

*With Compliments to Dr Perch-Nielsen
U. Z. Bilal ul Haq*

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STUDIES ON UPPER EOCENE
CALCAREOUS NANNOPLANKTON
FROM NW GERMANY

By

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2. Studies on Upper Eocene calcareous nannoplankton from NW Germany

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Abstract. Calcareous nannoplankton from an Upper Eocene marl of NW Germany have been studied by means of phase-contrast light microscope, transmission electron microscope and scanning electron microscope. A total of 35 species are described. Four new genera (*Rotalithus*, *Cycloplacolithella*, *Stradnerius* and *Tessellatolithus*) and seven new species (*Rotalithus teutonicus*, *Cycloplacolithella simplex*, *C. blacki*, *Coccolithus perforatus*, *Stradnerius daviesi*, *Discolithina rectipons* and *Tessellatolithus dentatus*) are reported. An attempt is made to present a picture of the mondial distribution of calcareous nannoplankton during the Eocene.

INTRODUCTION

The calcareous nannoplankton content of drilling samples from an Upper Eocene marl from NW Germany is described in this paper. The study was mainly carried out by means of a transmission electron microscope, using carbon replication methods. Wherever possible the electronmicrographs have been compared with the corresponding photomicrographs taken under both positive and negative phase-contrast conditions. The phase-contrast pictures show a definite advantage over pictures taken under ordinary polarized light and crossed nicols in showing greater structural details. The author was also able to observe many of the species by means of a scanning electron microscope which enables a better understanding of their architecture. The use of this type of microscope may modify many of our ideas about the general structure and the relationship of various parts of coccoliths to each other by revealing such features as the relative depths of openings and perforations and greater surfacial details. The advantages of this instrument are multiple. Unlike the transmission electron microscope, it allows the original specimens to be observed under its beam, thereby avoiding the time consuming procedures of carbon replication. A dried drop of a coccolith suspension or even a small piece of the rock itself can be directly introduced into the microscope for observation. The stage holding the specimen can be turned to orientate the specimen in a desired position or to observe its side view. However, the resolution power of this instrument is low (500—200 Å) as compared to the transmission electron microscope (up to 40 Å in Zeiss EM9) so that it cannot be used very effectively for the study of ultrastructures, for which the transmission electron microscope will still be necessary.

ACKNOWLEDGEMENTS

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DESCRIPTION OF MATERIAL

A number of Paleogene samples from various closely situated boreholes in NW Germany were provided by the Deutsche Erdöl-Aktiengesellschaft for the study of their calcareous nannoplankton content. Most of these samples contain well preserved assemblages of nannoplankton. Out of a number of Upper Eocene samples in this collection six samples which contain well preserved coccoliths, were selected for the present study. The other samples which range from Paleocene to Upper Oligocene will form a part of a future study.

The samples studied here, came from borehole Hohne 1001; level 115.7—121.7 m, bags 1—6, collected at one meter intervals. They contain a comparatively high percentage of sand and some clay. The relatively large sand particles were easily removed by short-centrifuging and the clay was dissolved by the use of a dilute solution of sodium-hexametaphosphate (methods discussed in a separate chapter, p. 16). These samples, together with other Eocene samples from NW Germany, had been studied earlier by MARTINI (1958 and 1959), who reported a well preserved nannoplankton assemblage. He also discussed the relative position of these samples in the stratigraphic column.

The present study yields some 23 genera and 35 species, including 4 new genera and 7 new species. The state of preservation is good or very good. Very few discoasters and rhabdoliths were found, and those which were observed were

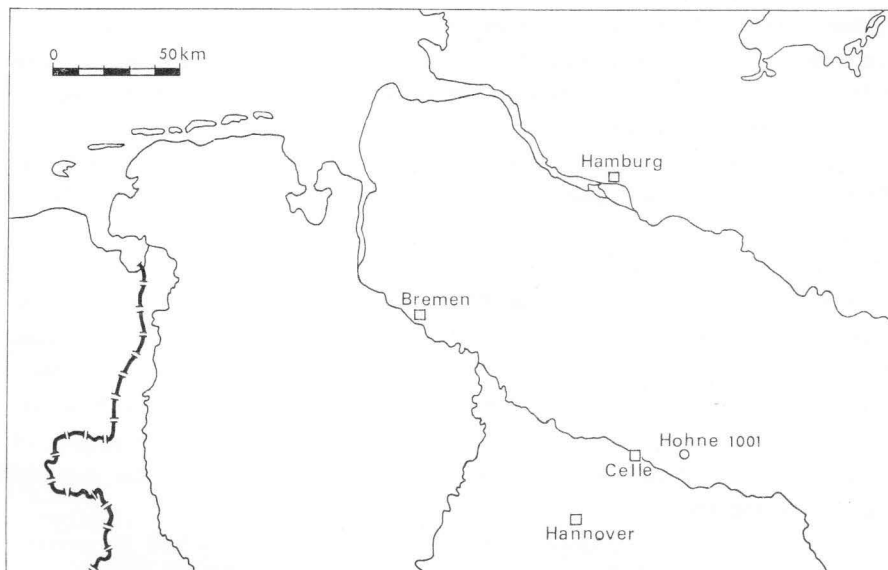


Fig. 1. Location of borehole Hohne 1001.

usually in a fragmentary state. This could be due to three main reasons: their highly three dimensional form, their delicate nature, and/or the application of ultrasonics in the laboratory treatment. Because of their large third dimension they seem to fall off the carbon film which is unable to support them unless it is too thick. Ultrasonics may also disperse their various parts. They are more often encountered in the light microscope where no ultrasonic treatment is used in the preparation of the suspension.

Some reworked Cretaceous forms such as *Arkhangelskiella cymbiformis* VEKSHINA, *Kamptnerius magnificus* DEFLANDRE, and *Parhabdolithus embergeri* (NOËL) STRADNER were observed, but they are easily distinguishable from the Upper Eocene forms by their usually poor state of preservation. The description of three other reworked forms, viz. *Coccolithus perforatus* n.sp., *Marthasterites* cf. *tribrachiatatus* (BRAMLETTE and RIEDEL) DEFLANDRE and *Discoaster multiradiatus* BRAMLETTE and RIEDEL has been included in this paper.

METHODS OF INVESTIGATION

The techniques of carbon replication and electron microscopy have been discussed by many authors. Workers in the field of calcareous nannoplankton have adopted a number of methods — depending mainly on the type of rock samples they were working with. Each of these methods takes into consideration the various constituents of the rock other than the nannoplankton, and those which are undesirable, such as sand and clay and organic matter, have to be removed before an effectively clean suspension for carbon replication can be obtained.

In 1964 HAY described replication methods in a general way stressing particularly preparation methods for Foraminifera (also HAY in KUMMEL and RAUP, 1965, pp. 3—7). BLACK and BARNES (1961) briefly mentioned their method for replication of coccoliths from the English Chalk. COHEN (1965) for the first time described preparation techniques for nannoplankton (from Adriatic sediments) in some detail. He also discussed some technical imperfections. The present author enumerated methods used by him in preparation of samples from marly limestones (1966).

HONJO and FISCHER (1964, also in KUMMEL and RAUP, 1965, pp. 326—334) described a preparation method for the study of coccoliths on the surface of hard limestones which cannot be powdered without destroying the essential features of the coccoliths.

In a recent paper, MARESCH (1966) described a new method of treating coccolith suspensions with hydrofluoric acid and nascent chlorine resulting in the desolving of clayey material and in the replacement of calcium-carbonate

with calcium-flouride, without any adverse effects on the ultrastructure of the coccoliths.

There is no effective method up to date of transferring individual coccoliths from a light microscope unto an electron microscope grid. HALLDAL, MARKALI and NAESE (1954) described such a method using an inverted microscope and a special micropipette attached to the microscope. However, this technique is useful only for such comparatively large specimens as complete coccospheres and cannot be effectively used for isolated coccoliths. Meanwhile, MARESCHE (Vienna) and PERCH-NIELSEN (Copenhagen) are learned to be developing methods in this direction with good success. Until such time that these methods are available, specific correlations between electronmicrographs and photomicrographs will remain uncertain and should be attempted with some reservations. The confusion in the taxonomy of nannoplankton (see discussion on taxonomy) will also largely remain until a reliable transferring technique has been developed.

The methods of preparation used for the samples described in this paper are the same as those employed in HAQ, 1966. However, certain difficulties have been overcome and some improvements have been made which are described below.

Cleaning of suspension

In case of marls and limestones with comparatively high percentage of silicious matter it is desirable to clean the coccolith suspension of these 'impurities' before carbon replication. After normal dispersion of grains by means of a dilute solution of hydrogen-peroxide and application of ultrasonics, and the concentration of coccoliths by short-centrifuging (EDWARDS, 1963) the suspension is treated with a small amount of dilute sodiumhexametaphosphate (two to three drops of a 3 percent solution in a suspension about 10 c.c.) for a period of 48 or more hours. The effect of this treatment can be clearly seen when a comparison is made between figs. 1 and 2 of Pl. I. In fig. 1, where no hexametaphosphate had been used, dark, irregular patches of clay are visible and cover most of the coccoliths either partly or completely. Fig. 2 shows the same suspension after treatment with hexametaphosphate for a period of 48 hours before replication. However, if too strong a solution of hexametaphosphate is used, it etches the surface of the coccoliths, thereby destroying important features. A little experimentation with the strength of the hexametaphosphate solution and the time of treatment proves beneficial.

Shadowing

Platinum, gold and chromium have proved to be good shadowing media. A combination of platinum-iridium has also been used and recommended by some

authors. (Compare Pl. I, figs. 1 and 2, where fig. 1 is unshadowed and fig. 2 is shadowed.) A double shadowing (one with platinum at a steep angle, and the other with carbon at a low angle) seems to give a better three dimensional effect (Pl. I, fig. 3).

Removing the carbon-film from the glass slide

This part of the preparation frequently offers the greatest difficulty and can be responsible for long periods of frustration. In such a case it is extremely helpful if a thin base film of some plastic or other easily removable material is first deposited on the glass slide before the deposition of the coccoliths. Formvar and "fax-film" have often been used as base films, but the most readily available and the easiest base-material proved to be ordinary soap. A clean glass slide is dipped into a weak solution of soap for a short time, then gently removed and left to dry in vertical position in a stand. After drying, the suspension is deposited, dried and then shadowed in a high-vacuum evaporator before carbon replication. The carbon film is cut into small squares and removed on water. However, if any difficulty in the removal of the film is still encountered, the slide is dipped for 2 to 3 seconds in a 4 percent solution of HF. Squares of film then come off the glass slide easily. After treatment of the film with HCl and HF to remove CaCO_3 and silicates it is also desirable to wash the film several times over distilled water before transferring it unto the electron microscope grids.

For the scanning electron microscope a very simple preparation method was adopted. Since this instrument is a reflection microscope no carbon replication is necessary and the specimen is directly observed under the scanning electron beam. A drop of coccolith suspension is deposited on the specimen holder and left to dry. It is then covered with a thin metallic film in order to decrease the absorption of the electron beam (copper was used in the present case), and then introduced into the microscope for study.

A Zeiss EM/9 transmission electron microscope was used for the present study. The phase-contrast pictures were taken by means of a Reichert Zetopan optical research microscope. All electronmicrographs were photographed with the carbon film on the grids facing towards the electron beam. A steroscan electron microscope Sr. 1 of the Cambridge Instrument Co. at the Silicate Research Institute of the Chalmers Technical University at Gothenburg, Sweden was used.

TAXONOMY

The present confusion in the taxonomy of fossil Coccolithophorales began to arise mainly when better descriptions were rendered by means of electron microscope studies which did not take any account of those characteristics which were considered important when coccoliths were studied only with the light microscope. Since the first use of the transmission electron microscope by DEFLANDRE and FERT, in 1954, for fossil calcareous nannoplankton and its subsequent use by many authors, it has become clear that although the light microscope descriptions based on such characteristics as birefringence and extinction figures under crossed nicols may help in identifying the presence of certain types in certain samples and thus being useful in biostratigraphy, they, however, do not permit true morphological descriptions of these types. With the possibility of better descriptions by means of the transmission electron microscope arose the problem of correlation between the taxa based on light microscope descriptions and those obtained by electron microscopy. The problem has proved to be exceedingly difficult to solve as no reliable method of transferring specimens from the light microscope unto the electron microscope exists (see chapter on methods). This problem is the major cause for the confusion in taxonomy and for the so often erroneous designations.

With the advent of the scanning electron microscope in which a three dimensional view of the original specimen is possible there is bound to be further confusion, at least in the initial stages. This instrument has revealed characteristics hitherto unknown and it seems that many of the transmission electron microscope descriptions, which are descriptions of two dimensional replicas, will have to be revised. However, it is hoped that the use of these two microscopies together will make it possible to clear the confusion to a great extent.

