with 11—15 pointed segments, which on their concave side show concentric lines formed by two to four parallel ribs. Stem not flaring, but rounded and smaller than in *Discoaster kuepperi* Stradner.

From Lower Eocene to Upper Eocene. In the Lower Eocene of the Hagenbach Valley also intermediary forms between *D. kuepperi* and D. *elegans*.

Discoaster cf. gemmifer Stradner

Plate LXXXII, figs. 5—10

1961 *Discoaster gemmifer*, p. 86, fig. 83.
1961 *Discoaster gemmifer* Stradner; Stradner & Papp, p. 69, pl. 8, figs. 1—10, pl. 9, figs. 1—5, text-fig. 6, 7/1, 8/6.
1968 *Discoaster gemmifer* Stradner; Samuel & Bystrická, p. 122.

Asteroliths with 4—10 rays. Tips widely bifurcating with adjacent lateral nodes. Highly variable and difficult to delimit from similar species (*D. distinctus, D. deflandrei*). Lower Eocene to lower Middle Eocene.

Discoaster gemmeus Stradner

Plate LXXX, fig. 3

1959 *Discoaster gemmeus* Stradner, p. 1086, text-fig. 21.
1961 *Discoaster gemmeus* Stradner; Stradner & Papp, p. 77, pl. 12, figs. 1, 2, 4, 8, text-fig. 8/13.
1963 *Discoaster gemmeus* Stradner; in Gohrbandt, p. 79, pl. 11, figs. 4, 5.
1964 *Discoaster gemmeus,* Stradner; Bystrická, p. 214, pl. 5, fig. 11.
1965 *Discoaster* cf. *gemmeus* Stradner; Bystrická, p. 7.
1967 *Discoaster gemmeus* Stradner; Hay & Mohler, p. 1538, pl. 204, figs. 19—21; pl. 206, figs. 3, 5.
1968 *Discoaster* cf. *gemmeus* Stradner; Samuel & Bystrická, p. 121—122.

Primitive heliodiscoasters with 8—18 blunt segments. No stem, but a central crater on the conical side (facies inferior). Guide fossil of the „*Discoaster gemmeus* Zone". Apparently the rare specimens of the Hagenbach Valley were reworked into the Lower Eocene from exposed Paleocene sediments.

Discoaster kuepperi Stradner

Plate LXXX, figs. 6, 9, 11 and 12; text-fig. 1/1—3

1959 *Discoaster kuepperi* Stradner, p. 478, figs. 17, 21.
1961 *Discoaster kuepperi* Stradner; in Stradner & Papp, p. 93, pl. 27, figs. 1—6, text-figs. 9/6; 16.
1961 *Discoaster kuepperi* Stradner; Martini, p. 14, pl. 3, fig. 29.

1961 *Discoasteroides kuepperi* (Stradner) Bramlette & Sullivan, p. 163, pl. 13, figs. 16a, b, 17, 18 a—c, 19.

1963 *Discoasteroides kuepperi* (Stradner) Bramlette & Sullivan; Bystrická, p. 279, pl. 4, figs. 7—9.

1964 *Discoasteroides kuepperi* (Stradner) Bramlette & Sullivan; Sullivan, p. 192, pl. 12, figs. 1a, b, 2a, b.

1965 *Discoasteroides kuepperi* (Stradner); Bystrická, p. 8.

1968 *Discoasteroides kuepperi* (Stradner) Bramlette & Sullivan; Samuel & Bystrická, p. 122, 125.

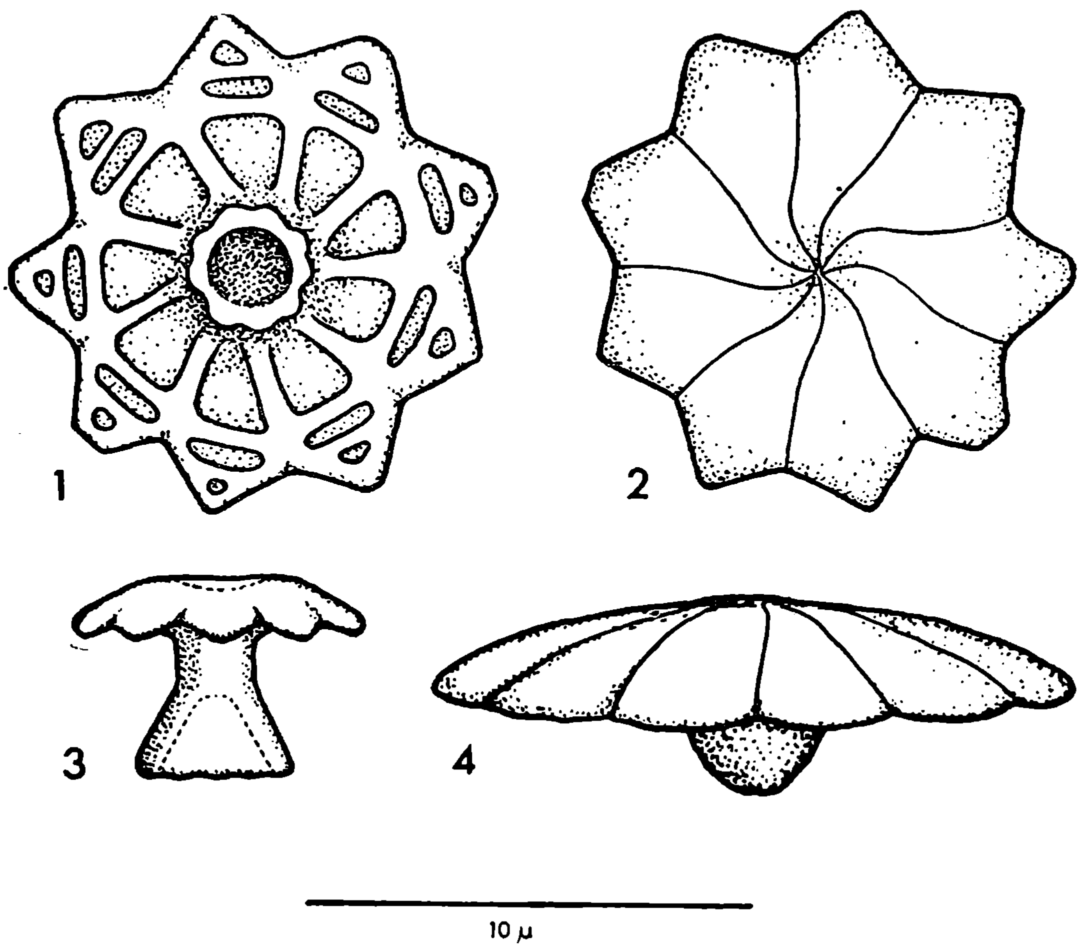

Fig. 1. *Discoaster kuepperi* Stradner, concave side (1); convex side (2); side view of a smaller specimen (3); *Discoaster elegans* Martini, side view (4)

Discoasters with 7—10 bluntly pointed segments, which on their concave side show concentric lines formed by two or three parallel ribs. Large flaring hollow stem. Characteristic species of the „*Marthasterites tribrachiatus* Zone".

Discoaster lenticularis Bramlette & Sullivan

Plate LXXX, figs. 1, 2

1961 *Discoaster lenticularis* Bramlette & Sullivan, p. 160, pl. 12, figs. 1a, b, 2.

1964 *Discoaster lenticularis* Bramlette & Sullivan; Sullivan, p. 42, pl. 10, fig. 10.

1967 *Discoaster lenticularis* Bramlette & Sullivan; Hay & Mohler, p. 1521, 1539.

1967 *Discoaster lenticularis* Bramlette & Sullivan; Hay et al., p. 436.

Discoidal discoasters with 20—26 rays; central area depressed.
Typical occurrence in the „*Discoaster multiradiatus* Zone" (Bramlette & Sullivan 1961), rare (reworked?) in the Lower Eocene of the Hagenbach Valley.

Discoaster lodoensis Bramlette & Riedel

Plate LXXXI, figs. 1—8

1954 *Discoaster lodoensis* Bramlette & Riedel, p. 398, pl. 39, figs. 3a, b.
1960 *Discoaster lodoensis* Bramlette & Riedel; Brönnimann & Stradner, p. 369.
1961 *Discoaster lodoensis* Bramlette & Riedel; Stradner & Papp, p. 92, pl. 25, figs. 1—10, pl. 26, figs. 1—6, text-figs. 9/2, 9/3, 24/9.
1961 *Discoaster lodoensis* Bramlette & Riedel; Bramlette & Sullivan, p. 161, pl. 12, figs. 4a—b, 5.
1962 *Discoaster lodoensis* Bramlette & Riedel; Hay & Towe, p. 514, pl. 10, figs. 2, 4, 6.
1963 *Discoaster lodoensis* Bramlette & Riedel; Bystrická, p. 278.
1967 *Discoaster lodoensis* Bramlette & Riedel; Radomski, p. 388.
1967 *Discoaster lodoensis* Bramlette & Riedel; Hay & Mohler, p. 1523.

Stellate asteroliths with usually six rays, which are all curved in the same sense in the plane of the body of the asterolith. Short knobs on one or either side in the center of the flat asteroliths. Large variation in size and in number of rays (3—10).
Very common in the „*Marthasterites tribrachiatus* Zone" and the „*Discoaster lodoensis* Zone" (Lower Eocene).

Discoaster mirus Deflandre

Plate LXXXII, fig. 2, 3

1954 *Discoaster mirus* Deflandre, in Deflandre & Fert, p. 168, text-fig. 118.
1961 *Discoaster mirus* Deflandre; Stradner & Papp, p. 68, pl. 6, figs. 1—6, pl. 7, figs. 1—5, text-figs. 8/5, 24/7.
1963 *Discoaster mirus* Deflandre; Bystrická, p. 278, pl. 2, fig. 12.
1964 *Discoaster mirus* Deflandre; Stradner, p. 136, text-fig. 28.
1965 *Discoaster mirus* Deflandre; Bystrická, p. 8.
1968 *Discoaster mirus* Deflandre; Samuel & Bystrická, p. 122, 125, 126.

Asteroliths with usually 6—8 heavy rays, which have two terminal and two lateral nodes. Intermediary forms to *Discoaster binodosus* Martini also occurring in the Hagenbach Valley. Lower to Middle Eocene.

Discoaster multiradiatus Bramlette & Riedel

Plate LXXX, fig. 5

1954 *Discoaster multiradiatus* Bramlette & Riedel, p. 396, pl. 38, fig. 10.
1961 *Discoaster multiradiatus* Bramlette & Riedel; Stradner & Papp, p. 98, pl. 29, figs. 1—7, text-figs. 9/9, 16, 24/1.
1963 *Discoaster multiradiatus* Bramlette & Riedel; Bystrická, p. 278, pl. 3, figs. 7—10.
1964 *Discoaster multiradiatus* Bramlette & Riedel; Bystrická, p. 216, pl. 7, fig. 1.
1965 *Discoaster multiradiatus* Bramlette & Riedel; Bystrická, p. 7, 9.

1967 *Discoaster multiradiatus* Bramlette & Riedel; Radomski, p. 387.
1967 *Discoaster multiradiatus* Bramlette & Riedel; Hay & Mohler, p. 1539, pl. 204, fig. 22, pl. 206, figs. 1, 4, 7.
1967 *Discoaster multiradiatus* Bramlette & Riedel; Hay et al., p. 436.
1968 *Discoaster multiradiatus* Bramlette & Riedel; Samuel & Bystrická, p. 122, 124.

Large, flat rosette-shaped asteroliths with 16—24 segments.

Important guide-fossil marking the „*Discoaster multiradiatus* Zone" of Upper Paleocene age. Rather rare, apparently reworked in the Lower Eocene of the Hagenbach Valley.

Discoaster salisburgensis Stradner
Plate LXXX, fig. 4

1961 *Discoaster salisburgensis* Stradner, p. 84, figs. 77, 78.
1961 *Discoaster salisburgensis* Stradner, in Stradner & Papp, p. 96, pl. 28, figs. 3a, b, 5; text-figs. 18/1—5, 24/2.
1965 *Discoaster salisburgensis* Stradner; Bystrická, p. 8.
1968 *Discoaster salisburgensis* Stradner; Samuel & Bystrická, p. 122, 124.

Rosette-shaped discoasters with about a dozen of thick segments and a heavy robust stem on the conical side (facies inferior). In side view easy to distinguish from the more delicate, umbrella-shaped *Discoaster barbadiensis* Tan Sin Hok.

Frequent in Upper Paleocene together with *Discoaster multiradiatus* Bramlette & Riedel; not so common in Lower Eocene (reworked?).

Marthasterites tribrachiatus (Bramlette & Riedel) Deflandre
Plate LXXXIII, fig. 1—5

1954 *Discoaster tribrachiatus* Bramlette & Riedel, p. 397, pl. 38, fig. 11.
1959 *Marthasterites tribrachiatus* (Bramlette & Riedel) Deflandre, pp. 138, 139.
1960 *Marthasterites tribrachiatus* (Bramlette & Riedel) Deflandre, Brönnimann & Stradner, p. 368, 369, Correlation Chart.
1961 *Marthasterites tribrachiatus* (Bramlette & Riedel) Deflandre; Stradner & Papp, p. 110, pl. 35, figs. 1—4, 7; text-figs. 11/5, 11/6, 20/2.
1963 *Marthasterites tribrachiatus* (Bramlette & Riedel) Deflandre; Bystrická, p. 279, pl. 4, figs. 1—4.
1964 *Marthasterites tribrachiatus* (Bramlette & Riedel) Deflandre; Stradner, p. 135, 136, text-fig. 23.
1965 *Marthasterites tribrachiatus* (Bramlette & Riedel; Bystrická, p. 8.
1967 *Marthasterites tribrachiatus* (Bramlette & Riedel); Radomski, p. 388.
1967 *Marthasterites tribrachiatus* (Bramlette & Riedel); Hay & Mohler, p. 1522.

Three-rayed asteroliths with variation in the form of their tips (rounded or nodged) and the width of their rays (parallel-edged or tapering). Curvature of the rays only to be seen in side-view.

Guide-fossil of the „*Marthasterites tribrachiatus* Zone", in which it occurs together with *Discoaster lodoensis*. Its first occurrence lies already at the base of the „*Discoaster binodosus* Zone".

Chiasmolithus bidens (Bramlette & Sullivan) Hay, Mohler & Wade

Plate LXXXV, figs. 9—11

1961 *Coccolithus bidens* Bramlette & Sullivan, p. 139, pl. 1, fig. 1.
1966 *Chiasmolithus bidens* (Bramlette & Sullivan) Hay, Mohler & Wade, p. 388.

Central area of the elliptical placoliths open and spanned by a diagonal cross. Small tooth-like projections into the central area occasionally present, but they are not a reliable symptom (!). According to Bramlette & Sullivan this species is to be considered the progenitor of *Chiasmolithus grandis* (Bramlette & Sullivan) Hay, Mohler & Wade.

Possibly reworked from Paleocene.

Chiasmolithus grandis (Bramlette & Riedel) Hay, Mohler & Wade

Plate LXXXV, figs. 12—14

1954 *Coccolithus grandis* Bramlette & Riedel, p. 391—392, pl. 38, fig. 1a, b.
1961 *Coccolithus grandis* Bramlette & Riedel, Bramlette & Sullivan, p. 140, pl. 2, figs. 1a, b, 2a—c, 3.
1966 *Chiasmolithus grandis* (Bramlette & Riedel) Hay, Mohler & Wade, p. 388.

Unusually large placoliths with the wide central window spanned by a diagonal x-shaped structure. Four tooth-like projections are directed towards the inner of the central opening. Fine striation of the rim is shown in pl. LXXXV, fig. 14.

Typical species of Lower and Middle Eocene.

Coccolithus bisulcus Stradner

Plate LXXXIV, fig. 7—10

1963 *Coccolithus bisulcus* Stradner, in Gohrbandt, p. 72, pl. 8, figs. 3—6, text-figs. 3 (1a, b).

Placoliths with two longitudinal slots in their central area closer to the margin that in *Coccolithus pelagicus*. An electronmicrograph published by Hay & Mohler 1967, pl. 197, fig. 6 of the distal view indicates some similiarity with the genus *Reticulofenestra*.

Possibly reworked from Paleocene.

Coccolithus cribellum (Bramlette & Sullivan) Stradner

Plate LXXXV, fig. 5—8

1961 *Coccolithites cribellum* Bramlette & Sullivan, p. 151, pl. 7, figs. 5a, b, 6a, b.
1962 *Coccolithus cribellum* (Bramlette & Sullivan) Stradner, p. 178.
1964 *Coccolithus cribellum* (Bramlette & Sullivan) Sullivan, p. 181, pl. 3, fig. 5a, b.
1965 *Coccolithus cribellum* (Bramlette & Sullivan) Sullivan, p. 31, pl. 3, figs. 1a, b, 2a, b, 3a, b, 4a, b.

Elliptical placoliths with large central area perforated by several rows of fine pores and a faintly visible axial cross (pl. LXXXV, fig. 5).

In phase contrast and between crossed nicols another, but diagonal, cross becomes visible (pl. LXXXV, figs. 6—8). Possibly this species is closely related to *Arkhangelskiella cymbiformis* Vekshina, where similar subdivision of the central area are to be found.

Lower and Middle Eocene.

Coccolithus eopelagicus Bramlette & Riedel
Plate LXXXIV, fig. 11

1954 *Tremalithus eopelagicus* Bramlette & Riedel, p. 392, pl. 38, figs. 2a, b.
1968 *Coccolithus eopelagicus* (Bramlette & Riedel); Stradner & Edwards, p. 15, pl. 6.

and

Coccolithus pelagicus (Wallich) Schiller
Plate LXXXIV, figs. 12—14

1877 *Coccosphaera pelagicus* Wallich, p. 348, pl. 17, figs. 1, 2—7, 10.
1930 *Coccolithus pelagicus* (Wallich) Schiller, p. 246, Bild 123.
1967 *Coccolithus pelagicus* (Wallich) Schiller; McIntyre, Be & Preikstas, p. 11, pl. 4, figs. A—B.

Elliptical placoliths with larger distal and smaller proximal curved shields. Central area closed except for one longitudinal central window (*C. eopelagicus*) or a longitudinal groove (*C. pelagicus*), which in light microscope appears pronounced near the foci of the ellipse. Both of the above species designations are uncertain regarding their generic affiliation, as only light microscopic pictures are available. Electronmicrographs from proximal shields given in recent literature indicate that the generic system for the „coccoliths sensu stricto" is likely to be subject to changes.

Coccolithus macellus (Bramlette & Sullivan) Stradner
Plate LXXXIV, figs. 18—20

1961 *Coccolithites macellus* Bramlette & Sullivan, p. 152, pl. 7, figs. 11—13.
1963 *Coccolithus macellus* (Bramlette & Sullivan) Stradner, in Gohrbandt, p. 75, pl. 8, figs. 7—9, text-figs. 3/3a, b.

Very thin placoliths with compressed flat shields and a longitudinal groove in the central area. In normal light this species is almost invisible, in phase contrast not very conspicuous, but under crossed nicols extraordinary bright. Very rare.

Apparently reworked from Paleocene.

Coccolithus petrinus nov. spec.
Plate LXXXIV, figs. 1—6

Derivation of name: *petrinus* (lat.) = from the rocks.
Holotype: Prep. HV 1968/1 (figs. 1—3).
Locus typicus: Hagenbach Valley, Lower Austria, Stat. 4.
Stratum typicum: Lower Eocene.
Syn. *Coccolithus* cf. *pelagicus* (Wallich); Bouché, p. 83, pl. 1, fig. 24.

Diagnosis: Elliptical placoliths with proximal and distal plate, the central area perforated by two circular pores. Transversal bridge not as pronounced as in the larger *Coccolithus crassipons* Bouché. Rare.

Campylosphaera dela (Bramlette & Sullivan) Hay & Mohler
Plate LXXXV, figs. 1—4

1961 *Coccolithites delus* Bramlette & Sullivan, p. 151—152, pl. 7, figs. 1a—c, 2a, b.
1963 *Campylosphaera bramlettei* Kamptner, p. 150—152, pl. 1, fig. 6, text-fig. 7.
1967 *Campylosphaera dela* (Bramlette & Sullivan) Hay & Mohler, p. 1531, pl. 198, fig. 14.

Elliptical placoliths, the ends of which are inward curved thus giving a subquadrate outline. Central axial cross very delicate and not in all specimens preserved.

Upper Paleocene to Oligocene.

Reticulofenestra cf. *placomorpha* (Kamptner) Stradner
Plate LXXXIV, fig. 15—17

1948 *Tremalithus placomorphus* Kamptner, p. 7, pl. 2, fig. 11.
1956 *Coccolithus placomorphus* Kamptner, p. 10.
1965 *Coccolithus umbilicus* Levin, p. 265, pl. 41, fig. 2.
1966 *Reticulofenestra caucasica* Hay, Mohler & Wade, p. 386—387, pl. 2, fig. 5, pl. 3, figs. 1—2, pl. 4, figs. 1—2.
1968 *Reticulofenestra placomorpha* (Kamptner) Stradner, in Stradner & Edwards, p. 22, pl. 19—21, 22, fig. 1—3; pl. 23, 24, 25, figs. 1, 2; text-fig. 2A.

The Lower Eocene specimens of the Hagenbach Valley appear slightly more rounded than the Upper Eocene ones; the diameters of the central area are smaller than one third of the overall diameters of the broad--elliptical placoliths.

Not very common.

Cyclococcolithus gammation (Bramlette & Sullivan) Sullivan
Plate LXXXVI, figs. 5—7

1961 *Coccolithites gammation* Bramlette & Sullivan, p. 152, pl. 7, figs. 7a—c, 14a—b.
1964 *Cyclococcolithus gammation* (Bramlette & Sullivan) Sullivan, p. 181, pl. 3, figs. 7a, b.

Circular placoliths consisting of two convex plates; in polarized light the proximal plate shows an extinction cross with strongly curved lines resembling a swastika. Common.

Lower to Middle Eocene.

Cyclolithella robusta (Bramlette & Sullivan) nov. comb.
Plate LXXXVI, figs. 1—4

1961 *Cyclolithus? robustus* Bramlette & Sullivan, p. 141, pl. 2, fig. 7a—c.
1963 *Cyclolithella* Loeblich & Tappan, p. 192 (nom. subst. pro *Cyclolithus* Kamptner ex Deflandre, 1952, non Koenig, 1825, Coelenterata).

Circular grooved rings with wide open central window. Generic assignment without electron microscopical examination uncertain.

First described from Middle Paleocene of California.

Rhabdosphaera herculea nov. spec.
Plate LXXXIX, figs. 9—11

Derivation of name: Hercules = name of hero (Greek Mythology).
Holotype: HV 1968/4 (figs. 9, 12).
Locus typicus: Hagenbach Valley, Northern Vienna Woods, Lower Austria Stat. 4 and 14.
Stratum typicum: Lower Eocene, „*Marthasterites tribrachiatus* Zone".
Diagnosis: Rhabdoliths with shaft in form of a large hollow tube, which is slightly constricted in its proximal quarter and slowly flaring towards its wide open distal opening. Striation of shaft enclosing an angle of about 70° with the direction of the main axis. Some specimens with shaft slightly tapering in its distal half. Greatest diameter of shaft equal or greater than that of basal plate.

Usually only the „club-shaped" shafts without basal plate are encountered. Therefore a zone of minor resistance can be expected within the collar-zone or between the collar and the basal plate.

Rhabdosphaera cf. *pinguis* Deflandre
Plate LXXXIX, figs. 13—15

1954 *Rhabdolithus pinguis* Deflandre, in Deflandre & Fert, p. 158, pl. 12, figs. 26, 27.

Rhabdoliths with comparatively small basal plate and long hollow shaft which is somewhat constricted in the proximal half and tapering to an open tip in its distal half. Differing from the original description by the smaller dimensions of the basal plate.

Lower Eocene — Middle Eocene.

Rhabdosphaera truncata Bramlette & Sullivan
Plate LXXXIX, figs. 6—8

1961 *Rhabdosphaera truncata* Bramlette & Sullivan, p. 147, pl. 5, fig. 15a, b.
1965 *Rhabdosphaera truncata* Bramlette & Sullivan, p. 37, pl. 7, fig. 1a—c.

Rhabdoliths with collar enlarged to about the same diameter as the basal plate or even slightly more. Stem somewhat constricted in the middle part, with truncate tip.

Blackites creber (Deflandre) Stradner
Pl. LXXXIX, fig. 4

1954 *Rhabdolithus creber* Deflandre, in Deflandre & Fert, p. 157, pl. 12, figs. 31—33, text-figs. 81—82.
1961 *Rhabdosphaera crebra* (Deflandre) Bramlette & Sullivan, p. 146, pl. 5, figs. 1—3.
1963 *Rhabdosphaera crebra* (Deflandre; Hay & Towe, p. 953, pl. 1, figs. 2—5, pl. 2, figs. 1—5.
1968 *Blackites creber* (Deflandre) Stradner, in Stradner & Edwards, p. 29.

Rhabdoliths[1] with flat conical basal plate, pronounced collar and tapering shaft.

Common in Lower and Middle Eocene.

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[1] Also the three *Rhabdosphaera*-species described above might eventually

Scyphosphaera apsteini Lohmann

Plate LXXXIX, figs. 1—3

1902 *Scyphosphaera apsteini* Lohmann, p. 132, pl. 4, figs. 26—30.
1930 *Scyphosphaera apsteini* Lohmann, corr. sc. ICBN Art. 73, note 3 by Schiller, p. 126.
1942 *Scyphosphaera apsteini* Lohmann; Deflandre, p. 6, figs. 2, 3—5, 10—15.
1967 *Scyphosphaera apsteini* Lohmann; Bramlette & Wilcoxon, p. 107, pl. 10, figs. 1, 2, 4.