TERMINOLOGY

The descriptive terms used in this paper are those which are widely used and have been accepted by many authors in this field. Most of these terms have been proposed by BLACK and BARNES (1959, 1961), BRAARUD, DEFLANDRE, HALLDAL and KAMPTNER (1955), DEFLANDRE (1959), HALLDAL and MARKALI (1955) and HAY and TOWE (1962). For the exact meanings of almost all the terms see HAY, MOHLER and WADE (1966, pp. 381—383).

TYPIIFICATION

The transmission electron microscope and the scanning electron microscope type negatives, identified by their serial numbers, are deposited in the type collection of the Geological Institute, University of Stockholm, Sweden.

SYSTEMATIC DESCRIPTIONS

The following system for genera and species is adopted in this paper. —

Family *COCCOLITHACEAE* KAMPTNER 1928

- Tribe *Coccolitheae* KAMPTNER 1958
Genus *Ericsonia* BLACK 1964
Genus *Coccolithus* SCHWARZ 1894
Genus *Cyclococcolithus* KAMPTNER 1954
Genus *Cycloplacolithella* HAQ, n. gen.
Genus *Rotalithus* HAQ, n. gen.
Genus *Cyclolithella* LOEBLICH and TAPPAN 1963
Genus *Reticulofenestra* HAY, MOHLER and WADE 1966
Genus *Stradnerius* HAQ, n. gen.
Genus *Rhabdosphaera* HAECKEL 1894
Genus *Cretarhabdus* BRAMLETTE and MARTINI 1964
Genus *Deflandrius* BRAMLETTE and MARTINI 1964
- Tribe *Pontosphaerae* HAY 1966
Genus *Discolithina* LOEBLICH and TAPPAN 1963
- Tribe *Zygosphaerae* KAMPTNER 1958
Genus *Zygrhablithus* DEFLANDRE 1959

Family *BRAARUDOSPHAERACEAE* DEFLANDRE 1947

- Genus *Braarudosphaera* DEFLANDRE 1947
Genus *Micrantholithus* DEFLANDRE 1954

Family *THORACOSPHAERACEAE* SCHILLER 1930

- Genus *Thoracosphaera* KAMPTNER 1927
Genus *Tessellatolithus* HAQ, n. gen.

Family *DISCOASTERACEAE* VEKSHINA 1959

- Genus *Discoaster* TAN SIN HOK 1927
Genus *Discoasteroides* BRAMLETTE and SULLIVAN 1961
Genus *Marthasterites* DEFLANDRE 1959

Genera *incertae sedis*

- Genus *Isthmolithus* DEFLANDRE 1954
Genus *Microrhabdulus* DEFLANDRE 1959
Genus *Trochoaster* KLUMPP 1953

Genus *Ericsonia* BLACK, 1964

Elliptical coccoliths with a large elliptical central opening which on the proximal side is surrounded by three or more concentric rings of crystals that are differently orientated in the adjacent rings. One or more of these proximal rings may be derivatives of the distal shield extending onto the proximal side.

TYPE SPECIES. — *Ericsonia occidentalis* BLACK.

Ericsonia ovalis BLACK, 1964

Pl. I, figs. 4—9; Pl. II, figs. 1—4; Pl. IV, figs. 1, 2

1964 *Ericsonia ovalis* BLACK, p. 312, pl. 52, figs. 5, 6

1964 *Coccolithus muiri* BLACK, p. 309, pl. 50, figs. 3, 4

1966 *Coccolithus muiri* BLACK, HAQ, p. 29, pl. 1, fig. 3

1967 *Ericsonia ovalis* BLACK, STRADNER in STRADNER and EDWARDS

DESCRIPTION. — A great number of photomicrographs and transmission electronmicrographs, as well as scanning electronmicrographs of this species are available.

The photomicrographs show, on the proximal side of the coccolith (Pl. I, figs. 5, 6), a broadly elliptical form with a large, oval central opening surrounded by three rings of crystals which are not clearly distinguishable from each other. The distal view (Pl. I, figs. 8, 9) shows only one ring around the central opening.

Transmission electronmicrographs of the proximal side of some very well preserved specimens reveal three concentric rings of crystals arranged around the elliptical central opening. The innermost ring which is actually an extension of the rays of the distal shield, is composed of large rectangular crystals. The two other rings are composed of numerous crystal-rays imbricated sinistrally in the second and dextrally in the third ring. In one of the electronmicrographs (Pl. II, fig. 4) the carbon replica is transparent and reveals the inner structure of the rays of the rings. It shows the edges of the second ring fitting into the notches between crystals of the innermost ring. It also shows the crystal-rays of the third ring to be beginning at the outer limits of the innermost ring. Scanning electronmicrographs of the proximal view show the form to be concave proximally, with an appreciable distance between the distal shield and the rings of the proximal side (Pl. II, fig. 3). Scanning pictures of some partly eroded specimen (Pl. IV, figs. 1, 2) clearly show the innermost ring of the proximal side to be a derivative of the rays of the distal shield.

The distal view, formerly described as a separate species *Coccolithus muiri* BLACK, of which numerous transmission and scanning electronmicrographs are available, shows a convex form, the distal shield composed of beautifully "chisled" rhombic crystal-rays showing a sinistral imbrication. The central opening is surrounded by a steeply inwards sloping arrangement of crystals which are

derivates of the second ring of the proximal side. The rays of the second ring fit into the notches between the crystals of the innermost ring and then extend out on the distal side to form a ring around the central opening (Pl. IV, figs. 1, 2).

DIMENSIONS. — Length 5.5—10.0 μ , width 5.1—9.8 μ , central opening 1.5—2.1 μ .

OCCURRENCE. — Middle Eocene of Atlantic seamounts (BLACK, 1964); Upper Eocene of Syria (HAQ, 1966); Upper Eocene of Oamaru, New Zealand (STRADNER and EDWARDS, 1967). One of the most common species in the present samples.

Ericsonia fenestrata (DEFLANDRE and FERT) STRADNER, 1967

Pl. I, figs. 10—12

1954 *Discolithus fenestratus* DEFLANDRE and FERT, p. 25, pl. 11, fig. 25, text-figs. 18, 52

1956 *Coccolithus sestromorphous* KAMPTNER, p. 10

1967 *Ericsonia fenestrata* (DEFLANDRE and FERT) STRADNER in STRADNER and EDWARDS

REMARKS. — STRADNER (1967) has given good illustrations and a thorough description of this species. A single transmission electronmicrograph of a partly corroded specimen and two photomicrographs are recorded here. The electronmicrograph (Pl. I, fig. 10) shows the proximal view of an elliptical form in which the central opening is surrounded by three rings of crystals orientated in different directions. The area is covered with 9 or 10 perforations or windows, arranged in such a manner as to leave a central longitudinal bridge with one row of windows on either side. The photomicrographs (Pl. I, figs. 11, 12) show a similar form but with a greater number of perforations in the central area and no central longitudinal bridge.

DIMENSIONS. — Length 5.0—5.3 μ , width 3.7—4.3 μ , pores 0.3—0.5 μ wide.

OCCURRENCE. — Originally described from the Upper Eocene of the Oamaru diatomite, New Zealand (DEFLANDRE and FERT, 1954; STRADNER and EDWARDS, 1967). Rare in the present samples.

Genus ***Coccolithus*** SCHWARZ, 1894

Elliptical placoliths with two shields of unequal size — the distal larger than the proximal, connected by a central tube.

TYPE SPECIES. — *Coccolithus oceanicus* SCHWARZ.

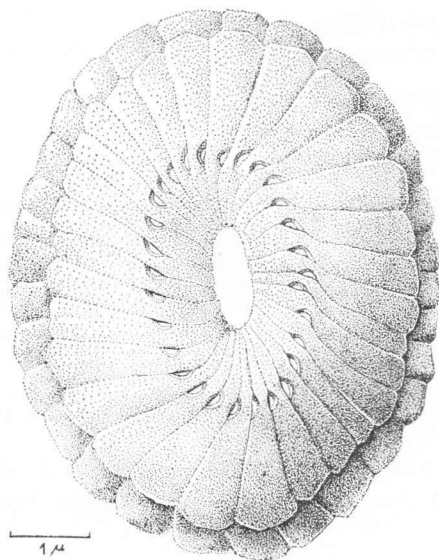


Fig. 2. *Coccolithus perforatus* n. sp., proximal view. An Albian species reworked in the present material.

***Coccolithus perforatus* HAQ, n. sp.**

Pl. VI, figs. 1—3; text-fig. 2

1965 "*Coccolithus*", BLACK, 1965, fig. 12

DERIVATION OF NAME. — *perforatus* (Latin) = with perforations.

DIAGNOSIS. — Narrow elliptical coccoliths with shields composed of broad, flat crystal-rays; a slot-like central opening surrounded by an elliptical ring of zig-zagging crystals. The margin of the ring possesses small oval perforations equal in number to the rays of the proximal shield.

DESCRIPTION. — All transmission electronmicrographs of this species illustrate only the proximal view. The species has a narrow elliptical form and there is only a very small difference in the sizes of the two shields. The number of rays in the two shields is equal (ranging from 29 to 35). The shields are broad and flat with a slight sinistral imbrication in the proximal shield and a dextral imbrication in the distal shield. Their ends are flattened into near-straight outlines. A narrow slot-like central tube is surrounded by a ring of crystals which fit together in a zig-zag manner and which are derivatives of the rays of the proximal shield. Each ray ends, along the outline of the ring, into a narrow eye-shaped

perforation, so that an ellipse of perforations surrounds the central ring of crystals. These perforations presumably extend to the distal shield.

HOLOTYPE NEGATIVE NUMBER. — E 337.

DIMENSIONS. — Holotype: length $7.1\ \mu$, width $5.9\ \mu$, central opening $1.2\ \mu$ long.

OCCURRENCE. — Dr. M. BLACK (personal communication, 1967) reports the occurrence of this species in the Gault of Cambridge, England. A few reworked specimens were found in the present samples.

Genus *Cyclococcolithus* KAMPTNER 1954

Circular placoliths with two unequal imperforate shields, the distal being larger than the proximal. A closed central area with a slight depression on the distal side.

TYPE SPECIES. — *Cyclococcolithus leptoporus* (MURRAY and BLACKMAN) KAMPTNER.

Cyclococcolithus inversus (DEFLANDRE) HAY, MOHLER and WADE 1966

Pl. VIII, figs. 1, (?) 2

- 1954 *Cyclococcolithus leptoporus* var. *inversus* DEFLANDRE in DEFLANDRE and FERT, p. 150, pl. 9, figs. 4, 5
- 1963 *Cyclococcolithus astroporus* STRADNER, p. 75, pl. 9, figs. 5—7
- 1964 *Markalius inversus* (DEFLANDRE) BRAMLETTE and MARTINI, p. 302, pl. 2, figs. 4—9, pl. 6, figs. 9, 10
- 1965 *Cyclococcolithus leptoporus* var. *inversus* DEFLANDRE, COHEN, p. 26, pl. 18, fig. e, pl. 20, fig. a
- 1966 *Cyclococcolithus inversus* (DEFLANDRE) HAY, MOHLER and WADE, p. 389, pl. 7, fig. 2
- 1967 *Cyclococcolithus inversus* (DEFLANDRE) HAY, MOHLER and WADE, STRADNER in STRADNER and EDWARDS

DESCRIPTION. — *Cyclococcolithus* consisting of a large convex distal shield, most of the area of which is covered by the smaller proximal shield. The rays of the two shields are straight but are also slightly inclined — the inclination being clockwise when viewed from the distal side and anti-clockwise from the proximal. The central area is closed by small crystal elements arranged in a radiating way from the centre to form a small circular disc. In the transmission electronmicrograph on Pl. VIII, fig. 1 the proximal shield is almost completely broken away, revealing the rays of the distal shield. The central area is covered effectively by the small circular disc composed of thin, slightly inclined (anti-clockwise) and

curved crystal-elements which end in rounded extremities. Both the shields have approximately equal number of rays.

Pl. VIII, fig. 2 is most probably the distal view of a juvenile form of *Cyclococcolithus inversus* with only 16 broad and straight rays radiating from a central focal point. The central depression of the distal side is, however, not seen here.

DIMENSIONS: Diameter of the distal shield 9 μ .

OCCURRENCE. — Upper Eocene of Oamaru, New Zealand (DEFLANDRE and FERT, 1954; STRADNER and EDWARDS, 1967); Upper Eocene of Nal'chik, the Caucasus, USSR (HAY, MOHLER and WADE, 1966). Rare in the present samples.

Genus *Cycloplacolithella* HAQ, n. gen.

Nomen substitutum pro *Cycloplacolithus* KAMPTNER, 1963

Circular placoliths with two shields of unequal size, the distal being larger than the proximal, and an open central tube.

TYPE SPECIES. — *Cycloplacolithella foliosa* (KAMPTNER).