Barrel-shaped lopadoliths with vaulted bottom plate, distal side open. Side-view contour rather variable.

Lower Eocene to Recent.
As yet no older occurrence than Oligocene (Bramlette & Wilcoxon) has been known of this species.

Scyphosphaera cf. *galeana* Kamptner

Plate LXXXVIII, figs. 1—3

1967 *Scyphosphaera galeana* Kamptner, p. 149, pl. 9, fig. 68, text-fig. 19.

Lopadolith resembling in overall dimension the original description, however more contracted in the middle part of the tube. In side- view twice as high as broad. Possibly related to *Scyphosphaera campanula* Deflandre and *Scyphosphaera intermedia* Deflandre.

Scyphosphaera columella nov. spec.

Plate LXXXVIII, figs. 4—8

Syn.: 1961 „*Lopadolith* from Lodo 39", Bramlette & Sullivan, pl. 5, fig. 19.

Derivation of name: *columella* (lat.) = small pillar.
Holotype: HV 1968/2 (figs. 7—8).
Locus typicus: Hagenbach Valley, Northern Vienna Woods, Lower Austria, Stat. 400.
Stratum typicum: Lower Eocene.

Diagnosis: Lopadoliths tube-shaped with almost parallel side lines, only slightly constricted above the somewhat widening bottom-end, which is closed by an inward vaulted plate. No striation of tube or perforation of bottom plate discernable.

Scyphosphaera tubicena nov. spec.

Plate LXXXVIII, fig. 9—12

Syn.: *Lopadolith* from Lodo 52, Bramlette & Sullivan, pl. 5, fig. 20.

Derivation of Name: *tubicen* (lat.) = „trumpet-blower".
Holotype: HV 1968/3 (figs. 9—10).
Locus typicus: Hagenbach Valley, Northern Vienna Woods, Lower Austria, Stat. 2060.
Stratum typicum: Lower Eocene.

Diagnosis: Trumpet-shaped lopadoliths. In side view shaft with parallel contour, flaring towards the bottom, which is closed by a plane

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have to be transferred to the Genus *Blackites*; that however can be done only after electron microscopical examination of their ultrastructure.

or only slightly vaulted bottom plate. No striation of shaft or perforation of bottom plate recognizable. Proximal end in many specimens damaged and bottom plate missing. Inside often filled with substance showing optical refraction similar to calcite.

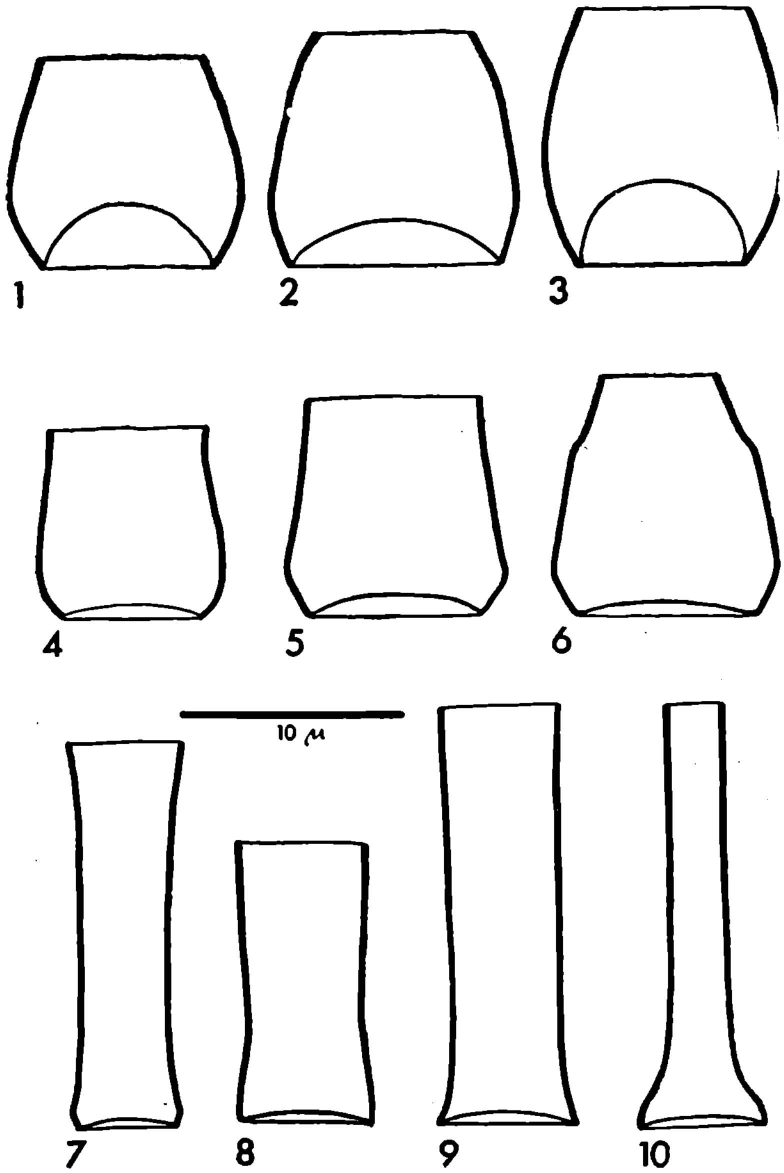

Fig. 2. Schematized side-views of Eocene lopadoliths of the genus *Scyphosphaera*: *Scyphosphaera apsteini* Lohmann (1—6), *Scyphosphaera columella* n. sp. (7—9) and *Scyphosphaera tubicena* (10) n. sp.

Heliorthus concinnus (Martini)
Hay & Mohler
Plate LXXXVII, figs. 4, 5

1961 *Zygolithus concinnus* Martini, p. 18, pl. 3, fgi. 35, pl. 5, fig. 54.
1961 *Zygolithus chiastus* Bramlette & Sullivan, p. 149, pl. 6, figs. 1a—d, 2a, b, 3a, b.
1967 *Heliorthus concinnus* (Martini); Hay & Mohler, p. 1533, pl. 199, figs. 16—18, pl. 201, figs. 6—7, 10.

Narrow elliptical rings bridged by an x-shaped structure, the bars of which inclose smaller angles in transversal direction.

Middle to Upper Paleocene; apparently reworked into the Lower Eocene of the Hagenbach Valley.

Heliorthus junctus (Bramlette & Sullivan) Hay & Mohler
Plate LXXXVII, figs. 9—12

1961 *Zygolithus junctus* Sullivan & Bramlette, pl. 6, fig. 11a—b, p. 150.
1967 *Heliorthus junctus* (Bramlette & Sullivan) Hay & Mohler, p. 1533.

Elliptical rings with very narrow cross in transversal direction. Very rare. Probably reworked from Middle Paleocene.

Heliorthus fallax Brönnimann & Stradner
Plate LXXXVII, fig. 6—8

1960 *Heliorthus fallax* Brönnimann & Stradner, p. 368, figs. 8—10.
1961 *Chiphragmalithus calathus* Bramlette & Sullivan, p. 156, pl. 10, figs. 7a—b, 8—10.
1963 *Heliorthus fallax* Brönnimann & Stradner; Brönnimann & Rigassi, pl. 15, figs. 3a—f.
1967 *Heliorthus fallax* Brönnimann & Stradner; Hay & Mohler, p. 1533.
1968 *Heliorthus fallax* Brönnimann & Stradner; Achuthan & Stradner (in press).

Subcircular, slightly conical, sturdy rings with high wall bridged by an x-shaped central structure. In Lower Eocene marine sediments, usually not frequent.

Neococcolithes dubius (Deflandre) Black
Plate LXXXVII, figs. 1—3

1954 *Zygolithus dubius* Deflandre, in Deflandre & Fert, p. 149, figs. 43, 44, 68.
1964 *Chiphragmolithus dubius* (Deflandre) Sullivan, p. 179, pl. 1, fig. 2.
1967 *Neococcolithes dubius* (Deflandre) Black, p. 143.

This species, since 1966 under the genus Neococcolithes Sujkowski (1931, p. 509, 619, fig. 1 (13) p. 508), occurs regularly throughout the Lower and Middle Eocene; also common in the Barton Clay from the type locality. Its main characteristic is the longitudinally extended x-shaped bridge spanning the high, but narrow elliptical ring.

Zygrhablithus bijugatus Deflandre
Plate LXXXIII, figs. 6, 7, 10, 11

1954 *Zygolithus bijugatus* Deflandre, in Deflandre & Fert, p. 148, pl. 11, figs. 2021; text-fig. 59.
1959 *Zygrhablithus bijugatus* Deflandre, pp. 135—136.
1966 *Sujkowskiella enigmatica* Hay, Mohler & Wade, p. 397, pl. 13, figs. 6, 7.
1967 *Zygrhablithus bijugatus* Deflandre; Gartner, p. 513.
1968 *Zygrhablithus bijugatus* (Deflandre); Stradner & Edwards, p. 44, pl. 42, 43.
1968 *Zygrhablithus bijugatus* (Deflandre) Deflandre; Haq, p. 40, pl. 7, fig. 10, pl. 9, figs. 10, 11.

Zygoform holococcoliths built of microcrystals of equal size. To be found more often in side view, when it appears wedge-shaped, than in the elliptical basal or apical view. Very common throughout the Eocene.

Discolithina[1] *plana* (Bramlette & Sullivan) Levin
Plate LXXXVII, figs. 15, 16

1961 *Discolithus planus* Bramlette & Sullivan, p. 143, pl. 3, fig. 7a—c.
1965 *Discolithina plana* (Bramlette & Sullivan) Levin, p. 266, pl. 41, figs. 9a—c.

Elliptical discoliths without pores, bisected by a longitudinal groove, which is indistinct in the center. Lower to Middle Eocene.

Apparently closely related to the genus *Pontosphaera* Lohmann 1902.

Discolithina pulchra (Deflandre) Levin
Plate LXXXVII, figs. 13, 14

1954 *Discolithus pulcher* Deflandre, p. 142, pl. 12, figs. 17, 18.
1965 *Discolithina pulchra* (Deflandre) Levin, p. 266, pl. 41, figs. 6a—c.

Elliptical rim which is perforated by one row of concentrical pores; transversal bridge almost in axial direction, separating two central windows. Not clearly separable from the following species in the Lower Eocene of the Hagenbach Valley.

Lower to Upper Eocene.

Discolithina pulcheroides (Sullivan) Levin & Joerger
Plate LXXXVII, figs. 17, 18

1964 *Discolithus pulcheroides* Sullivan, p. 183, pl. 4, figs. 7a, b.
1967 *Discolithina pulcheroides* (Sullivan) Levin & Joerger, p. 167, pl. 2, figs. 8a—c.

Elliptical discoliths with oblique central bridge. One concentrical row of small pores along periphery of the plate; two large oblique central windows.

Lower to Upper Eocene.

Helicopontosphaera seminulum (Bramlette & Sullivan) nov. comb.
Plate LXXXVII, figs. 19, 20

1961 *Helicosphaera seminulum* Bramlette & Sullivan, p. 144, pl. 4, figs. 1a—c, 2.
1967 *Helicopontosphaera* Hay et al. nov. gen. p. 488.
1968 *Helicosphaera seminulum* Bramlette & Sullivan; Stradner & Edwards, pl. 39, 40.

Helicoid discoliths with central opening spanned by a thick bar. Coiling of the flange anticlockwise.

[1] *Discolithina* Loeblich & Tappan 1963 (ICZN) = *Discolithus* Kamptner ex Deflandre 1952 (ICBN), non *Discolithus* Huxley 1868 (Foraminiferida). Generic names in both codes legal.

Lower to Middle Eocene. Usually not so common as *Helicopontosphaera carteri* occurring in Late Tertiary marine sediments.

Scapholithus fossilis Deflandre
Plate LXXXIII, figs. 13, 14

1954 *Scapholithus fossilis* Deflandre, in Deflandre & Fert, p. 165, pl. 8, figs. 12, 16, 17.

1968 *Scapholithus fossilis* Deflandre; Stradner, Adamiker & Maresch, p. 43, pl. 45, figs. 1—5.

Longitudinal parallelogram outlines and identical optical behaviour of parallel flanks between crossed nicols mark this slender and easily overlooked nannofossil.

Lower Cretaceous to Pliocene. The recent genera *Calciosolenia, Acanthosolenia* and *Anoplosolenia* produce very similar coccoliths (Halldal & Markali 1955, pl. 16, 17).

Braarudosphaera bigelowi (Gran & Braarud) Deflandre
Text-fig. 3/2, 3

1935 *Pontosphaera bigelowi* Gran & Braarud, p. 388, fig. 67.

1947 *Braarudosphaera bigelowi* (Gran & Braarud) Deflandre, p. 439, figs. 1—5.

Pentagonal elements of dodekahedral shells; sparsely occurring in the Lower Eocene of the Hagenbach Valley.

Cretaceous to Recent.