DISCUSSION. — KAMPTNER (1963, p. 167) provisionally proposed the taxon *Cycloplacolithus* for circular placoliths as observed by the electron microscope. However, such provisional names (vide ICBN Art. 34) are invalid (see LOEBLICH and TAPPAN, 1966, p. 121). The present new name is proposed for *Cyclococcolithus*-like forms, from which they are distinguished by the presence of an open central tube, which in *Cyclococcolithus* is closed by a small circular structure or lid of crystals.

However, not only the species described under the genus *Cycloplacolithus* by KAMPTNER in 1963 (*Cycloplacolithus amerensis*, *C. disciformis*, *C. foliosus*, *C. laevigatus*, *C. planus*, *C. prominens*, and *C. sejunctus*) but also the species described by him under the genus *Cyclococcolithus* (*Cyclococcolithus decorus*, *C. formosus*, *C. humilis*, *C. minutus*, *C. multistriatus*, and *C. spatiosus*) seem to belong to *Cycloplacolithella* as they all possess an open central tube.

Cycloplacolithella simplex HAQ, n. sp.

Pl. VIII, figs. 8—10

DERIVATION OF NAME. — *simplex* (Latin) = simple, simply formed.

DIAGNOSIS. — Circular placoliths with two unequal shields, having a large number of differently orientated and imbricated crystal-rays, and an open circular tube with a ratio of approximately 1:3.5 to the diameter of the complete placolith.

DESCRIPTION. — A number of transmission electronmicrographs and photomicrographs of this species are available, but only three are figured here. The electronmicrograph (Pl. VIII, fig. 1) shows a proximal view of this species, in which the rays of the larger distal shield can be seen extending below the smaller proximal shield. The ratio of the diameters of the distal and proximal shields is nearly 1.5:1. The rays in the proximal shield are dextrally and in the distal shield sinistrally imbricated. The photomicrographs (Pl. VIII, figs. 9, 10) reveal nothing more than the basic architecture and a circular central opening.

HOLOTYPE NEGATIVE NUMBER. — E 326.

DIMENSIONS. — Holotype: diameter $4.5\ \mu$, central opening $1.5\ \mu$.

OCCURRENCE. — A few specimens in the present samples, and usually poorly preserved.

Cycloplacolithella blacki HAQ, n. sp.

Pl. IV, figs. 7—9

DERIVATION OF NAME. — In honour of Dr. M. BLACK, Cambridge, England.

DIAGNOSIS. — Circular placoliths with a large central opening and a proximal shield constructed in a petalled-flower manner, with thick crystal-rays; each crystal-ray has a parallelogramic cross-section, one acute angle of which rests against the distal shield and the other is free towards the proximal side.

DESCRIPTION. — The scanning electronmicrograph of the proximal view (Pl. IV, fig. 8) shows the proximal shield to be only slightly smaller than the distal shield and composed of thick crystal-rays which are joined along their margins and give the impression of a centrally-depressed calyx of a flower. The central opening is rimmed by a ring of crystals which is a derivate of the distal shield. The distal views (Pl. IV, figs. 7, 9) exhibit the forms to be highly convex distally. The rays of the distal shield are slightly dextrally imbricated. The central opening on this side is also lined by a ring of crystals which seem to be derived from the distal shield rays, like on the proximal side. The opening may be filled with extra crystals.

HOLOTYPE NEGATIVE NUMBER. — SM/B 18.

DIMENSIONS. — Holotype: diameter of the distal shield $7.5\ \mu$, diameter of the proximal shield $6.3\ \mu$.

REMARKS. — This species is only provisionally placed under the genus *Cycloplacolithella*. It may eventually belong to a different genus.

OCCURRENCE. — Rare in the present samples.

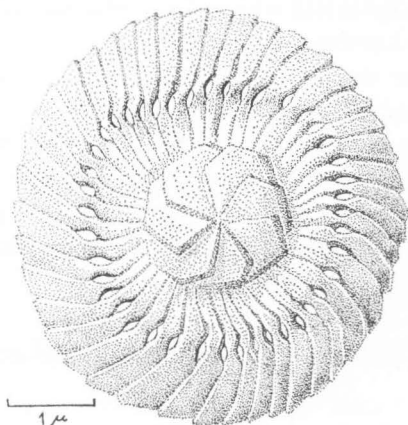


Fig. 3. Reconstruction of *Rotalithus teutonicus*
n. sp., distal view.

Genus ***Rotalithus*** HAQ, n. gen.

DERIVATION OF NAME. — *Rota* (Latin) = wheel.

DIAGNOSIS. — Cyclococcolith-type forms, with two unequal, circular shields, a closed central area which is elevated on the distal side by a knob of large overlapping crystals.

DISCUSSION. — This genus is distinguished from the genus *Cyclococcolithus* KAMPTNER by the knob-like crystal structure on the central area of the distal shield. In *Cyclococcolithus* the centre of the distal shield is depressed, rather than elevated.

TYPE SPECIES. — *Rotalithus teutonicus* HAQ, n. sp.

Rotalithus teutonicus HAQ, n. sp.

Pl. VIII, figs. 6, 7; text-fig. 3

DERIVATION OF NAME. — Teuton — ancient Germanic tribe.

DIAGNOSIS. — A rotolith with a central rosette of large crystals (5—7 in number) on the distal side, each overlapping more than half of the area of the proceeding one, and arranged in a spiral manner around a central pivot. The rays of the distal shield thin out to produce small elliptical eye-shaped pores half way towards the centre.

DESCRIPTION. — The distal view (Pl. VIII, fig. 6) shows a circular disc with

numerous (about 42) crystal-rays with a slight sinistral imbrication and curving in an anti-clockwise direction. The proximal view (Pl. VIII, fig. 7) shows a dextral imbrication of the rays of the distal shield and a sinistral imbrication of the rays of the proximal shield, which thin out and are produced into bars towards the centre. The reconstruction of the distal view (text-fig. 3) also shows the central knob of the overlapping crystals (about 6) and the rays thinning out half way towards the centre to produce small elliptical eye-shaped pores between them into which the edges of the crystal rays of the proximal shield fit in.

HOLOTYPE NEGATIVE NUMBER. — E 459.

DIMENSIONS. — Holotype: diameter of distal shield $5.1\ \mu$; 3.8 — $5.3\ \mu$ in other specimens.

OCCURRENCE. — Rare in the present samples.

Genus *Cyclolithella* LOEBLICH and TAPPAN, 1963

Nomen substitutum pro *Cyclolithus* KAMPTNER ex DEFLANDRE, 1952

Circular or elliptical ring-shaped discs with a large central opening and the disc composed of one or two cycles of crystals.

TYPE SPECIES. — *Cyclolithella inflexa* (KAMPTNER) LOEBLICH and TAPPAN (suggested by them 1963).

Cyclolithella inflexa (KAMPTNER) LOEBLICH and TAPPAN, 1963

Pl. VIII, figs. 3—5

- 1948 *Cyclolithus inflexus* KAMPTNER, p. 7, pl. 2, fig. 14
- 1948 *Cyclolithus ellipticus* KAMPTNER, p. 6, pl. 2, fig. 18
- 1952 *Cyclolithus inflexus* KAMPTNER ex DEFLANDRE in PIVETAU, p. 111, fig. 50
- 1963 *Cyclolithella inflexa* (KAMPTNER) LOEBLICH and TAPPAN, p. 192
- 1967 *Cyclolithella inflexa* (KAMPTNER) LOEBLICH and TAPPAN, STRADNER, ADAMIKER and MARESCH, pl. 10
- 1967 *Cyclolithella inflexa* (KAMPTNER) LOEBLICH and TAPPAN, STRADNER in STRADNER and EDWARDS

DESCRIPTION. — Ring-shaped elliptical cycloliths of 25—35 crystal-plates which are more or less rectangular in shape. The ratio of the short diameter of the whole cyclolith to the short diameter of the central opening is usually 1:0.5. The electronmicrograph on Pl. VIII, fig. 3 shows the crystal-plates to be rectangular, fitting loosely in a mosaic manner. The photomicrographs (Pl. VIII, figs. 4, 5)

do not show the details of the crystals but only the general structure of the elliptical ring.

DIMENSIONS. — Length 8.3—9.9 μ , width 7.0—8.2 μ .

OCCURRENCE. — Tortonian of the Vienna Basin, (KAMPTNER, 1948); Upper Eocene of Oamaru, New Zealand (STRADNER in STRADNER and EDWARDS, 1967). Rare in the present samples.

Genus *Reticulofenestra* HAY, MOHLER and WADE, 1966

Elliptical to sub-circular coccoliths with a large central opening spanned by a reticulate membrane which is a derivate of the crystal-rays of the proximal shield spanning the central area. On the distal side a ring of crystals surrounds the central area. This ring on the distal side is actually the extension of the crystals of the proximal shield on the distal side.

TYPE SPECIES. — *Reticulofenestra placomorpha* (KAMPTNER) STRADNER = *Reticulofenestra caucasica* HAY, MOHLER and WADE (syn). (Type species re-designated by STRADNER, 1967.)

Reticulofenestra placomorpha (KAMPTNER) STRADNER, 1967

Pl. V, figs. 1—5; Pl. III, fig. 3

- 1948 *Tremalithus placomorphus* KAMPTNER, p. 7, pl. 2, fig. 11
- 1952 *Tremalithus placomorphus* KAMPTNER, DEFLANDRE in PIVETEAU, p. 111, fig. 3
- 1956 *Coccolithus placomorphus* KAMPTNER, p. 10
- 1962 *Coccolithus placomorphus* KAMPTNER, STRADNER, p. 178
- 1963 *Coccolithus tenuistriatus* KAMPTNER, p. 160, pl. 2, figs. 14, 15, text-fig. 16
- 1964 *Coccolithus placomorphus* KAMPTNER, STRADNER, p. 135, text-fig. 10
- 1964 *Ellipsolithus spec.* BACHMAYER, p. 184, pl. 2, fig. 10
- 1965 *Coccolithus umbilicus* LEVIN, p. 265, pl. 41, fig. 2
- 1965 *Coccolithus tenuistriatus* KAMPTNER, MARTINI, p. 403, pl. 34, figs. 10—12
- 1966 *Coccolithus cf. placomorphus* (KAMPTNER) REINHARDT, p. 21, pl. 22, figs. 29, 30, pl. 30, fig. 3
- 1966 * *Reticulofenestra caucasica* HAY, MOHLER and WADE, p. 386, pl. 2, fig. 5, pl. 3, figs. 1, 2, pl. 4, figs. 1, 2, non pl. 2, figs. 6—8
- 1967 *Coccolithus pelycomorphus* REINHARDT, p. 515, pl. 1, figs. 2, 6, text-fig. 5
- 1967 * *Reticulofenestra placomorpha* (KAMPTNER) STRADNER in STRADNER and EDWARDS, 1967, Pl. 19, 20, 22, 23, 24, 25: 1, 2; Nov 21

DESCRIPTION. — Elliptical to nearly circular coccoliths with shields consisting of a large number of thin, curved rays (about 50—100), and central opening in form of a wide deep tube (Pl. V, fig. 2). On the proximal side the central

opening is spanned by a reticulate membrane which is formed by the extension of the rays of the proximal shield into the central opening. Along the rim of the central tube the membrane has long, narrow pores, but towards the centre these pores become small, elliptical or irregular in shape. The membrane is very delicate and in most specimen either partly or completely broken away. The central opening can vary considerably in size, and looks larger on the distal side than on the proximal, due to the distally, outwards sloping walls of the central tube.

The distal side shows a ring of dextrally imbricated crystals surrounding the central area. It is clear from many electronmicrographs (e.g. Pl. V, figs. 2, 5) that this ring is formed by the extension of the crystal-rays of the proximal shield on the distal side.

DIMENSIONS. — Larger diameter 6.0—9.2 μ , central tube 1.3—3.5 μ .

OCCURRENCE. — Tortonian of the Vienna Basin (KAMPTNER, 1948); Upper Eocene of Mississippi and Alabama; Lower Lutetian of the Paris Basin (LEVIN, 1965); Eocene 5 of the Dolgen borehole 1/63 (REINHARDT, 1966); Upper Eocene of Nal'chik, the Caucasus, USSR (HAY, MOHLER and WADE, 1966); Upper Eocene of Oamaru, New Zealand (STRADNER and EDWARDS, 1967). Abundant in the present samples.

***Reticulofenestra oamaruensis* (DEFLANDRE) STRADNER, 1967**

Pl. V, figs. 6—8

- 1954 *Discolithus oamaruensis* DEFLANDRE, in DEFLANDRE and FERT, p. 139, pl. 12, figs. 1, 2
 1966 *Reticulofenestra caucasica* HAY, MOHLER and WADE (pro parts), pl. 2, figs. 6—8, non pls. 3, 4
 1967 *Reticulofenestra oamaruensis* (DEFLANDRE) STRADNER in STRADNER and EDWARDS

REMARKS. — Two photomicrographs of a complete specimen and one electronmicrograph of a probable fragment of this species are figured here. The photomicrographs (Pl. V, figs. 7, 8) show an elliptical coccolith in which the proximal shield is completely covered by a reticulate membrane with a large number of pores. The transmission electromicrograph (Pl. V, fig. 6) of a fragment, most probably of the proximal shield, shows triangular pores arranged in regular rows and at almost equal distances from each other. STRADNER, (1967) has rendered a good description and illustrations of this species.

DIMENSIONS. — Length 10.0 μ , width 8.8 μ .

OCCURRENCE. — Originally described from Upper Eocene of Oamaru, New Zealand (DEFLANDRE and FERT, 1954; STRADNER and EDWARDS, 1967). Rare in the present samples.

Genus *Stradnerius* HAQ, n. gen.

DERIVATION OF NAME. — In honour of Dr. H. STRADNER, Vienna, Austria.

DIAGNOSIS. — Elliptical to sub-circular placoliths with a large central opening into which extend vertical septa derived from the rays of the shields.

DISCUSSION. — This genus is distinguished from the genus *Reticulofenestra* HAY, MOHLER and WADE, which is a similar form, but in which the central area is spanned by a reticulate membrane and not by vertical septa. This, however, became evident only after the study of these forms by means of the scanning electron microscope. In the transmission electron microscope these septa look like bars, as seen from the proximal side. A comparison with scanning electron-micrographs of the central areas of *Reticulofenestra placomorpha* (KAMPTNER) STRADNER (Pl. V, fig. 3) revealed the difference, showing that *Reticulofenestra* possesses a reticulate membrane as described originally by the authors of this genus, and the *Stradnerius* has distinct vertical septa.

TYPE SPECIES. — *Stradnerius dictyodus* (DEFLANDRE and FERT) n. comb.

Stradnerius dictyodus (DEFLANDRE and FERT) n. comb.

Pl. II, figs. 5—8; Pl. III, figs. 1, 2, 4—8; Pl. IV, figs. 3, 6

- 1954 *Discolithus dictyodus* DEFLANDRE and FERT, p. 140, text-fig. 15
 1962 *Cyclococcolithus dictyodus* (DEFLANDRE and FERT) HAY and TOWE, p. 503, pl. 5, fig. 4, (?) 5, pl. 7, fig. 1
 1966 *Cyclococcolithus dictyodus* (DEFLANDRE and FERT) HAY and TOWE, HAQ, p. 31, pl. 2, figs. 2, 5, pl. 6 figs. 2, 6
 + 1966 *Reticulofenestra scissura* HAY, MOHLER and WADE, p. 387, pl. 5, figs. 1—6
 + 1966 *Syracosphaera bisecta* HAY, MOHLER and WADE, p. 393, pl. 10, figs. 1—6
 = HT 1967 *Dictyococcites danicus* BLACK, p. 141, fig. 2
 1967 *Reticulofenestra dictyoda* (DEFLANDRE and FERT) STRADNER in STRADNER and EDWARDS.

DESCRIPTION. — The test consists of two elliptical shields which are joined along a large, wide central tube so that the two shields are a continuous structure rather than two separate entities. The shields are composed of an equal number of thin slightly curved rays, ranging from 40 to 60 in number. Thin vertical septa extend from each ray of the proximal shield into the central opening, but generally only every alternate septum reaches the centre. The septa in some specimens do not reach the exact centre or the medial line, but end around a small elliptical reticulate pattern, which is formed by the continuation of the septa in a reticulate manner. The presence of septa becomes evident only after the study of scanning electronmicrographs (Pl. II, fig. 5; Pl. IV, fig. 6). In the transmission electronmicrographs the septa look like bars —

cf. Pl. II, fig. 5 (scanning electronmicrograph) and Pl. II, fig. 6 (transmission electronmicrograph) of specimens of almost the same size.

This species is also represented by forms in which the central area on both distal and proximal side is closed by lids of crystals. More often the sloping walls of the distal side are lined with broad almost rectangular crystals arranged in an elliptical ring around the filled-in central area. The central opening thus decreases considerably in size (Pl. II, figs. 7, 8; Pl. III, figs. 4—8).

HOLOTYPE NEGATIVE NUMBER. — SM/A 04.

DIMENSIONS. — Length 4.0—9.0 μ , width 3.3—8.4 μ .

OCCURRENCE. — Upper Eocene of Oamaru, New Zealand (STRADNER in STRADNER and EDWARDS, 1967); Middle Eocene of Donzacq, France (DEFLANDRE and FERT, 1954; HAY and TOWE, 1962); Upper Eocene of the NW Caucasus, USSR (HAY, MOHLER and WADE, 1966); Upper Eocene of Syria (HAQ, 1966). Recently also reported from Middle Oligocene of Denmark (BLACK, 1967). Abundant in the present samples.

Stradnerius daviesi HAQ, n. sp.

Pl. IV, figs. 4, 5

DERIVATION OF NAME. — In honour of Prof. R. G. DAVIES, Lahore, West Pakistan.

DIAGNOSIS. — An elliptical placolith in which, as seen from the proximal side, the central area is spanned by vertical septa, extending from the rays of the shield, initially around a number of large pores (10—15 in number) and then merging together to form a reticulate structure in the centre with numerous smaller pores.

DESCRIPTION. — Like in *Stradnerius dictyodus*, the two shields are a continuous structure joined along the central area and inseparable from each other morphologically. The scanning electronmicrograph of the proximal view (Pl. IV, fig. 4) reveals the two shields to be a single entity. The shields possess numerous thin laminar crystal-rays. The central area is spanned by septa which form large pores along the rim of the central area and then anastomose to form a network with numerous smaller pores. The distal view (Pl. IV, fig. 5) shows these septa to extend all the way to the level of the highest point on the convex side of the distal shield. The extension, of the septa on this side into the central area also confirms that the two shields are a unit structure and inseparable in terms of morphology.

HOLOTYPE NEGATIVE NUMBER. — SM/B 33.

DIMENSIONS. — Holotype: length 7.6 μ , width 6.4 μ .

DISCUSSION. — In *Stradnerius dictyodus*, the vertical septa extend from each ray of the shield straight into the centre and may then form a reticulate pattern near the medial line. In *S. daviesi*, the septa are much thicker and extend only a little way from the rim of the central opening, surrounding a few large pores, and then merge to form a network which covers most of the central opening and has a roughly elliptical outline. The septa in this species do not extend from each ray of the shield as in *S. dictyodus*, but from every second or third crystal-ray of the shield.

OCCURRENCE. — Only a few specimens from the present samples observed in the scanning electron microscope.

Genus *Rhabdosphaera* HAECKEL, 1894

"Forms with a circular basal shield and a robust tubular stem on the distal side."

TYPE SPECIES. — *Rhabdosphaera clavigera* MURRAY and BLACKMANN (designated by HAY and TOWE, 1962).

Rhabdosphaera recta (DEFLANDRE)

Pl. IX, fig. 8; Pl. XI, figs. 17, 18

1954 *Rhabdolithus rectus* DEFLANDRE in DEFLANDRE and FERT, p. 157, pl. 11, fig. 11

1954 *Discolithus spinosus* DEFLANDRE and FERT, p. 143, pl. 4, figs. 13—15

1962 *Rhabdosphaera* sp. HAY and TOWE, p. 505, pl. 9, fig. 1

DESCRIPTION. — In the light microscope this species reveals a circular basal plate, slightly concave on the proximal side and convex on the distal side, surmounted by a thick long stem, which does not taper but has the same thickness throughout its length, and finishes in a bluntly rounded end.

The single electronmicrograph available (Pl. IX, fig. 8) illustrates the proximal view of the basal shield in which the outermost ring of crystals has been completely broken away. The stem is made up of thick long crystals and seems to be widening upwards which could be due to a fracture and splitting-off of the crystals. The crystals of the inner ring of the basal shield are arranged in a dextral manner. As indicated by the central opening in the basal shield there is a cylindrical tube extending from the basal shield upwards into the robust stem.

DISCUSSION. — In the electronmicrograph reproduced by HAY and TOWE (1962,

pl. 9, fig. 1), this species is preserved in the same way as the one figured here, i. e. without the outer ring of the basal shield which has been broken away. Their figure shows clearly the extension of the cylindrical tube into the remnant of the stem.

OCCURRENCE. — Middle Eocene of Donzacq, France (DEFLANDRE and FERT, 1954; HAY and TOWE, 1962). Few specimens observed in the present samples.

Rhabdosphaera perlonga (DEFLANDRE) BRAMLETTE and SULLIVAN, 1961

Pl. XI, fig. 19

- 1954 *Rhabdolitus perlongus* DEFLANDRE in DEFLANDRE and FERT, p. 44, pl. 12, figs. 34, 35, text-fig. 86
 1961 *Rhabdosphaera perlonga* (DEFLANDRE), BRAMLETTE and SULLIVAN, p. 146, pl. 5, figs. 7 a, c
 1964 *Rhabdosphaera perlonga* (DEFLANDRE), SULLIVAN, p. 185, pl. 7, fig. 8
 1965 *Rhabdosphaera perlonga* (DEFLANDRE), SULLIVAN, p. 36, pl. 7, figs. 7 a, b

DESCRIPTION. — A circular basal shield, very slightly concave on the proximal side and distinctly convex on the distal side with a thick, long tubular stem. The tube of the stem passes through the basal shield.

The specimen photomicrographed in Pl. XI, fig. 19 is similar to that figured by SULLIVAN, 1965 (pl. 7, fig. 7 b) under crossed nicols.

OCCURRENCE. — Lower and Middle Eocene of California (BRAMLETTE and SULLIVAN, 1961; SULLIVAN, 1964, 1965); Middle Eocene of Texas (BRAMLETTE and SULLIVAN, 1961); Middle Eocene of Donzacq, France (DEFLANDRE and FERT, 1954). Rare in the present samples.

Rhabdosphaera sp.

Pl. XI, figs. 9, 10, 15, 16

REMARKS. — Forms with thick, slightly bulging tubular stems and comparatively thick but narrow basal shields are included here. The basal shield is only slightly wider than the stem and is highly convex on the distal side (Pl. XI, figs. 15, 16). The rim of the basal shield seems to be the continuation of the walls of the stem. Figs. 9 and 10 in Pl. XI are probably of a similar specimen but with the basal shield missing. It shows a long, upwards tapering stem with a thick medial canal.

OCCURRENCE. — Frequent in the present samples.

Genus *Cretarhabdus* BRAMLETTE and MARTINI, 1964

Rhabdolith-like forms with an elliptical basal shield possessing a peripheral groove in the rim, a central network extending distally to a central tubular stem or knob. Buttressing bars, commonly four in number, support the central network and join with the base of the stem (from BRAMLETTE and MARTINI, 1964).

TYPE SPECIES. — *Cretarhabdus conicus* BRAMLETTE and MARTINI.

Cretarhabdus sp.

Pl. XI, fig. 14

REMARKS. — A photomicrograph of the side view shows a basal shield with a peripheral groove in the rim and a central network with a number of small bars. The rim is slightly tilted upwards. A thick tubular stem extends upwards from the distal side but continues only for a short distance.

OCCURRENCE. — Rare and probably reworked.

Genus *Deflandrius* BRAMLETTE and MARTINI, 1964

Elliptical to sub-circular basal shields with an open central area bridged by cross-bars which are arched and surmounted by a small knob or an elongate non-tubular stem of complex construction (from BRAMLETTE and MARTINI, 1964).

TYPE SPECIES. — *Deflandrius intercisus* (DEFLANDRE) BRAMLETTE and MARTINI.

Deflandrius sp.

Pl. XI, fig. 13

REMARKS. — The single, extremely small specimen photographed under light microscope negative phase-contrast condition figured here shows an elliptical disc with a large central opening which is bridged by cross-bars. The bar along the long axis of the ellipse is curved at its ends in a clockwise direction. This picture shows some similarity to *Deflandrius intercisus* pictured by BRAMLETTE and MARTINI, 1964 (pl. 2, fig. 20).

OCCURRENCE. — Rare in these samples.

Genus ***Discolithina*** LOEBLICH and TAPPAN, 1963Nomen substitutum pro *Discolithus* HUXLEY, 1868

Elliptical shields composed of two layers of crystals, concave towards the proximal side, with a wide central opening or numerous pores perforating the shield.

LOEBLICH and TAPPAN designated *Discolithina vigintiforata* (KAMPTNER) LOEBLICH and TAPPAN as the type species for this genus. However, as shown by STRADNER in STRADNER and EDWARDS (1967) and also as shown here, this species is only a variety of the species *Discolithina multipora* (KAMPTNER) MARTINI. STRADNER, therefore, suggested *Discolithina multipora* as the new type species which incorporated *Discolithina vigintiforata*.

TYPE SPECIES. — *Discolithina multipora* (KAMPTNER) MARTINI, 1965.