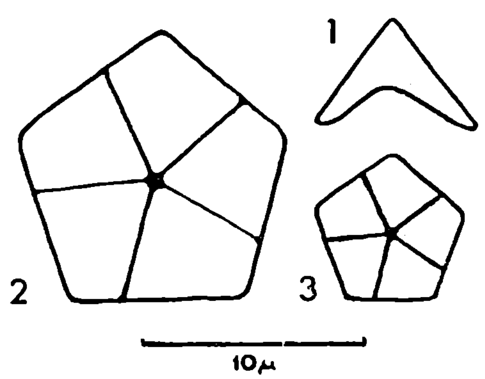

Fig. 3. One of the five segments of a pentalith of the star-shaped *Micrantholithus vesper* Deflandre (1); *Braarudosphaera bigelowi* (Gran & Braarud) Deflandre, distal view of a larger (2) and a smaller (3) specimen

Micrantholithus vesper Deflandre
Text-fig. 3/1

1954 *Micrantholithus vesper* Deflandre, in Deflandre & Fert, p. 52, pl. 13, fig. 7, text-figs. 5, 115, 116.

Single elements of the pentagonal, star-shaped plates are to be found in the sample from the *Scyphosphaera tubicena* Subzone (Sta. 14). Already Bramlette & Sullivan 1961 reported on the simultaneous occurrence of *Micrantholithus vesper* with the now newly described *Scyphosphaera tubicena* (their lopadolith, pl. 5, fig. 20).

Lower Eocene to Miocene.

Spenolithus radians Deflandre
Plate LXXXIII, figs. 8, 9

1952 *Spenolithus radians* Deflandre, in Grassé, p. 466, figs. 343 J-K, 363 A-G.

In side view wedge-shaped calcareous bodies composed of several radially arranged plates. Possibly closely related to the Paleocene genus *Fasciculithus*. Common in the Lower Eocene of the Hagenbach Valley.

Thoracosphaera deflandrei Kamptner
Plate LXXXVI, figs. 8—11

1956 *Thoracosphaera deflandrei* Kamptner, p. 448, fig. 1—4.

Hollow spherical shells formed of interlocking prismatic elements, which under crossed nicols show a „jig saw puzzle" pattern. No buccal opening observed.

Common in Eocene marine sediments.

Clathrolithus ellipticus Deflandre
Plate LXXXVI, fig. 12; text-fig. 4

1954 *Clathrolithus ellipticus* Deflandre, in Deflandre & Fert, p. 169, pl. 12, fig. 19, pl. 14, fig. 7, text-figs. 123, 124.

Elliptical, calcareous bodies with three rows of three to five hexagonal pores arranged in quincunx pattern, similar to a honey comb; additional marginal pores smaller, irregular and partly open in peripheral direction. Rare.

Usually very poorly preserved due to its delicate structure.

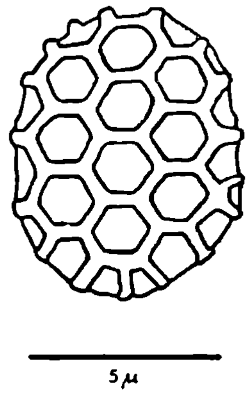

Fig. 4. *Clathrolithus ellipticus* Deflandre, plan view

REWORKING OF NANNOFOSSILS

Because of their small dimensions coccoliths and discoasters are more readily reworked and redeposited into younger sediments than any other group of marine fossils. Larger fossils are shifted as single pieces, whereas nannofossils are apt to travel in bulk, dozens and hundreds in each small partical of nannofossiliferous marl. This transporting out of older deposits and resedimentation into younger marine bottom mud was caused by turbidity currents mainly, sweeping over and eroding what had been deposited long before. This process, possibly reproduced more than once during the deposition of the Flysch sediments, has contributed „foreigner" nannofossils into the indigenous Eocene of the Hagenbach Valley. They came from the

Lower Cretaceous:

Nannoconus steinmanni
Nannoconus globulus
Parhabdolithus embergeri et cet.

from the Upper Cretaceous:

Arkhangelskiella cymbiformis
Lucianorhabdus cayeuxi
Micula staurophora
Zygolithus crux
Zygolithus litterarius et cet.

For these cretaceous species occurring in the Eocene an extended range can be excluded because of the mass extinction of the nannoplankton at the Maestrichtian-Danian time-boundary, to be observed world-wide in socalled „clean" samples (without any reworked forms). More about it in Bramlette & Martini 1964, Bramlette 1965, Hay & Mohler 1967, Tappan 1967.

For the Paleocene species occurring in the Lower Eocene of the Hagenbach Valley there still remains some uncertainty whether they were all reworked, other whether some of these typical Paleocene species were still occurring in the Lower Eocene, in other words that they had not become extinct yet but were still within their normal stratigraphic range. There are among others:

Discoaster gemmeus
Discoaster lenticularis
Discoaster multiradiatus
Discoaster salisburgensis
Coccolithus bidens
Coccolithus bisulcus
Coccolithus macellus
Heliorthus concinnus
Heliorthus junctus

to be mentioned as species occurring already in the Paleocene. In the plates and descriptions only Tertiary nannofossils are shown, all the Cretaceous forms, for which heterochrony and allochthony is evident, were excluded. Of the Tertiary species some or even all of the „Paleocene" species may be reworked or not. They have been included in plates and text, in order not to omit any possible Eocene occurrence of them.

NANNOPLANKTON ZONATION OF PALEOCENE AND EOCENE FLYSCH SEDIMENTS

Within the past few years several papers on the nannoplankton zonation of the Flysch sediments in Austria, Czechoslovakia, Poland and Switzerland (Brix 1961, Bystrická 1965, Hay & Schaub 1960, Hekel 1966, 1968, Radomski 1967, 1968, Samuel & Bystrická 1968, Stradner 1961, 1964) have been published. The nannoplankton zonation given by Hay & Mohler 1967 for SW France, and by Hay, Mohler, Roth, Schmidt & Boudreaux 1967 for the Gulf Coast and the Carribbean-Antillean Area enables us to correlate nannoplanktonic assemblages over wide geographic distances. As identical nannofossil species occur in marine sediments in world-wide distribution and as they are rather indifferent regarding the sediment facies, they are ideally suited for correlation purposes.

Nannoplankton zonation of Paleocene- Eocene according to Hay & al. 1967:

Isthmolithus recurvus	-Zone	Oligocene / Upper Eocene
Discoaster tani nodifera	-Zone	
Chiphragmalithus quadratus	-Zone	
Discoaster sublodoensis	-Zone	
Discoaster lodoensis	-Zone	
Marthasterites tribrachiatus	-Zone	Lower Eocene / Upper Paleocene
Discoaster binodosus	-Zone	
Marthasterites contortus	-Zone	
Discoaster multiradiatus	-Zone	
Heliolithus riedeli	-Zone	
Discoaster gemmeus	-Zone	
Heliolithus kleinpelli	-Zone	
Fasciculithus tympaniformis	-Zone	
Cruciplacolithus tenuis	-Zone	
Markalius astroporus	-Zone	Danian / Upper Maastrichtian

To characterize the stratigraphic position of the Lower Eocene of the Hagenbach Valley also the preceeding nannoplankton zones as well as the subsequent ones of the Austrian Flysch region are discussed. Beginning from below to above the oldest nannoplankton-zone recognized in the Paleocene-Eocene flysch of Austria is:

The *Heliolithus riedeli* Zone. It is the interval from the first occurrence of *Heliolithus riedeli* to the first occurrence of *Discoaster multiradiatus* (Bramlette & Sullivan 1961).

In Austria this zone was found in the Flyschzone north of Vienna outcropping at the Stetten football field (Hekel 1968). In the Helvetikum of Salzburg it was found in the Craniensandstone and the Grypheenbank (lower part of Zone E = *Globorotalia pseudomenardii* Zone according to Gohrbandt 1963, Stradner 1963). In the Outer-Carpathians Flysch of Poland a *Heliolithus* Zone was described by Radomski 1967 and correlated with the lower part of Gohrbandt's zone E and considered as Upper Thanetian. The nannofossil assemblage of the Thanet sands at their type locality in England belongs into the *Heliolithus riedeli* zone. Also at Trinidad, Lizard Springs strata, at the type locality of *Globorotalia pseudomenardii*, the *Heliolithus riedeli* assemblage was found (Bramlette & Sullivan 1961).

The *Discoaster multiradiatus* Zone is the interval from the first occurrence of *Discoaster multiradiatus* to the first occurrence of *Marthasterites bramletti*. (The term *D. multiradiatus* zone was first used by Brönnimann & Stradner 1960 and described in more detail by Bramlette & Sullivan 1961 and Hay & Mohler 1967).

In Austria this zone is exposed in many places in the Flysch region west of Vienna between Hainfeld, Hochstraß and Steinriegel (Brix 1961, Stradner 1961, 1964, Grün et al. 1964). In the Helvetikum of Salzburg the *Discoaster multiradiatus* zone corresponds to the upper part of the Zone E of Gohrbandt 1963. In the flysch of Slovakia it is correlated with the *Globorotalia aequa* and *Globorotalia subbotinae marginodentata* occurrences of Upper Paleocene (Upper Illerdian) age. (Bystrická 1965, Samuel & Bystrická 1968). In the flysch of Poland (Radomski 1967, 1968) this zone is correlated with the *Nummulites planulatus* Zone (Bieda 1959) and the occurrences of *Globorotalia aequa, Gl. rex* and *Gl. marginodentata*. In the Schlierenflysch of Switzerland (Hay & Schaub 1960) this zone corresponds to the beds bearing *Nummulites deserti* and *Nummulites solitarius* [1], At Paderno d'Adda it lies entirely within the *Globorotalia velascoensis* Zone (Hay & Mohler 1967), in Switzerland it was found to straddle the *Gl. pseudomenardii*-Zone *Gl. velascoensis* Zone boundary (Hay & Mohler 1966). Also at Velasco, Mexico, it covers the upper part of the *Gl. pseudomenardii* Zone and at least the lower part of the *Gl. velascoensis* Zone.

The *Marthasterites contortus* zone (Hay 1964) is the interval from the first appearance of *Marthasterites bramlettei* to the last occurrence of *Marthasterites contortus.*

In Austria this zone was registered in the flysch deposits north of Vienna at Kleinrötz by Hekel 1968. In Poland this zone is considered as part or extension of the *Discoaster multiradiatus* Zone (Radomski 1968). In Slovakia, this zone is evident in the Upper Paleocene, from which also *Marthasterites contortus* is reported (Samuel & Bystrická 1968). At the type Spilecciano, Italy, the microfauna of rare *Globorotalia velascoensis* and abundant specimens of *Globorotalia rex* is correlated with the lower part of the *Marthasterites contortus* Zone (Brönnimann, Stradner & Szöts 1965; Hay & Mohler 1967). The type locality of *Globorotalia rex* in Trinidad belongs to the upper part of the *Marthasterites contortus* Zone (Hay & Mohler 1967). This zone also was reported from the Upper Paleocene of Israel, from the Negev Desert, by Moshkovitz 1967, and from the Upper Paleocene of New Zealand (or. comm. by A. R. Edwards 1968).

The *Discoaster binodosus* Zone is defined as the interval from the last occurrence of *Marthasterites contortus* to the first occurrence of *Discoaster lodoensis* (Mohler & Hay in Hay et al. 1967). In Austria, in the flysch north of Vienna, the evolutionary steps between *Marthasterites bramlettei, M. contortus* and *M. tribrachiatus* were shown by Hekel 1968 in a sequence of samples just before the extinction *Marthasterites contortus,* which is considered the bottom of the *Discoaster binodosus* zone. In the Helvetikum of Salzburg this zone is represented in the Roterzschichten (Zone F of Gohrbandt 1963 = *Globorotalia rex Zone*). In the flysch of Slovakia this zone is described as that part of the Lower Eocene, in which *Marthasterites tribrachiatus* does occur, but not yet *Discoaster lodoensis.* (Samuel & Bystrická 1968). Also part of the Paleocene-Eocene assemblage, in which *Marthasterites tribrachiatus* is present, might have to be included in this zone. At Paderno d'Adda, the *Discoaster binodosus* zone coincides with the upper part of the *Globorotalia formosa formosa — Glr. aragonensis Zone.* In the Crimea, USSR, the *D. binodosus* zone was found in the *Operculina semiinvoluta* Zone of the Bakhchisaraian Stage (Hay & Mohler 1967).

The *Marthasterites tribrachiatus* Zone (Brönnimann & Stradner 1960, nannoflora listed in Brönnimann & Rigassi 1963) is defined as the interval from the first occurrence of *Discoaster lodoensis* to the last occurrence of *Marthasterites tribrachiatus.* (Hay & Mohler 1967). In Austria, this zone was found typically represented in the

[1] That is one Zone lower than the *N. planulatus* Zone.

Hagenbach Valley and other stations in the Vienna Woods by Brix 1961, Stradner 1961. Hekel in 1968 describes nannofossil assemblages characteristic for this zone from the flysch north of Vienna (lower part of his „Obere Coccolithenschiefer"). In the Helvetikum of Salzburg this zone is exposed in the Mattsee area, Stat. 130, with a microfauna containing *Globorotalia aragonensis.* (Stradner & Papp 1961).