Discolithina multipora (KAMPTNER) MARTINI, 1965

Pl. VI, figs. 4—9

- 1948 *Discolithus multiporus* KAMPTNER; p. 5, pl. 1, fig. 9
- 1948 *Discolithus vigintiforatus* KAMPTNER, p. 5, pl. 1, fig. 8
- 1959 *Discolithus multiporus* KAMPTNER, DEFLANDRE, p. 148
- 1961 *Discolithus distinctus* BRAMLETTE and SULLIVAN, p. 141, pl. 2, figs. 8 a, b, 9 a—c
- 1964 *Discolithus distinctus* BRAMLETTE and SULLIVAN, SULLIVAN, p. 18, pl. 4, figs. 4 a, b
- 1964 *Discolithus multiporus* KAMPTNER, STRADNER, p. 134, text-figs. 4—8
- 1965 *Discolithina multipora* (KAMPTNER) MARTINI, p. 400
- 1966 *Discolithina confossa* HAY, MOHLER and WADE, p. 392, pl. 9, figs. 1—9
- 1966 *Pontosphaera vadosa* HAY, MOHLER and WADE, p. 391, pl. 8, fig. 4
- 1966 *Discolithus multiporus* KAMPTNER, STRADNER and ADAMIKER, p. 340, pl. 2, fig. 1
- 1967 *Discolithina multipora* (KAMPTNER) MARTINI, STRADNER in STRADNER and EDWARDS

DESCRIPTION. — Elliptical shields with a ratio between the long and short axes of the ellipse ranging between 1.3:1 and 1.6:1. Most of the discolith surface is covered with subcircular, elliptical or irregular pores ranging from about 14 to 50 in number. A narrow rim which seems to be curved upwards, as seen from the proximal side, is not covered with pores.

The light microscope phase-contrast pictures of this species (Pl. VI, figs. 5, 6, 8, 9) show a large number of pores covering the surface of the discolith in case of Pl. VI, figs. 5 and 6, and only about 20 pores in case of figs. 8 and 9, (ex. *Discolithina vigintiforata*).

The transmission electronmicrographs present a clearer picture of the ultra-structure, although only distal view of the discoliths could be observed. This could

be due to the curvature of these forms, which may cause a tendency for the discoliths to rest with their convex or distal side upwards. These views show parallel striations along the entire rim. Near the centre these striations align themselves along the long axis rather than parallel to the outline of the rim. These striations are actually minute, long prismatic crystals. The extension of the crystals of the proximal side into the pores indicates that there are at least two layers of crystals present.

DIMENSIONS. — Length 5.0—8.4 μ , width 3.2—6.0 μ .

DISCUSSION. — Electron and light microscope pictures of ex *Discolithina vigintiforata*, shown to be a variety of *Discolithina multipora* by STRADNER (1967), are also included in the present species (Pl. VI, figs. 7—9). The transmission electron-micrograph (fig. 7) exhibits a similar structure to that of *D. multipora*, but has about 20 pores only. Light microscope phase-contrast pictures (figs. 8, 9), however, show the rim to be thicker than that of *D. multipora* (figs. 5, 6). STRADNER (1967) reported that although the striations are arranged in a circular or spiral manner on the distal side, they are radially arranged on the proximal side, which further indicates the presence of at least two layers of crystal-plates.

OCCURRENCE. — Tortonian of the Vienna Basin (KAMPTNER, 1948); Middle Eocene of California, Texas, Trinidad and France (BRAMLETTE and SULLIVAN, 1961); Upper Eocene of the Caucasus, USSR (HAY, MOHLER and WADE, 1966); Upper Eocene of Oamaru, New Zealand (STRADNER and EDWARDS, 1967). Common in the present samples.

***Discolithina macropora* (DEFLANDRE)**

(?) Pl. X, fig. 8; Pl. XI, figs. 11, 12

1954 *Discolithus macroporus* DEFLANDRE in DEFLANDRE and FERT, p. 138, pl. 11, fig. 5

DESCRIPTION. — Only photomicrographs of this species are available. They show an elliptical form slightly compressed on two opposite sides at an angle of about 30 degrees to the long axis, so as to give a parallelogramish impression. The positive phase-contrast picture (Pl. XI, fig. 11) exhibits 9—10 large irregular to subcircular pores, whereas the negative phase-contrast (fig. 12) shows elliptical to narrow-elongate pores. The pores cover the central part of the discolith only so that a broad rim is left around them. The positive phase-contrast picture shows the outline of the discolith to be more irregular. Nothing more can be discerned from these pictures of the single specimen found.

The scanning electronmicrograph (Pl. X, fig. 8) is probably a corroded specimen of this species. It shows a somewhat parallelogramish outline, a thick rim and about eight pores on the surface.

DIMENSIONS. — Length $4.3\ \mu$, width $3.0\ \mu$.

OCCURRENCE. — Reported originally from the Upper Eocene of Oamaru, New Zealand by DEFLANDRE and FERT (1954, p. 138). Very rare in the present samples.

***Discolithina pulcheroides* (SULLIVAN) STRADNER, 1967**

Pl. VII, figs. 1—3

- 1961 *Discolithus* aff. *D. pulcher* BRAMLETTE and SULLIVAN, p. 143, pl. 3, figs. 9, 10
 1964 *Discolithus pulcheroides* SULLIVAN, p. 183, pl. 4, figs. 7 a, b
 1965 *Discolithus pulcheroides* SULLIVAN, p. 143
 1967 *Discolithina pulcheroides* (SULLIVAN) STRADNER in STRADNER and EDWARDS

DESCRIPTION. — Discoliths with an oblique bridge spanning the wide central opening, and a broad peripheral rim. The bridge divides the central opening into two large semicircular windows. It forms an angle of about 45 degrees to the long axis of the ellipse.

The transmission electronmicrographs of the distal side show the rim to be composed of long thin crystals arranged in a spiral manner in the same way as in *Discolithina multipora*. The outline of the rim seems to be slightly tilted upwards. The bridge is constructed by the extension into the center of two or more robust crystals, slightly tapering towards the inside (Pl. VII, fig. 1). These crystals touch each other along the medial line but do not merge as in *Discolithina obliquipons*. The photomicrographs do not show anything beyond the basic architecture of these forms (figs. 2, 3).

DIMENSIONS. — Length $7.3\text{--}9\ \mu$, width $5.2\text{--}6.1\ \mu$.

OCCURRENCE. — Eocene of California (BRAMLETTE and SULLIVAN, 1961; SULLIVAN, 1964, 1965); Upper Eocene of New Zealand (STRADNER and EDWARDS, 1967). Rare in the present samples.

***Discolithina obliquipons* (DEFLANDRE) STRADNER, 1967**

Pl. VII, figs. 4—6; Pl. XI, fig. 2

- 1954 *Discolithus obliquipons* DEFLANDRE in DEFLANDRE and FERT, p. 139, pl. 11, figs. 1, 2, text-fig. 53
 1964 *Zycolithus obliquipons* DEFLANDRE, STRADNER, p. 135, fig. 19
 1966 *Transversopontis obliquipons* (DEFLANDRE) HAY, MOHLER and WADE, p. 391, pl. 8, fig. 5
 1967 *Discolithina obliquipons* (DEFLANDRE), STRADNER in STRADNER and EDWARDS

DESCRIPTION. — Discoliths with an oblique bridge at an angle of about 25 degrees to the long axis, spanning the wide central opening. The rim is either less thick or approximately of the same thickness as the bridge, which divides the central opening into two narrow, oblique and slightly inside-curving windows.

The transmission electronmicrographs show the rim to be composed of thin, long crystals in the same manner as in *Discolithina multipora* (Pl. VII, fig. 4). The crystal-rays tend to be orientated along the long axis of the ellipse. The bridge is formed of two thick elements extending diagonally into the centre where they meet at the medial line and almost merge into each other. These elements are also composed of long, thin prismatic crystals which look like parallel striations. The narrow long oblique windows tend to become slightly wider and bulbous at the ends.

The scanning electronmicrograph of this species (Pl. XI, fig. 2) shows beyond any doubt that the discoliths are composed of two layers or discs of crystals of exactly equal size superimposed upon each other. The proximal layer or disc is comparatively thinner than the distal layer of crystals.

The windows in well preserved specimens are filled with a grille of thin crystal-rays as shown by STRADNER in STRADNER and EDWARDS, 1967. In the transmission electronmicrograph pictured here (Pl. VII, fig. 4) the remnants of the ends of the grille can still be seen on the edges of the windows.

DIMENSIONS. — Length 5.0—7.0 μ , width 3.4—4.3 μ .

DISCUSSION. — This species is similar to *Discolithina pulcheroides* in having an oblique bridge. However, the angle of the bridge, its thickness, the thickness of the rim (which is broader in *D. pulcheroides*), the shape of the two windows, and the details of the ultrastructure are quite different in these two species.

OCCURRENCE. — Eocene of France (DEFLANDRE and FERT, 1954, p. 139); Upper Eocene of the Caucasus, USSR, (HAY, MOHLER and WADE, 1966, p. 39); Upper Eocene of Oamaru, New Zealand (STRADNER and EDWARDS, 1967).

***Discolithina rectipons* HAQ, n. sp.**

Pl. VII, figs. 7—9; Pl. XI, fig. 1

DERIVATION OF NAME. — *rectipons* (Latin) = straight bridge, perpendicular to the long axis.

DIAGNOSIS. — Elliptical discoliths with a bridge at right angle to the long axis, spanning the central opening and dividing it into two large almost circular windows.

DESCRIPTION. — The single transmission electronmicrograph available of this species (Pl. VII, fig. 7) shows a broad rim composed of thin flat crystals super-

imposed on each other and arranged in a spiral manner. Towards the inner edge of the rim the crystals become straight and lie at right angles to the outline of the ellipse and are slightly raised above the rest of the rim so as to form an "inner rim". The bridge is formed by the extension of some of these straight crystal-rays along the short axis at 90 degrees to the long axis. The crystal-rays taper towards the centre so that only three or four large rays reach the medial line and touch the rays of the opposite side, but do not merge with them. The bridge divides the opening into two large circular windows. The photomicrographs (Pl. VII, figs. 8, 9) do not show much beyond the main structure, i.e. a broad rim and two circular windows on each side of the bridge, which is perpendicular to the long axis of the ellipse.

The single scanning electronmicrograph available (Pl. XI, fig. 1) shows the distal view of a small specimen (length about $4.2\ \mu$) with a broad rim, and a bridge perpendicular to the long axis dividing the central opening into two semi-circular windows.

HOLOTYPE NEGATIVE NUMBER. — E 461.

DIMENSIONS. — Holotype: length $8.5\ \mu$, width $6.6\ \mu$, diameter of the windows $2.5\ \mu$.

DISCUSSION. — This species is similar to *Discolithina pulcheroides* in having a similar broad rim and crystals extending into the centre, but not merging, to form a bridge. However, in the present species the detailed structure of the rim, the angle of the bridge to the long axis, and the shape of the windows are different from *D. pulcheroides*.

OCCURRENCE. — Few specimens encountered in the present samples.

Genus *Zygrhablithus* DEFLANDRE, 1959

Holococcoliths composed of a ring-shaped subcircular to elliptical basal shield with a diagonal cross which is mounted by a four-ridged shaft, tapering upwards.

TYPE SPECIES. — *Zygrhablithus bijugatus* (DEFLANDRE) DEFLANDRE.

Zygrhablithus bijugatus (DEFLANDRE) DEFLANDRE 1959

Pl. VII, fig. 10; Pl. IX, figs. 10, 11

1954 *Zygotlithus bijugatus* DEFLANDRE in DEFLANDRE and FERT, p. 148, pl. 11, figs. 20, 21

1954 *Rhabdolithus costatus* DEFLANDRE in DEFLANDRE and FERT, p. 157, pl. 11, figs. 8—11, text-figs. 41, 42, 77—79

- 1959 *Zygrhablithus bijugatus* (DEFLANDRE) DEFLANDRE, p. 135
1960 *Isthmolithus claviformis* BRÖNNIMANN and STRADNER, p. 368, text-figs. 25—43
1961 *Zygrhablithus bijugatus* DEFLANDRE, BRAMLETTE and SULLIVAN, p. 151, pl. 6, figs. 16—18
1962 *Zygrhablithus bijugatus* DEFLANDRE, BOUCHÉ, p. 84, pl. 1, figs. 4, 9, 11
1964 *Zygrhablithus bijugatus* DEFLANDRE, SULLIVAN, p. 187, pl. 7, figs. 9, 10
1965 *Zygrhablithus bijugatus* DEFLANDRE, SULLIVAN, p. 38
1965 *Zygrhablithus bijugatus* DEFLANDRE, LEVIN, p. 267, pl. 42, figs. 1 a, b
1966 *Sujkowskiella enigmatica* HAY, MOHLER and WADE, p. 397, pl. 13, figs. 6, 7
1967 *Zygrhablithus bijugatus* DEFLANDRE, STRADNER in STRADNER and EDWARDS

DESCRIPTION. — The basal shield is an elliptical ring-shaped disc slightly concave proximally, and with the rim tilted upwards on the distal side which gradually widens. The single photomicrograph figured (Pl. VII, fig. 10) shows three of the four ridges of the shaft which rise from the basal shield in a pyramidal manner and taper sharply upwards to a pointed end which bends slightly. The shaft is presumably surmounting the diagonal cross of the basal plate. There are wide depressed grooves between the four ridges of the shaft which become narrower upwards until they disappear before the tip of the shaft.