In the flysch of Slovakia Samuel & Bystrická 1968 found their „*M. tribrachiatus + D. lodoensis*" Zone to fall into the range of *Globorotalia aragonensis.* In Poland (Radomski 1967, 1968) this zone is correlated with the *Nummulites planulatus + N. burdigalensis* Zone (Bieda 1959, Schaub 1965) and is found contemporaneous with the occurrence of *Globorotalia aragonensis.*

At Paderno d'Adda the *Marthasterites tribrachiatus* Zone extends from the upper part of the *Globorotalia formosa formosa — Globorotalia aragonensis* Zone to the lower part of the *Hantkenina aragonensis* Zone of Bolli & Cita 1960 (Hay & Mohler 1967). According to Hay & Mohler 1967, who give a detailed discussion on the correlation of this zone in America and in Europe, the lower boundary of the Lower Eocene, for which the base of the *Nummulites planulatus* Zone is taken (Höttinger & Schaub 1960) lies about the middle of the *Marthasterites tribrachiatus* Zone (Schaub 1965, Hay & Mohler 1965).

In the Hagenbach Valley, Austria, as well as in the Lodo Section, California, two new sub-zones can be discerned within the *Marthasterites tribrachiatus* zone:

the „*Scyphosphaera tubicena subzone*" and the
„*Scyphosphaera columella subzone*".

Definitions: The *Scyphosphaera tubicena* subzone is characterized by the occurrence of *Scyphosphaera tubicena,* accompanied by no other *Scyphosphaera* species of same frequence. Also *Micrantholithus vesper* in present. The *Sc. tubicena* subzone lies in the lower middle part of the *Marthasterites tribrachiatus* zone of the Lodoformation in California (Bramlette & Sullivan 1961, sample no. 52) and in the upper part of the section exposed in the Hagenbach Valley, Vienna Woods, Austria. (Type locality Stat. 14).

The *Scyphosphaera columella* subzone is characterized by the occurrence of *Scyphasphaera columella,* accompanied by *Sc. apsteini* and *Sc. cf. galeana* in lesser frequence. The *Sc. columella* subzone lies in the lower part of the *Marthasterites tribrachiatus* zone of the Lodo formation in California (Bramlette & Sullivan 1961, sample no. 39) in strata near those with the first occurrence of *Discoaster lodoensis.* In the Hagenbach Valley, Vienna Woods, Austria, it lies in the lower part of the exposed section of the *Marthasterites tribrachiatus* zone. (Type locality Sta. 4).

The *Discoaster lodoensis* Zone (Brönnimann & Stradner 1969, nannoflora listed in Brönnimann & Rigassi 1963) is defined as the interval from the last occurrence of *Marthasterites tribrachiatus* to the first occurrence of *Discoaster sublodoensis.*

In Austria this zone is exposed in the flysch north of Vienna at Oberkreuzstetten near the Hipplinger Heide (Hekel 1968, Stat. 535) with a nannoplankton assemblage of *Discoaster lodoensis* without *Marthasterites tribrachiatus* (Lower part of the upper Zone of „Obere Coccolithenschiefer").

In the Slovakian flysch this zone is considered as lower Middle Eocene and described as „*Discoaster*-Zone" with *D. lodoensis* and *D. elegans*, but without *Marthasterites tribrachiatus* (S a m u e l & B y s t r i c k á 1968). It lies in the *Turborotalia (A.) crassata densa* Zone, in which also *Globigerina senni, Gl. boweri, Globorotalia renzi* and *Glr. spinulosa* occur.

In the flysch of the Polish Outer Carpathians this zone is termed „*Discoaster lodoensis* Zone" (without *Marthasterites tribrachiatus*) and is considered Lower Lutetian on account of *Nummulites laevigatus* (B i e d a, 1959, 1966; R a d o m s k i, 1967). In the Caucasus, at Cherkessk, USSR, the *Discoaster lodoensis* zone was found to correspond the *Acarinina crassaformis* Zone of the Simferopolian Stage (H a y & M o h l e r 1967).

The *Discoaster sublodoensis* Zone is defined as the interval from the first occurrence of *Discoaster sublodoensis* to the first occurrence of *Chiphragmalithus quadratus* (H a y et al. 1967).

In Austria this zone is possibly represented in the upper part of the „Obere Coccolithenschiefer" in the flysch north of Vienna, from where H e k e l 1968 reported the occurrence of *Discoaster sublodoensis*. This seems to be the youngest part of flysch sediments in the sequences of that area (flysch senso stricto according to the Austrian geologists interpretation of „flysch"). In Czechoslovakia and Poland also sediments ranging into the Upper Eocene and Oligocene show flysch features and are termed „flysch", whereas in Austria such sediments would be called „flyschoid".

In Slovakia this zone seems to be aequivalent with the „middle *Discoaster*-Zone" of the Middle Eocene, for which *Discoaster barbadiensis* and *D. saipanensis* was found characteristic (S a m u e l & B y s t r i c k á 1968). As *D. sublodoensis* and *D. saipanensis* are two very closely related species with rather similar outline, it might be rather a matter of different interpretation than of different species.

After this short survey on the present status of flysch stratigraphy by means of nannofossils the author and the reader are confronted with better possibilities and new chances for the application of this branch of micropaleontology. It can be assumed, that the stratigraphic zonation of flysch sediments will be improved and worked out in a much more detailed way within the near future, in cooperation of the geologists of all countries, in which flysch sediments occur and in which nannoplankton research is done.

Preparation Techniques

The nannofossiliferous samples from the Eocene of the Hagenbach Valley did not require any special treatment or time-consuming concentration procedures. The clay matrix, which envelops the nannofossils, is readily removed by stirring in water. A few drops of the watery suspension of the original marl samples are dried up on a cover glass. A drop of Caedax (artificial canada balsam by MERCK AG., Darmstadt, Germany; refracting index 1,55) is used to enclose the nannofossils and to seal the cover glass to the glass slide. Besides this routine preparation, which proved quite sufficient with such rich nannoplankton assemblages, special methods, such as concentration by partial sedimentation or centrifugalisation, transformation of the calcium carbonate into calcium fluoride, heavy metall shadowing, might be applied. For more detailed information vide: D e f l a n d r e & F e r t 1954, S t r a d n e r & P a p p

1961, Bramlette & Sullivan 1961, Hay in Kummel & Raup 1965, Maresch 1966, Hekel 1968.

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ADDENDUM

The following paper dealing with the nannoplankton zonation of Italian flysch sediments has unfortunately come too late to my notice to be included in the text:

Barbieri F. & Panicieri E. (1968), Calcareous nannoplankton from the Upper Cretaceous and early Tertiary flysch of Baganza Valley (North Italy), *Riv. Ital. Paleont. Stratigr.*, 74, no. 2, p. 421—448, 5 pls.

ZUSAMMENFASSUNG

Vergesellschaftungen von Nannofossilien (Schalen-Elemente von marinen Kalkflagellaten) aus dem Eozänflysch des Hagenbachtales im nördlichen Wienerwald, Österreich, wurden analysiert und beschrieben. Außer 46 typisch tertiären Nannofossil-Arten wurden auch umgelagerte Arten aus Unter- und Oberkreide nachgewiesen. Die Nannofossil-Vergesellschaftungen gehören der „Marthasterites tribrachiatus-Zone" an und werden als Untereozän angesehen. Zwei neue Unterzonen, die „*Scyphosphaera columella*-Unterzone" (tieferes Untereozän) und die „*Scyphosphaera tubicena*-Unterzone" (mittleres Untereozän) werden auf Grund

der zwei neuentdeckten *Scyphosphaera*-Arten vorgeschlagen. Die Nannoplankton-Zonengliederungen von Flyschsedimenten aus dem Paleozän und dem Eozän von Österreich, der Tschechoslovakei, von Polen und der Schweiz werden erörtert und verglichen.

EXPLANATION OF PLATES

Plate LXXX

Figs. 1, 2. *Discoaster lenticularis* Bramlette & Sullivan, phc
Fig. 3. *Discoaster gemmeus* Stradner, nl
Fig. 4. *Discoaster salisburgensis* Stradner, nl
Fig. 5. *Discoaster multiradiatus* Bramlette & Riedel, phc
Figs. 6, 9, 11, 12. *Discoaster kuepperi* Stradner, nl, anc, nl, anc
Figs. 7, 8, 10. *Discoaster elegans* Bramlette & Sullivan, nl, anc, x-nic
Magnification: 2800X

Plate LXXXI

Fig. 1. *Discoaster lodoensis* Bramlette & Riedel, very small specimen, nl
Fig. 2. *Discoaster lodoensis* Bramlette & Riedel, nl
Fig. 3, 4. Teratological (abnormally formed) asteroliths of *Discoaster lodoensis* Bramlette & Riedel, nl, phc
Figs. 5, 8. *Discoaster lodoensis* Bramlette & Riedel, phc, anc
Figs. 6, 7. *Discoaster lodoensis* Bramlette & Riedel, large seven-rayed asterolith, anc, nl
Magnification: 2800X

Plate LXXXII

Fig. 1—4. *Discoaster binodosus* Martini (1) and *Discoaster mirus* Deflandre (2); intermediary forms (3 and 4)
Fig. 5—10. *Discoaster* cf. *gemmifer* Stradner, normal (5, 6, 8, 9) and irregular forms (7, 10); phc
Magnification: 2800X

Plate LXXXIII

Fig. 1—5. *Marthasterites tribrachiatus* (Bramlette & Riedel) Deflandre; different specimens in plan view (1—3) and in oblique side view (4, 5); phc, ac, nl, x-nic, x-nic
Fig. 6, 7, 10—12. *Zygrhablithus bijugatus* Deflandre, sideviews (6, 7) x-nic; apical view (10, 11) phc, x-nic; split fragment in oblique sideview (12) phc
Fig. 8, 9. *Sphenolithus radians* Deflandre, side views; anc, x-nic
Fig. 13, 14. *Scapholithus fossilis* Deflandre, plan view; phc, x-nic
Magnification: 2800X

Plate LXXXIV

Fig. 1—3. *Coccolithus petrinus* nov. spec.; nl, phc, x-nic
Fig. 4—6. *Coccolithus petrinus* nov. spec.; phc, anc, x-nic
Fig. 7—10. *Coccolithus bisulcus* Stradner; phc, anc, x-nic, x-nic
Fig. 11. *Coccolithus eopelagicus* Bramlette & Riedel; nl
Fig. 12—14. *Coccolithus pelagicus* (Wallich) Schiller; phc, anc, x-nic
Fig. 15—17. *Reticulofenestra cf. placomorpha* (Kamptner) Stradner; nl, phc, x-nic
Fig. 18—20. *Coccolithus macellus* (Bramlette & Sullivan) Stradner; phc, x-nic, x-nic

Magnification: 2800X

Plate LXXXV

Fig. 1—4. *Camphylosphaera dela* (Bramlette & Sullivan) Hay & Mohler; phc, x-nic, phc, anc
Fig. 5—8. *Coccolithus cribellum* Sullivan; phc, anc, phc, x-nic
Fig. 9—11. *Chiasmolithus bidens* (Bramlette & Sullivan) Hay & Mohler; phc, anc, x-nic
Fig. 12—14. *Chiasmolithus grandis* (Bramlette & Riedel) Hay, Mohler & Wade; anc, x-nic, nl
Magnification: 2800X

Plate LXXXVI

Fig. 1—4. *Cyclolithella robusta* (Bramlette & Sullivan) nov. comb., nl, phc, anc, x-nic
Fig. 5—7. *Cyclococcolithus gammation* (Bramlette & Sullivan) Sullivan; nl, phc, x-nic
Fig. 8—11. *Thoracosphaera deflandrei* Kamptner; nl, optical section (8); nl, high focus (9) x-nic, high focus (10), x-nic, shell fragment (11)
Fig. 12. *Clathrolithus ellipticus* Deflandre; anc, demaged specimen
Magnification: 2800X

Plate LXXXVII

Fig. 1—3. *Neococcolithes dubius* (Deflandre) Black; nl, x-nic, phc
Fig. 4—5. *Heliorthus concinnus* (Martini) Hay & Mohler; phc, anc
Fig. 6—8. *Heliorthus fallax* Brönnimann & Stradner; nl, phc, anc
Fig. 9—12. *Heliorthus junctus* (Bramlette & Sullivan) Hay & Mohler; nl, phc, anc, x-nic
Fig. 13—14. *Discolithina pulchra* (Deflandre) Levin; phc, x-nic
Fig. 15—16. *Discolithina plana* (Bramlette & Sullivan) Levin; anc, x-nic
Fig. 17—18. *Discolithina pulcheroides* (Sullivan) Levin & Joerger; anc, x-nic
Fig. 19—20. *Helicopontosphaera seminulum* (Bramlette & Sullivan) nov. comb. anc, x-nic
Magnification: 2800X

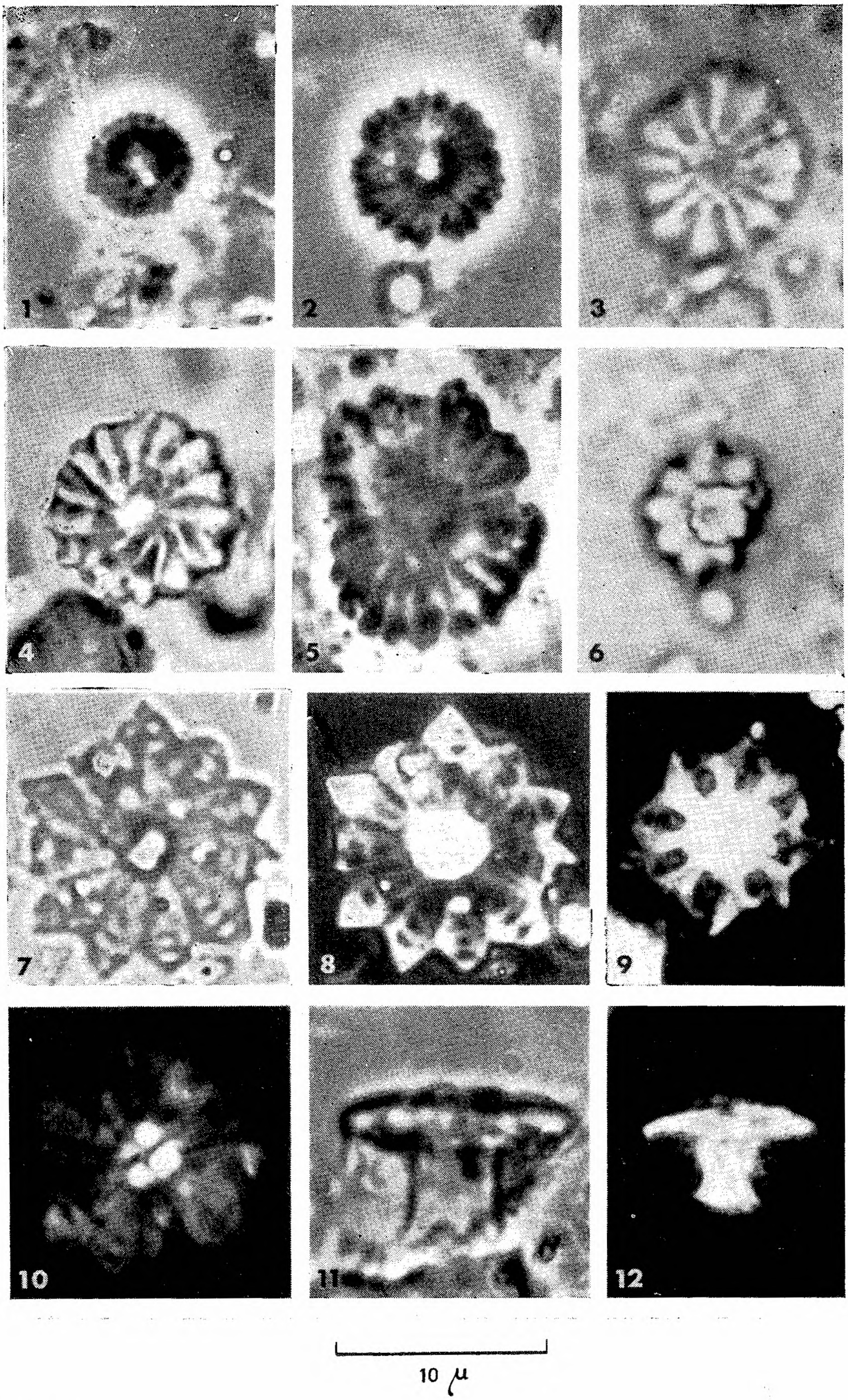
Plate LXXXVIII

Fig. 1—3. *Scyphosphaera* cf. *galeana* Kamptner; nl, phc, anc
Fig. 4—8. *Scyphosphaera columella* nov. spec.; phc, x-nic, x-nic, anc, x-nic
Fig. 9—12. *Scyphosphaera tubicena* nov. spec.; x-nic + gypsum plate (9,10), anc, x-nic
Magnification: 2800X

Plate LXXXIX

Fig. 1—3. *Scyphosphaera apsteini* (Lohmann) Schiller; nl, phc, x-nic
Fig. 4—5. *Blackites creber* (Deflandre) Stradner; nl, x-nic
Fig. 6—8. *Rhabdosphaera truncata* Bramlette & Sullivan; phc, anc, x-nic
Fig 9—12. *Rhabdosphaera herculea* nov. spec.; phc, anc, x-nic, x-nic
Fig. 13—15. *Rhabdosphaera* cf. *pinguis* Deflandre; phc, x-nic, phc
Magnification: 2800X

Abbreviations: nl = normal light (green filter); x-nic. = crossed nicols; phc = positive phase contrast; anc = anoptral contrast.



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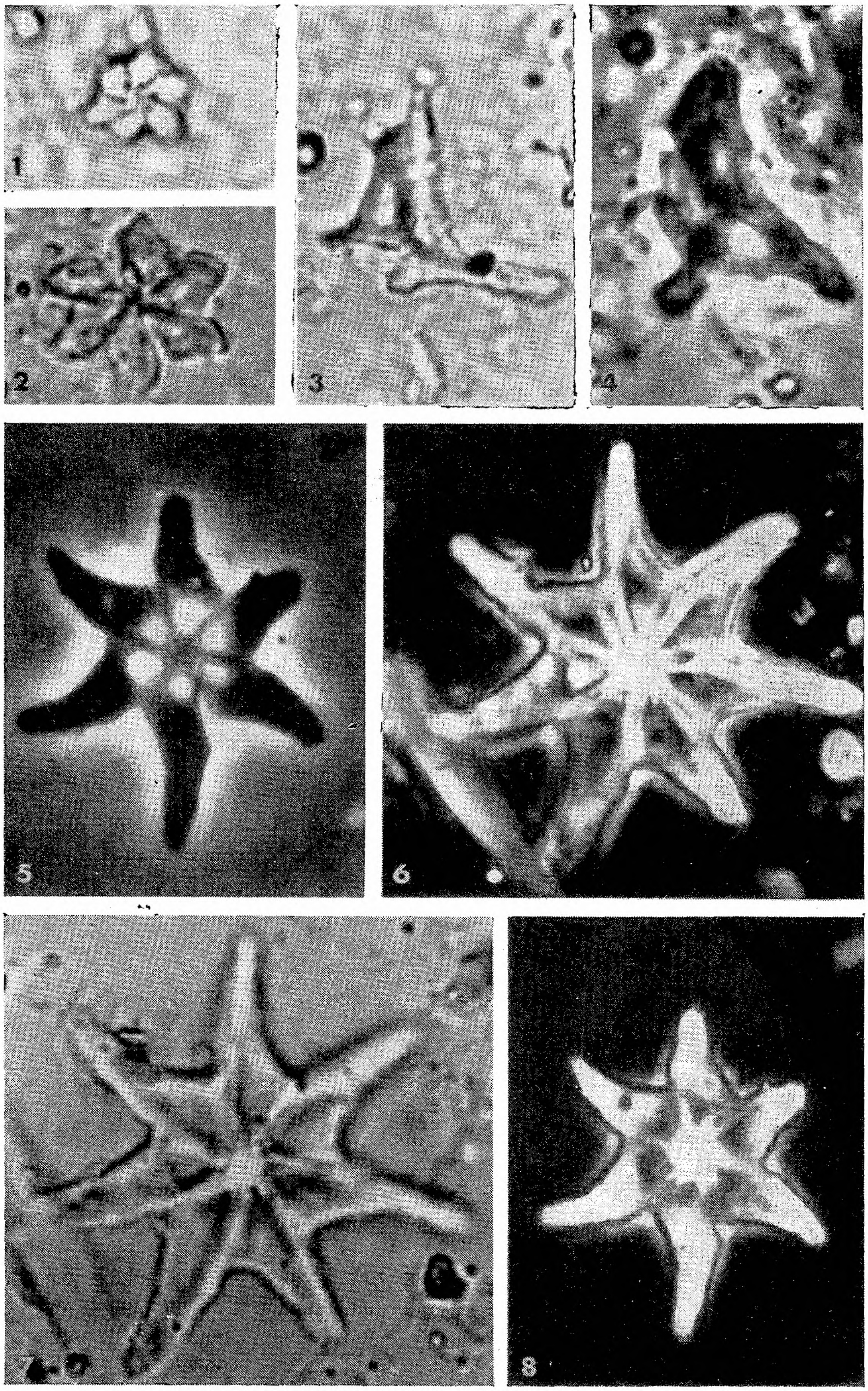

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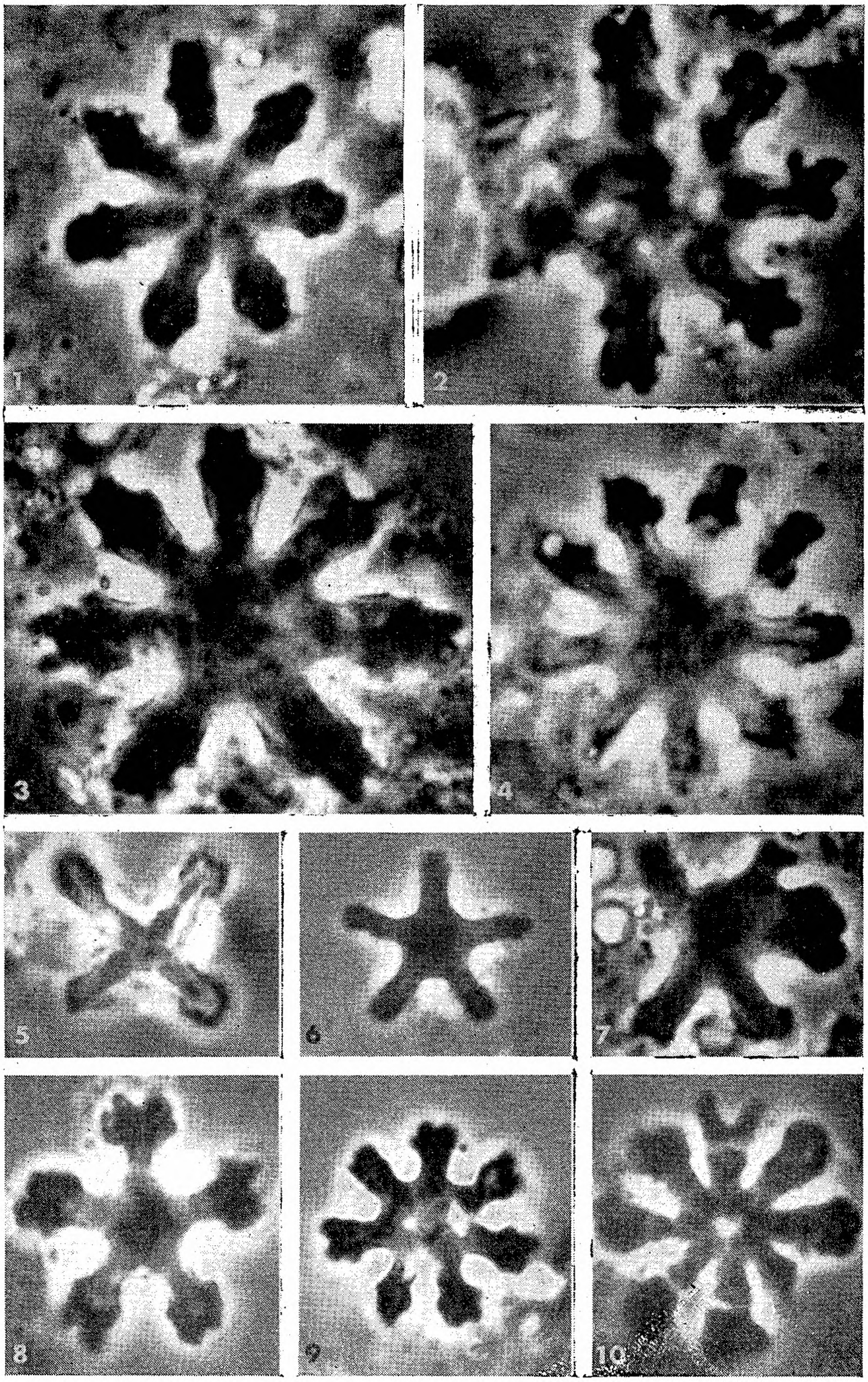