According to STRADNER (1967) these forms are entirely composed of microcrystals of equal size, and he believes the transmission electronmicrographs pictured here to be side views of fragments of *Z. bijugatus* (Pl. IX, figs. 10, 11). They occur frequently in the present samples and seem to confirm STRADNER's view that these forms are holococcoliths composed of minute calcite rhombohedrons.

OCCURRENCE. — Upper Eocene of Oamaru, New Zealand (DEFLANDRE, 1954; STRADNER and EDWARDS, 1967); Upper Eocene of Mississippi (LEVIN, 1965); Lower-Middle Eocene of California (BRAMLETTE and SULLIVAN, 1961). Frequent in the present samples.

Genus *Braarudosphaera* DEFLANDRE, 1947

Pentaliths composed of five crystal-elements with straight or outwards curving outer-margins. This genus is distinguished from the genus *Micrantholithus* DEFLANDRE in which the outer-margins of the crystal-elements are curved inwards.

TYPE SPECIES. — *Braarudosphaera bigelowi* (GRAN and BRAARUD) DEFLANDRE.

Braarudosphaera bigelowi (GRAN and BRAARUD) DEFLANDRE, 1947

Pl. XI, figs. 3, 4

- 1935 *Pontosphaera bigelowi* GRAN and BRAARUD, p. 388, fig. 67

- 1947 *Braarudosphaera bigelowi* (GRAN and BRAARUD) DEFLANDRE, p. 439, figs. 1—5
- 1952 *Braarudosphaera bigelowi* (GRAN and BRAARUD) DEFLANDRE, KAMPTNER, p. 236, figs. 15 a, b
- 1954 *Braarudosphaera bigelowi* (GRAN and BRAARUD) DEFLANDRE, DEFLANDRE in DEFLANDRE & FERT, p. 51, pl. 10, figs. 8—12, pl. 13, figs. 7—9
- 1954 *Braarudosphaera bigelowi* (GRAN and BRAARUD) DEFLANDRE, KAMPTNER, p. 46, figs. 46, 47
- 1954 *Braarudosphaera bigelowi* (GRAN and BRAARUD) DEFLANDRE, BRAMLETTE and RIEDEL, p. 393, pl. 38, figs. 6 a, b
- 1955 *Braarudosphaera bigelowi* DEFLANDRE, GARDET, p. 520, pl. 7, figs. 64, 65 a, b
- 1958 *Braarudosphaera bigelowi* (GRAN and BRAARUD) DEFLANDRE, MARTINI, p. 355, pl. 2, figs. 6 a, b
- 1959 *Braarudosphaera bigelowi* (GRAN and BRAARUD) DEFLANDRE, MANIVIT, p. 24, pl. 4, fig. 1
- 1959 *Braarudosphaera bigelowi* (GRAN and BRAARUD) DEFLANDRE, STRADNER, p. 482, figs. 63, 64, 68
- 1960 *Braarudosphaera bigelowi* (GRAN and BRAARUD) DEFLANDRE, MARTINI, p. 396, fig. 9
- 1960 *Braarudosphaera bigelowi* (GRAN and BRAARUD) DEFLANDRE, MARTINI, p. 73, pl. 8, fig. 1
- 1960 *Braarudosphaera bigelowi* (GRAN and BRAARUD) DEFLANDRE, MARTINI, p. 31, figs. 1—3
- 1960 *Braarudosphaera bigelowi* (GRAN and BRAARUD) DEFLANDRE, STRADNER, p. 430, fig. 1
- 1961 *Braarudosphaera bigelowi* (GRAN and BRAARUD) DEFLANDRE, BRAMLETTE and SULLIVAN, p. 153, pl. 8, figs. 1 a, b, 3—5
- 1961 *Braarudosphaera bigelowi* (GRAN and BRAARUD) DEFLANDRE, STRADNER in STRADNER and PAPP, p. 116, pl. 37, figs. 1—3, text-fig. 12/1
- 1962 *Braarudosphaera bigelowi* (GRAN and BRAARUD) DEFLANDRE, BOUCHÉ, p. 85, pl. 4, figs. 1, 5
- 1965 *Braarudosphaera bigelowi*, BLACK, fig. 23
- 1965 *Braarudosphaera bigelowi* (GRAN and BRAARUD) DEFLANDRE, LEVIN, p. 268, pl. 42, figs. 4, 5
- 1966 *Braarudosphaera bigelowi* (GRAN and BRAARUD) DEFLANDRE, HAY, MOHLER and WADE, p. 394

DESCRIPTION. — Only light microscope phase-contrast pictures are figured here (Pl. XI, figs. 3, 4). They show the pentalith form with five asymmetrical crystals, in which the sutures occur slightly inside the corners of the pentalith. BLACK (1965, fig. 23) reproduced an excellent electronmicrograph of this species.

OCCURRENCE. — This species has been reported from Lower Cretaceous to Recent from widely separated regions of Europe and North and Central America.

***Braarudosphaera* sp.**

Pl. XI, figs. 5, 6

DESCRIPTION. — A pentalith form essentially similar to *Braarudosphaera bigelowi*

but without sutures. The surface of the pentolith seems to be traversed by faint striations from the margins towards the central focal point.

Genus *Micrantholithus* DEFLANDRE, 1954

Asteroliths composed of five crystal-elements. Distinguished from the genus *Braarudosphaera* by the inward curving of the outer-margins of the crystal-elements.

TYPE SPECIES. — *Micrantholithus flos* DEFLANDRE.

Micrantholithus vesper DEFLANDRE, 1954

Pl. VII, fig. 11

- 1950 *Micrantholithus vesper* DEFLANDRE, p. 1157, text-figs. 5—7 (invalid)
1954 *Micrantholithus vesper* DEFLANDRE, DEFLANDRE, p. 116, pl. 13, fig. 17, text-fig. 5
1954 *Micrantholithus vesper* DEFLANDRE, BRAMLETTE and RIEDEL, p. 394, pl. 38, fig. 8
1958 *Micrantholithus vesper* DEFLANDRE, MARTINI, p. 356, pl. 1, fig. 3
1959 *Micrantholithus vesper* DEFLANDRE, STRADNER, p. 482, fig. 59
1961 *Micrantholithus vesper* DEFLANDRE, BRAMLETTE and SULLIVAN, p. 156, pl. 9, fig. 10
1961 *Micrantholithus vesper* DEFLANDRE, MARTINI, pl. 1, figs. 9, 10
1961 *Micrantholithus vesper* DEFLANDRE, STRADNER in STRADNER and PAPP, p. 121, pl. 39, figs. 5 a, b, 6 a, b, text-fig. 12/8
1964 *Micrantholithus vesper* DEFLANDRE, SULLIVAN, p. 189, pl. 8, fig. 4
1965 *Micrantholithus vesper* DEFLANDRE, SULLIVAN, p. 40, pl. 9, figs. 4—7 a, b
1966 *Micrantholithus vesper* DEFLANDRE, HAY, MOHLER and WADE, p. 395, pl. 12, fig. 4

DESCRIPTION. — Although not rare in the present samples, this species is invariably represented as isolated crystals of the pentolith. This could be due to the application of ultrasonics and the tendency of the five crystal-elements to break along the sutures. Each crystal is triangular with one side forming the free outer-margin, broadly depressed or curved inwards. The other two sides, forming an angle of about 72 degrees, are the sutural margins along which the crystals are fitted to the two adjoining crystal-elements.

OCCURRENCE. — Lower Eocene of the Lodo Formation of California (BRAMLETTE and SULLIVAN, 1961); Middle or Lower Eocene of Haiti; Middle Eocene of Donzacq, France; Helvetian of Austria (STRADNER and PAPP, 1961); Upper Eocene of Nal'chik, the NW Caucasus, USSR (HAY, MOHLER and WADE, 1966). Frequent in the present samples.

Genus ***Thoracosphaera*** KAMPTNER, 1927

Spherical tests composed of interlocking crystal-units of regular or irregular shape, arranged in a mosaic pattern. With or without an opening.

TYPE SPECIES. — *Thoracosphaera pelagica* KAMPTNER.

Thoracosphaera deflandrei KAMPTNER, 1956

Pl. X, figs. 1, 2

1956 *Thoracosphaera deflandrei* KAMPTNER, p. 448, fig. 4

1961 *Thoracosphaera deflandrei* KAMPTNER, STRADNER, p. 84, fig. 74

DESCRIPTION. — Because of its large size (15—30 microns) this species seems to be unsupportable by the carbon-film, and appears therefore rarely and usually in a fragmentary state. Highly magnified electronmicrographs (Pl. X, fig. 2) indicate this species to have close resemblance to the drawing of *Thoracosphaera deflandrei* in STRADNER, 1961 (fig. 74). Comparatively complete specimens show a spherical form (Pl. X, fig. 1) composed of mosaic-patterned crystals of approximately equal size but irregular shape. No opening can be observed.

OCCURRENCE. — Reported as occurring from Lower Cretaceous to Recent (STRADNER, 1961, p. 84). Originally described from the Middle Eocene of Donzacq, France (KAMPTNER, 1956). Rare in the present samples.

Genus ***Tessellatolithus*** HAQ, n. gen.

DERIVATION OF NAME. — *tessellatum* (Latin) = mosaic.

DIAGNOSIS. — Non-spherical or irregularly-shaped composites of calcite crystals arranged in loosely fitting mosaic patterns.

TYPE SPECIES. — *Tessellatolithus dentatus* HAQ, n. sp.

Tessellatolithus dentatus HAQ, n. sp.

Pl. X, figs. 3, 4

DERIVATION OF NAME. — *dentatus* (Latin) = crenated.

DIAGNOSIS. — Tessellates of irregularly-shaped crystals with crenated margins. The whole composite enclosed by a wall of thick, almost rectangular crystals.

DESCRIPTION. — The holotype electronmicrograph (Pl. X, fig. 3) shows an

almost triangular form with broadly rounded corners. Two sides of the triangle are slightly curved inwards and the third side is curved outwards. A wall of thick, almost rectangular crystals forms a rim around the tessellate body. The rim seems to be slightly tilted upwards. The teeth of the crenated crystals fit into sockets of the adjoining crystals (Pl. X, fig. 4). The sutures between the crystals are depressed and the central areas of the crystals are raised above them.

HOLOTYPE NEGATIVE NUMBER. — E 981.

DIMENSIONS. — Holotype: maximum length $10\ \mu$, maximum width $8.1\ \mu$.

DISCUSSION. — Like *Tessellatolithus*, the genus *Thoracosphaera* is composed of mosaic patterns, but it includes spherical bodies. *Tessellatolithus* is proposed to include all non-spherical or irregularly tessellate forms.

OCCURRENCE. — Few specimens encountered in the present samples.

Genus *Discoaster* TAN SIN HOK, 1927

A general term used for asteroliths (rosette-like or star-shaped) ortholithid forms.

TYPE SPECIES. — *Discoaster pentaradiatus* TAN SIN HOK (designated by LOEBLICH and TAPPAN, 1963).

Discoaster multiradiatus BRAMLETTE and RIEDEL, 1954

Pl. X, fig. 5

- 1954 *Discoaster multiradiatus* BRAMLETTE and RIEDEL, p. 396, pl. 38, fig. 10
- 1956 *Discoaster multiradiatus* BRAMLETTE and RIEDEL, HILTERMAN, p. 752, fig. 15
- 1958 *Discoaster multiradiatus* BRAMLETTE and RIEDEL, STRADNER, p. 181, fig. 2—4
- 1959 *Discoaster multiradiatus* BRAMLETTE and RIEDEL, STRADNER, p. 1082, fig. 1
- 1960 *Discoaster multiradiatus* BRAMLETTE and RIEDEL, MARTINI, figs. 1, 10
- 1960 *Discoaster multiradiatus* BRAMLETTE and RIEDEL, BÁLDI, p. 222, pl. 14, fig. 17
- 1960 *Discoaster multiradiatus* BRAMLETTE and RIEDEL, MARTINI, p. 75, pl. 8, fig. 9
- 1961 *Discoaster multiradiatus* BRAMLETTE and RIEDEL, BRAMLETTE and SULLIVAN, p. 161, pl. 12, fig. 10
- 1961 *Discoaster multiradiatus* BRAMLETTE and RIEDEL, STRADNER in STRADNER and PAPP, p. 98, pl. 29, figs. 1—7, text-figs. 9/9, 16, 24/1
- 1964 *Discoaster multiradiatus* BRAMLETTE and RIEDEL, SULLIVAN, p. 191, pl. 10, figs. 8, 9

- 1965 *Discoaster multiradiatus* BRAMLETTE and RIEDEL, SULLIVAN, p. 43, pl. 10, figs. 13, 15

DESCRIPTION. — Asteroliths with numerous crystal-rays of equal size (usually more than 15 and up to 27) radiating from a focal point and joined along their entire lengths. In the present electronmicrograph (Pl. X, fig. 5), which is of a poorly preserved specimen, the rays are 19 in number and have bluntly rounded ends. The characteristic knob in the centre has been broken away; however, the picture shows the centre to be slightly depressed.