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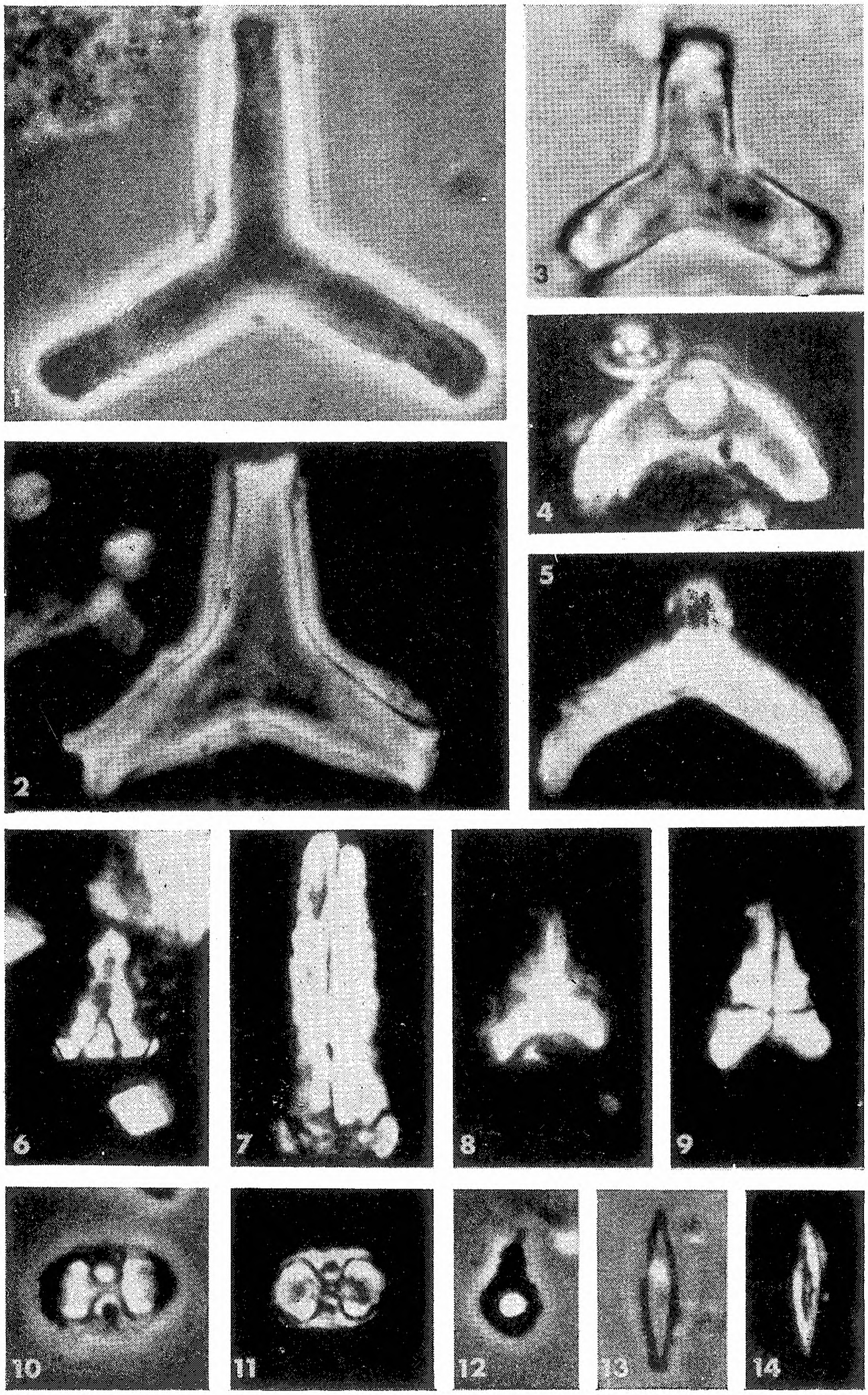

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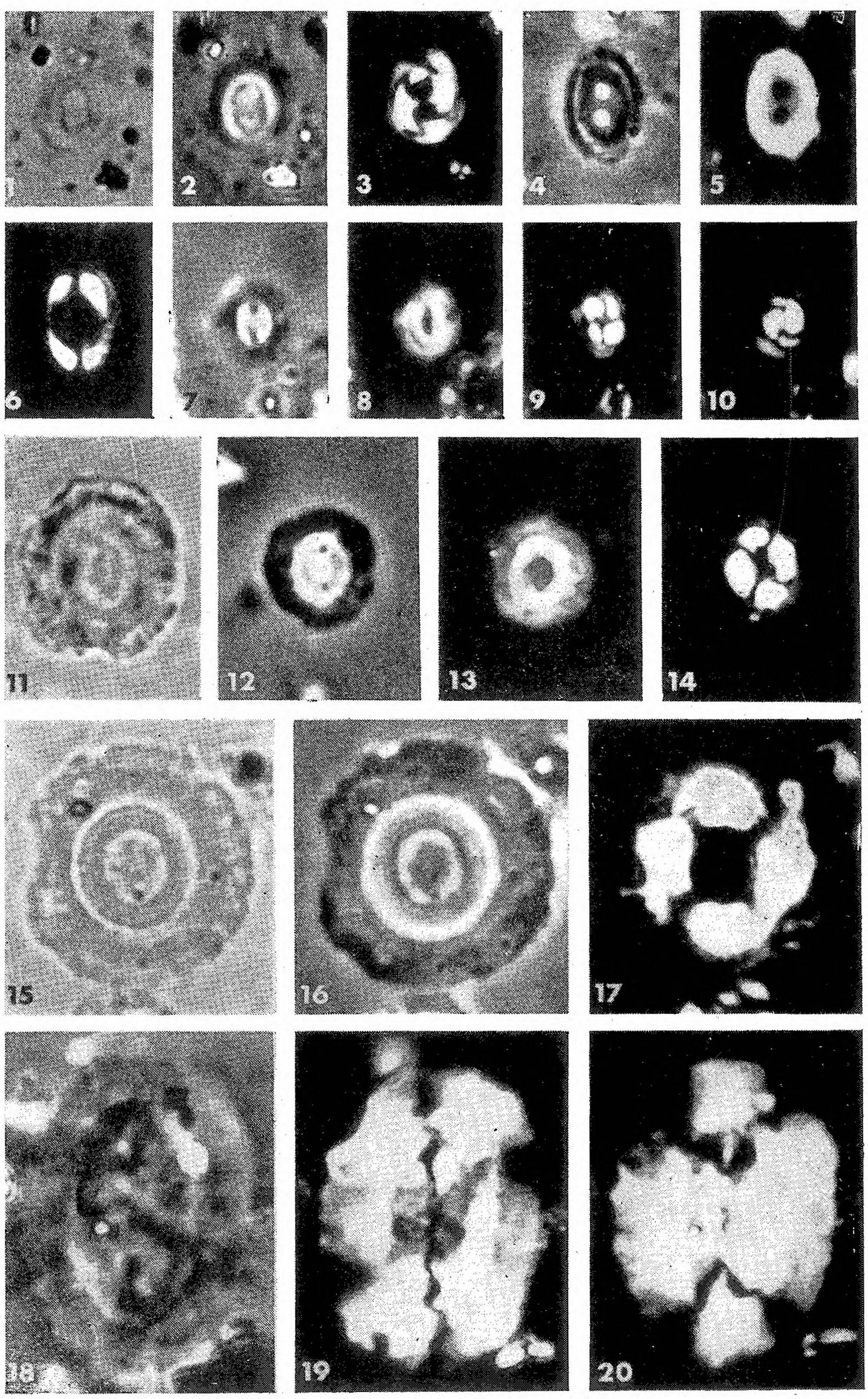

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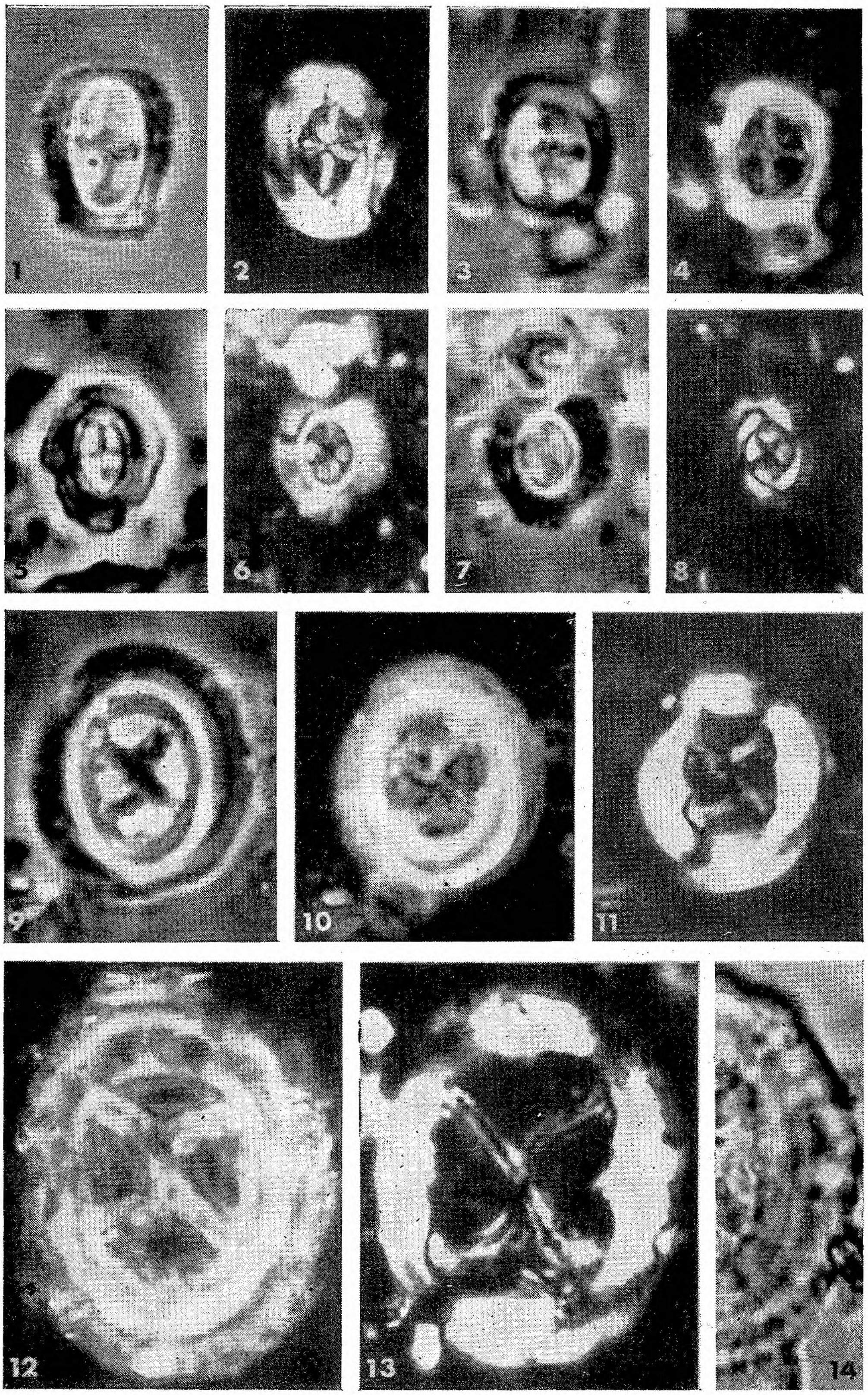

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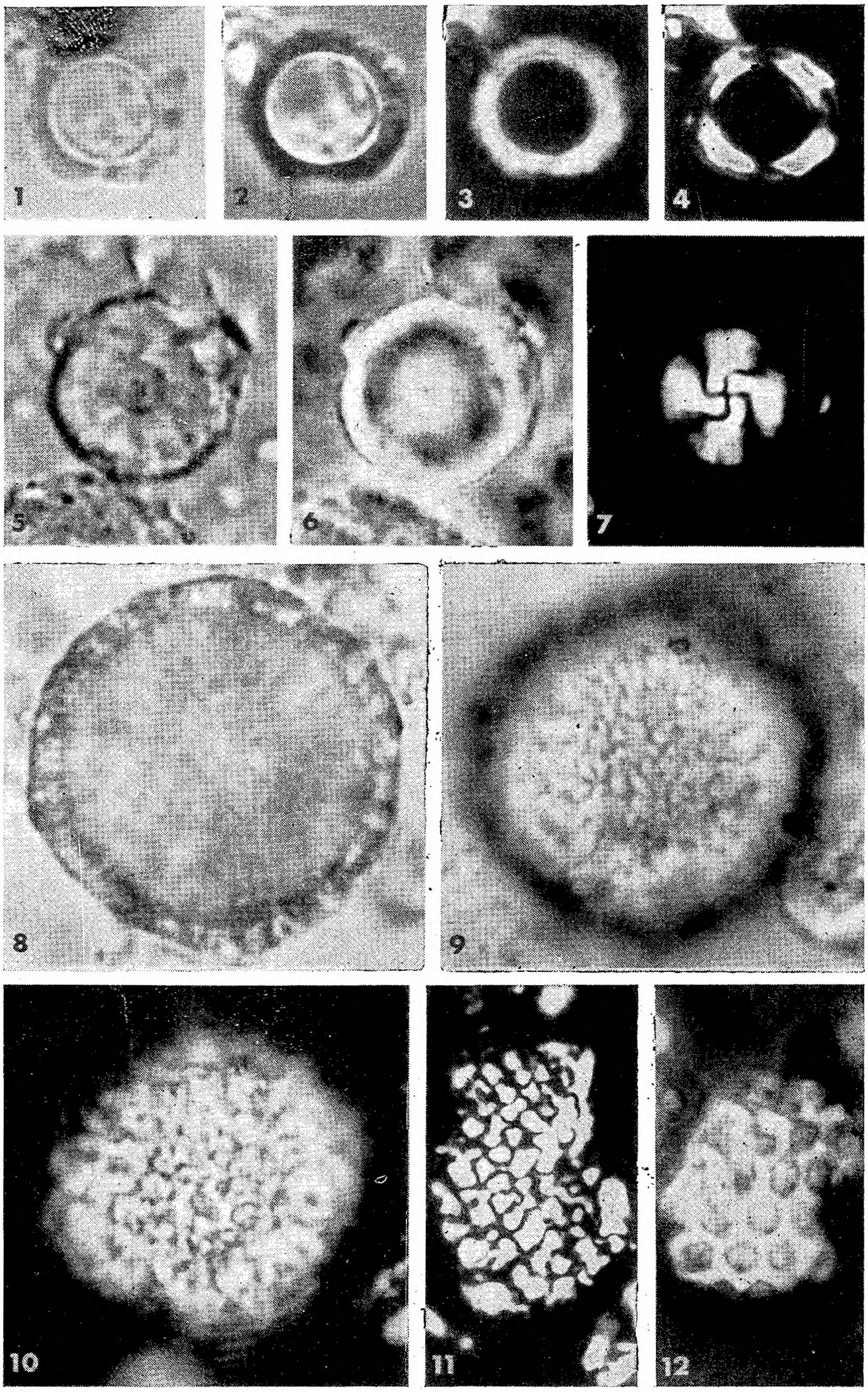

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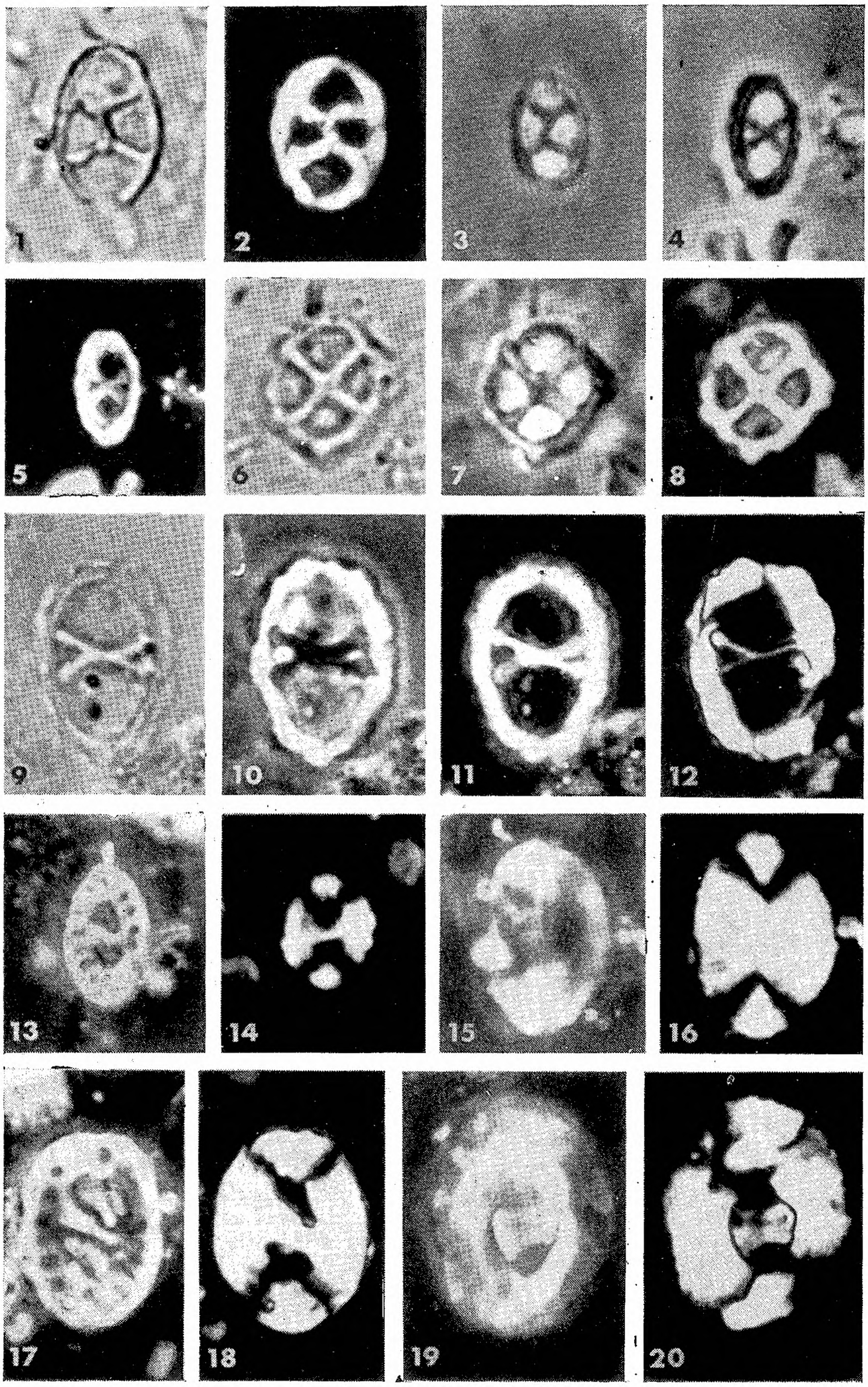

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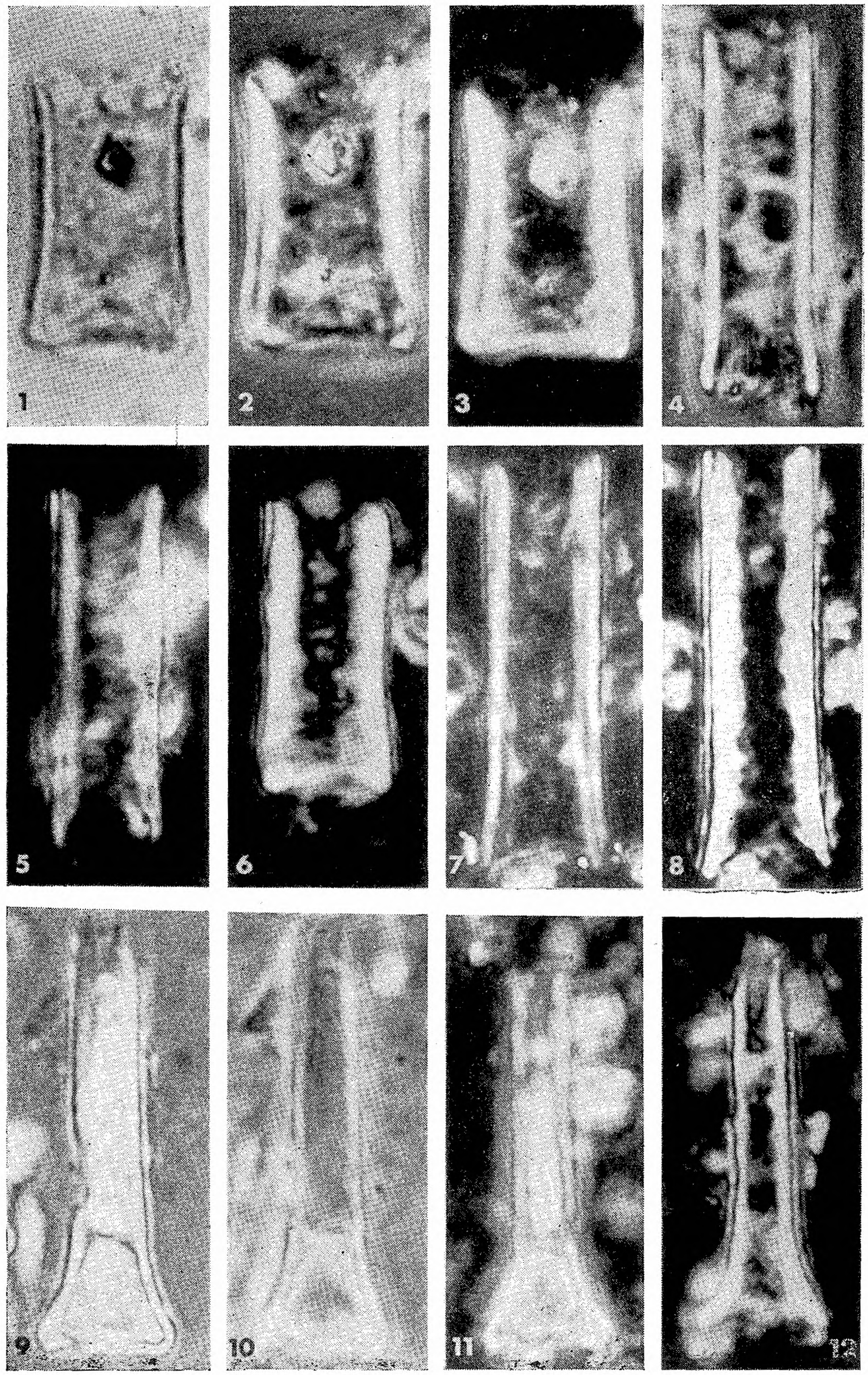

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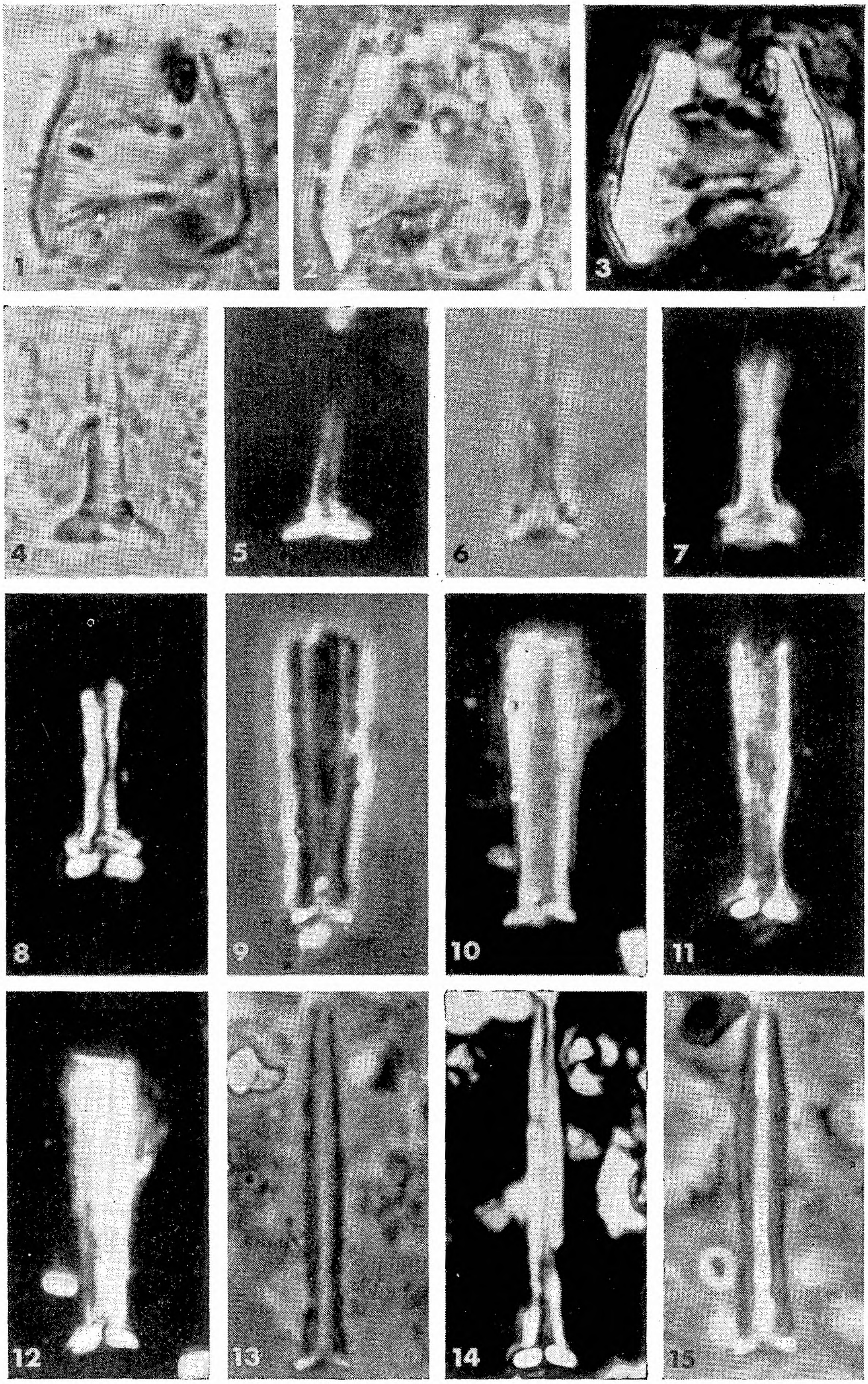

H. Stradner