OCCURRENCE. — Reported from Paleocene deposits in many parts of the world. Rare and reworked in the present samples.

***Discoaster tani nodifer* BRAMLETTE and RIEDEL, 1954**

Pl. X, fig. 7

- 1954 *Discoaster tani nodifer* BRAMLETTE and RIEDEL, p. 397, pl. 39, fig. 2
1960 *Discoaster tani nodifer* BRAMLETTE and RIEDEL, MARTINI, p. 78, fig. 19, table 9
1961 *Discoaster tani nodifer* BRAMLETTE and RIEDEL, STRADNER in STRADNER and PAPP, p. 83, text-figs. 7/2, 8/19
1965 *Discoaster tani nodifera* BRAMLETTE and RIEDEL, LEVIN, p. 270, pl. 34, fig. 5

DESCRIPTION. — A single scanning electronmicrograph (Pl. XI, fig. 7) shows a six-rayed asterolith with single pairs of nodes on each ray near the extremities. The ends of the rays, however, do not show the terminal notches. The central part, where the rays meet, have slight, irregular elevations and depressions. The specimen pictured is partly corroded, which explains the absence of terminal notches.

OCCURRENCE. — Upper Eocene of Oamaru, New Zealand; Upper Eocene of Saipan, Mariana Islands; Alabama and Mississippi (BRAMLETTE and RIEDEL, 1954; LEVIN, 1965) Upper Eocene of Germany (MARTINI, 1960). Rare in the present samples.

Genus *Discoasteroides* BRAMLETTE and SULLIVAN, 1961

Ortholithid discoasters with heliolithid stems which are formed by the continuation of the rays of the discoaster around a central pivot in a heliolithid manner.

TYPE SPECIES. — *Discoasteroides kuepperi* (STRADNER) BRAMLETTE and SULLIVAN.

Discoasteroides kuepperi (STRADNER) BRAMLETTE and SULLIVAN, 1961

Pl. X, fig. 6

- 1959 *Discoaster kuepperi* STRADNER, p. 478, text-figs. 17, 21
 1961 *Discoaster kuepperi* STRADNER, MARTINI, p. 14, pl. 3, fig. 29
 1961 *Discoasteroides kuepperi* (STRADNER) BRAMLETTE and SULLIVAN, p. 163, pl. 13, figs. 16—19
 1961 *Discoaster kuepperi* STRADNER, STRADNER in STRADNER and PAPP, p. 93, pl. 27, figs. 1—6, text-figs. 9/6, 16
 1962 *Discoasteroides kuepperi* (STRADNER), HAY and TOWE, p. 515, pl. 10, fig. 1
 1964 *Discoasteroides kuepperi* (STRADNER), SULLIVAN, p. 192, pl. 12, figs. 1 a, b, 2 a, b
 1965 *Discoasteroides kuepperi* (STRADNER), SULLIVAN, p. 44

DESCRIPTION. — Ten-rayed asterolith with rays joined throughout their length and ending in slightly rounded ends. The electronmicrograph (Pl. X, fig. 6) shows the proximal side on which one can clearly see the continuation of each ray into the centre to form the heliolithic stem with a sinistral imbrication around the central pivot. The sutures between the rays are slightly depressed.

DISCUSSION. — This species is very similar to *Discoaster barbadiensis* and can be distinguished from it only by the heliolith coiling of the stem (also see HAY and TOWE, 1962, pl. 10, figs. 1, 3, 5).

OCCURRENCE. — Rare in the present samples.

Genus ***Marthasterites*** DEFLANDRE, 1959

Three-armed asterolith forms, with straight or curved arms radiating from an undifferentiated centre.

TYPE SPECIES. — *Marthasterites furcatus* DEFLANDRE.

***Marthasterites* cf. *tribrachiatu*s** (BRAMLETTE and RIEDEL) DEFLANDRE, 1959

Pl. X, fig. 12

- 1954 *Discoaster tribrachiatu*s BRAMLETTE and RIEDEL, p. 397, pl. 38, fig. 11
 1958 *Discoaster tribrachiatu*s BRAMLETTE and RIEDEL, STRADNER, p. 181, fig. 5
 1958 *Discoaster tribrachiatu*s BRAMLETTE and RIEDEL, MARTINI, p. 357, pl. 2, figs. 8 a, b
 1959 *Discoaster tribrachiatu*s BRAMLETTE and RIEDEL, STRADNER, p. 477, figs. 5, 6, 10
 1959 *Marthasterites tribrachiatu*s (BRAMLETTE and RIEDEL) DEFLANDRE, p. 138, pl. 2, fig. 1

- 1960 *Discoaster tribrachiatus* BRAMLETTE and RIEDEL, MARTINI, p. 81, pl. 10, fig. 30
 1961 *Discoaster tribrachiatus* BRAMLETTE and RIEDEL, BRAMLETTE and SULLIVAN, p. 162, pl. 13, figs. 6a, b, 7—9, 11—13
 1961 *Marthasterites tribrachiatus* (BRAMLETTE and RIEDEL) DEFLANDRE, STRADNER in STRADNER and PAPP, p. 110, pl. 35, figs. 1—4, 7, text-figs. 11/5, 6, 20/2

DESCRIPTION. — Three equal-sized rays radiating from an undifferentiated centre and inseparable from each other. Only one electronmicrograph (Pl. X, fig. 12) was available showing the rays to be tapering towards the ends and finishing in pointed ends which are located asymmetrically towards one side of the ray. There is an angle of 120 degrees between adjacent rays. The top and the base of the rays seem to be broader than the central part, so that the rays have a doubly grooved cross-section.

OCCURRENCE. — A Lower Eocene species. Rare and reworked in the present samples.

Genus *Isthmolithus* DEFLANDRE, 1954

Boat-shaped elongate parallelograms with two transverse septa dividing the parallelogram into three almost equi-dimensional windows.

TYPE SPECIES. — *Isthmolithus recurvus* DEFLANDRE.

Isthmolithus recurvus DEFLANDRE, 1954

Pl. IX, figs. 1—7

- 1954 *Isthmolithus recurvus* DEFLANDRE in DEFLANDRE and FERT, p. 169, pl. 12, figs. 9—13, text-figs. 119—122
 1958 *Isthmolithus recurvus* DEFLANDRE, MARTINI, p. 37, pl. 12, figs. 5a, b
 1960 *Isthmolithus recurvus* DEFLANDRE, MARTINI, p. 84, pl. 11, fig. 38
 1960 *Isthmolithus recurvus* DEFLANDRE, BRÖNNIMANN and STRADNER, p. 367, text-fig. 44
 1961 *Isthmolithus recurvus* DEFLANDRE, MARTINI, p. 26
 1962 *Isthmolithus recurvus* DEFLANDRE, MARTINI, p. 280
 1962 *Isthmolithus recurvus* DEFLANDRE, DEFLANDRE, p. 5, fig. c
 1964 *Isthmolithus recurvus* DEFLANDRE, STRADNER, p. 135, text-figs. 20, 21
 1965 *Isthmolithus recurvus* DEFLANDRE, LEVIN, p. 269, pl. 42, fig. 10
 1966 *Isthmolithus recurvus* DEFLANDRE, HAY, MOHLER and WADE, p. 396, pl. 12, figs. 1—3, pl. 13, fig. 3
 1966 *Isthmolithus recurvus* DEFLANDRE, REINHARDT, p. 46, pl. 21, figs. 14, 15
 1967 *Isthmolithus recurvus* DEFLANDRE, STRADNER in STRADNER and EDWARDS

DESCRIPTION. — In photomicrographs (Pl. IX, figs. 4—7) the parallelogram outline and the three windows can be seen. In the transmission electronmicrograph (Pl. IX, fig. 3) the transverse septa look like a walled structure composed of two elements which are fused together along the medial line of the long axis of the parallelogram. These two elements are similar but not symmetrical, so that if the isthmolith is divided at the medial line of the long axis, and one of the halves is held upside down beside the other their outlines would seem to fit. At the three meeting points of the two halves the crystals seem to thicken and form nodules with positions slightly displaced. The photomicrographs of the side views (Pl. IX, figs. 4, 5) show the septa and the short sides of the parallelogram to be higher than the rest of the wall structure. The three windows are not similar in outline. The central window tends to be more rectangular, whereas the two outer windows are more trapezoidal.

The scanning electronmicrographs (Pl. IX, figs. 1, 2), which show fragmentary specimens, indicate that the walls and the septa are at least as high as the width of the windows. These pictures also give the impression that the short sides of the parallelogram are bent slightly inwards towards the distal side, so that the whole isthmolith is somewhat like a bottomless rectangular boat with two partitions to hold the sides together.

OCCURRENCE. — Reported as restricted to Upper Eocene from many parts of the world. Common in the present samples.

Genus *Microrhabdulus* DEFLANDRE, 1959

Long, cylindrical and tubular rod-like forms. Could be detached elements of other nannoplankton.

TYPE SPECIES. — *Microrhabdulus decoratus* DEFLANDRE.

Microrhabdulus sp.

Pl. IX, fig. 9

REMARKS. — The single electronmicrograph shows a cylindrical rod-like structure tapering towards the ends. It consists of bundles of minute, long prismatic crystals, essentially parallel to the axis of the rod. This specimen shows some similarity to *Microrhabdulus stradneri* BRAMLETTE and MARTINI, 1964 (pl. 6, figs. 3, 4).

OCCURRENCE. — Few specimens seen in the present samples; could be reworked.

Genus *Trochoaster* KLUMPP, 1953

Six-cornered asteroliths with regular and intricate surface details. Biconvex in cross-section.

TYPE SPECIES. — *Trochoaster simplex* KLUMPP.

Trochoaster simplex KLUMPP, 1953

Pl. XI, figs. 7, 8

- 1953 *Trochoaster simplex* KLUMPP, p. 385, pl. 11, fig. 7
- 1953 *Trochoaster duplex* KLUMPP, p. 386, pl. 16, fig. 10
- 1958 *Trochoaster simplex* KLUMPP, MARTINI, p. 368, pl. 5, fig. 25
- 1959 *Polycladolithus stellaris* STRADNER, p. 487, figs. 73—75, 77 e—h
- 1960 *Trochoaster simplex* KLUMPP, MARTINI and STRADNER, p. 269, figs. 19 a, b
- 1961 *Trochoaster simplex* KLUMPP, MARTINI, p. 101
- 1961 *Trochoaster simplex* KLUMPP, STRADNER in STRADNER and PAPP, p. 131, pl. 42, figs. 1—4, 6 a—d, text-figs. 14/1, 2, 24/12

DESCRIPTION. — The two phase-contrast pictures (Pl. XI, figs. 7, 8) give a slightly oblique view of a specimen. The positive phase-contrast picture illustrates the the general outline (fig. 7), whereas the negative phase-contrast picture (fig. 8) exhibits the intricate rays radiating from the centre. The positive phase-contrast picture also shows the six major depressions between the rays, and numerous smaller ones. The outlines of the six elements curve broadly inwards. The rays are slightly raised above the surrounding parts.

OCCURRENCE. — Upper Eocene of Kiel, West Germany (KLUMPP, 1953); Middle Eocene of Mexico; Lower Oligocene of Austria (STRADNER and PAPP, 1961). A few specimens found in the present samples.

THE DISTRIBUTION OF CALCAREOUS NANNOPLANKTON DURING THE EOCENE

The Eocene period saw a great increase in the calcareous nannoplankton population, both in types and number. More than three hundred species have been recorded from Eocene strata around the globe. This group of microfossils since its apparently sudden appearance in the Lower Jurassic had already achieved a high degree of development by the end of the Cretaceous showing a peak in the population curve during the Maestrichtian. At the close of the Maestrichtian an extinction of a large number of genera and species took place with new forms appearing at the dawn of the Danian (BRAMLETTE and MARTINI, 1964). The Pa-

leocene shows a somewhat gradual increase in the number of species. However, in the Eocene the number of species once again multiplied by nearly two-fold showing another peak in the population curve. Periods younger than Eocene have seen an irregular but gradual decline in the number of species with most species becoming extinct by the dawn of the Pleistocene. The discoasters completely disappear at the beginning of the Pleistocene and according to W. A. BERGGREN (personal communication) they reoccur once again for a short while during the Late Pleistocene in his samples from Central N. Atlantic.

A number of Eocene localities in Europe and the United States have been thoroughly studied for their nannofossil content, and the results have been quite effectively used for stratigraphic purposes. BRAMLETTE and SULLIVAN (1961) recognize four distinct biostratigraphic units in the Lower and Middle Eocene of the Lodo Formation of California. According to them, their unit 3 of the Lodo Formation (*Marthasterites tribrachiatus* Zone) corresponds well to the Ypresian stage. Although they could not find any calcareous nannoplankton in the samples from the type Ypresian, they correlate their unit 3 with other well established Ypresian equivalents such as the London Clay, the Rösnaes Clay of Denmark and the *Globorotalia aragonensis* Zone (BOLLI). Their unit 4 was assigned to the Lower Lutetian from the presence of an assemblage similar to that of Donzacq, France, and also considered equivalent to the lower part of the Weches Formation (Middle Eocene) of SE Texas. Units 5 and 6 were also assigned to the Middle Eocene. Unit 5 corresponds well with the upper part of the Weches Formation, but the exact correlation of unit 6, the upper limit of which they could not determine, may eventually prove to be Upper Eocene in age.

SULLIVAN (1965) divided the sections from the California coastal ranges into four faunizones. The upper part of his faunizone 2 roughly corresponds to the foraminiferal stage Penutian, and faunizones 3 and 4 correspond to the Ulatisian and Narizian stages, respectively. The foraminiferal stage Ulatisian represents the Middle Eocene in California, whereas the Narizian represents only the lower part of the Upper Eocene.

STRADNER and PAPP (1961) in their study of discoasters and other forms from the Tertiary of Austria based their divisions on the foraminiferal fauna of these samples which had been thoroughly studied previously. They were able to divide the Eocene into three units based on the study of fourteen samples, and they roughly correlate their units to Cuisian (Lower Eocene), Lutetian (Middle Eocene) and Ledian and Wemmelian (Upper Eocene).

MARTINI (1958, 1959a and 1959b) first studied the nannoplankton from the Eocene of NW Germany. He based his study on the division of the Eocene of NW Germany by BETTENSTAEDT (1949) who divided it into five units after the study of the included microfauna. The lower four units were assigned by him to the "Lower Eocene" and the fifth to the "Upper Eocene". The table after BETTENSTAEDT (1949) and MARTINI (1959) is reproduced below.

Table 1 (simplified after BETTENSTAEDT).

NW German divisions		International divisions
?		Upper Eocene (Bartonian and Ludian)
Upper Eocene	late	
	medial	
	early	Middle Eocene (Lutetian)
Lower Eocene 4	late	
	early	?
Lower Eocene 3	late	Lower Eocene (Ypresian)
	early	
Lower Eocene 2		
Lower Eocene 1		

According to MARTINI (1958) the "Lower Eocene" units 1, 2 and 4 contained either no or rare coccoliths. The "Lower Eocene" unit 3, however, yielded a rich *Discoaster*-flora. The fifth division ("Upper Eocene") the "early" part of which corresponds to the late Lutetian yielded a very rich assemblage of discoasters and related forms. The "medial Upper Eocene" which may be considered to represent the boundary between the Middle and Upper Eocene on the international time scale yielded only four species, three of which had been described from the "Lower Eocene" unit 3. He noted some development in the shape of these species, e. g. the arms of *Discoaster crassus* and *D. barbadiensis* had become more inflated than before, and *Braarudosphaera bigelowi* showed thickening. Again, the "late Upper Eocene" (Upper Eocene on the international time scale) showed the presence of a rich nannoplankton assemblage. The appearance of the typical Upper Eocene species *Isthmolithus recurvus* is noted at this level.

An attempt is made here to present a general idea of the distribution of all the species with relatively restricted vertical ranges which occur in the Eocene. A total of 225 species have been recorded. As far as possible the synonymies of various species have been considered in order to avoid repetition. Table 3 shows the geographical distribution of these species in twelve localities around the globe. Their stratigraphic ranges, based upon the reported occurrences by various authors have also been recorded. Those forms with relatively longer distribution in time have not been considered. Table 2 records the vertical distribution of various species occurring in at least three distinctly separated localities of Table 3.

It must be mentioned here that extreme caution should be the guiding line

when attempting a correlation on this scale. The accuracy of reported occurrences of different species at different stratigraphic levels by various authors can be taken into account only at its face value. A factor of personal errors can be introduced in such an attempt, unless various type materials used can be rechecked — a highly time consuming task. A second major error is introduced by the actually existing and possible discrepancies of correlation not only between the land based sequences and marine cores, but also between different land based sections. For example, until recently a sharp discrepancy in correlation existed between the Paleocene-Eocene boundary in the Gulf Coast region and Europe. This boundary was placed between the foraminiferal zones with *Globorotalia velascoensis* and *G. rex* in Europe, whereas in the Gulf Coast region it was placed below the Wilcox Group or the *G. pseudomenardii* Zone, which actually forms a part of the Upper Paleocene. The *Marthasterites contortus* Zone marks the break between the Paleocene and the Eocene, and dates also the beginning of *Pseudobastigerina eocenica* in the Bashi Marl Member in Alabama (BERGGREN, 1965, p. 282). According to BERGGREN the strata containing a mixture of *Globorotalia rex* and *G. velascoensis* should be considered a distinct zone corresponding to the *Marthasterites contortus* Zone, and the Paleocene—Eocene boundary be placed at the first appearance of *Pseudobastigerina eocenica* (personal communication, 1967).

This example illustrates the difficulties involved in correlating various boundaries, especially when many diverse opinions may exist as to their placement in different geographical areas. An author, for instance, reporting a certain species as occurring in Lower Eocene strata in the Gulf Coast region may or may not be referring to the corresponding Upper Paleocene strata in Europe.

The attempt at stratigraphy made here should, therefore, in no way be considered conclusive. It is, at the most, a preliminary compilation of Eocene occurrences of various species from different geographical localities as reported by various authors.

However, it can be seen from the correlation tables that a pattern can be recognised in the distribution of various nannoplankton species during the Eocene. In order to ensure both wide horizontal and short vertical distributions only those species with occurrences in a least three different geographical localities and with a comparatively restricted stratigraphic range have been considered in Table 2. It can be noted from Table 3 that a large number of species (which may occur in one or two localities only) have a distribution from Paleocene to the close of the Lower Eocene. The boundary between the Lower and Middle Eocene date an appreciable change in the nannoplankton population.

Only two species, namely *Marthasterites tribrachiatus* and *Discoaster diatypus* are restricted to the Lower Eocene. HAY (1964 a and *vide* BERGGREN, 1965) reported *D. diatypus* to be restricted to the lower part of Ypresian in the Swiss

Alps and he divided the *Marthasterites tribrachiatus* Zone into two subzones: a lower *Discoaster diatypus* subzone and an upper *D. lodoensis*—*D. deflandrei* subzone.

A large number of species first appearing in the Lower Eocene continue into the Middle Eocene. The boundary between the Middle and Upper Eocene seems to date another appreciable change in the nannoflora. Most discoasters disappear at this boundary so that only a few species remain in the Upper Eocene. However, many of the species of coccoliths reported ranging upto this boundary by various authors have recently been reported by SULLIVAN (1965) to occur as far as the Narizian (lower part of Upper Eocene) in the California coastal ranges. *Chiphragmalithus acanthodes* and *Discolithina distincta* are the only species which can be said to be restricted to the Middle Eocene with some confidence.

To the Upper Eocene are confined a comparatively larger number of species, such as *Chiasmolithus oamaruensis*, *Ericsonia fenestrata*, *Isthmolithus recurvus*, *Reticulofenestra oamaruensis*, and *Discoaster tani nodifer*. Many new species seem to appear at the beginning of the Upper Eocene, although not radically different, morphologically, from the Lower and Middle Eocene species. Upper Eocene is the highest development period in the nannoplankton history during the Eocene.

The sources for the compilation of the distribution tables 2 and 3 presented in this paper are as follows:

BLACK (1964), BLACK and BARNES (1961), BOUCHÉ (1962), BRAMLETTE and MARTINI (1964), BRAMLETTE and RIEDEL (1954), BRAMLETTE and SULLIVAN (1961), DEFLANDRE (1959), DEFLANDRE and FERT (1954), HAQ (1966, the present paper), HAY, MOHLER and WADE (1966), HAY and TOWE (1962, 1963), KAMPTNER (1962, 1963), KLUMPP (1953), LEVIN (1965), LOEBLICH and TAPPAN (1966), MARTINI (1958, 1959 a, b, c, 1960, 1961, 1962, 1965), SHAMRAI (1963), SHAMRAI and LAZAREVA (1956), STRADNER and PAPP (1961), STRADNER and EDWARDS (1967), and SULLIVAN (1965).

Table 2. Vertical distribution of species with wide geographical occurrences during the Eocene.

SPECIES	PALEOCENE	EOCENE			OLIGOCENE
		Lower	Middle	Upper	
<i>Coccolithus consuetus</i> BRAMLETTE and SULLIVAN					
<i>Ellipsolithus macellus</i> (BRAMLETTE and SULLIVAN) SULLIVAN					
<i>Heliolithus riedeli</i> BRAMLETTE and SULLIVAN					
<i>Marthasterites tribrachiatus</i> (BRAMLETTE and RIEDEL) DEFLANDRE					
<i>Discoaster diatypus</i> BRAMLETTE and SULLIVAN					
<i>Clathrolithus minutus</i> BRAMLETTE and SULLIVAN					
<i>Helicosphaera seminulum lophota</i> BRAMLETTE and SULLIVAN					
<i>H. seminulum seminulum</i> BRAMLETTE and SULLIVAN					
<i>Cyclococcolithus gammatum</i> BRAMLETTE and SULLIVAN					
<i>Coccolithus grandis</i> BRAMLETTE and RIEDEL					
<i>Discolithina plana</i> (BRAMLETTE and SULLIVAN) LEVIN					
<i>Discoaster lodoensis</i> BRAMLETTE and RIEDEL					
<i>Chiphragmalithus acanthodes</i> BRAMLETTE and SULLIVAN					
<i>Discolithina distincta</i> (BRAMLETTE and SULLIVAN)					
<i>Chiphragmalithus quadratus</i> BRAMLETTE and SULLIVAN					
<i>Coccolithus expensus</i> BRAMLETTE and SULLIVAN					
<i>C. marismontium</i> BLACK					
<i>Ericsonia ovalis</i> BLACK					
<i>Micrantholithus vesper</i> DEFLANDRE					
<i>Pemma pappillatum</i> MARTINI					
<i>Chiasmolithus oamaruensis</i> (DEFLANDRE) HAY, MOHLER and WADE					
<i>Discolithina obliquipons</i> (DEFLANDRE) STRADNER					
<i>Ericsonia fenestrata</i> (DEFLANDRE) STRADNER					
<i>Isthmolithus recurvus</i> DEFLANDRE					
<i>Reticulofenestra oamaruensis</i> (DEFLANDRE) STRADNER					
<i>Discoaster tani nodifer</i> BRAMLETTE and RIEDEL					
<i>Stradnerius dictyodus</i> (DEFLANDRE and FERT) HAQ					
<i>Goniolithus fluckigeri</i> DEFLANDRE					

Table 3. Distribution of calcareous

LOCALITIES SPECIES	New Zealand (Oamaru)	Syria	USSR (Russian Platform & Caucasus)	Austria	Germany	France (Paris Basin & Donzacq)
<i>Aspidorbabbus ovalis</i>						+
<i>Braarudosphaera africana</i>						
<i>B. bigelowi</i>	+		+	+	+	+
<i>B. discula</i>						
<i>B. perversa</i>						
<i>B. undata</i>				+		
<i>Calcitrema asymmetricum</i>						
<i>Campylosphaera bramlettei</i>						
<i>Cbiasmolithus oamaruensis</i>	+		+			
<i>Chiphragmalithus acanthodes</i>						+
<i>C. calathus</i>						
<i>C. dubius</i>						+
<i>C. quadratus</i>					+	
<i>Coccolithus consuetus</i>						+
<i>C. corticosus</i>			+			
<i>C. crassipons</i>						+
<i>C. crassus</i>						+
<i>C. cribellum</i>						+
<i>C. cruciatus</i>			+			
<i>C. crux</i>						+
<i>C. diaphragmus</i>						+
<i>C. eopelagicus</i>	+	+	+			
<i>C. expansus</i>						+
<i>C. gigas</i>						
<i>C. grandis</i>						+
<i>C. lacrimus</i>						+
<i>C. litos</i>			+			
<i>C. oculiferous</i>						
<i>C. marismontium</i>		+				
<i>C. martinii</i>						+
<i>C. oculuselectrae</i>						+
<i>C. oulchyensis</i>						+
<i>C. parvulus</i>	+					+

oplankton during the Eocene

Atlantic Ocean	Mississippi (Yazoo Formation)	California	Texas	West Indies and Mexico	Pacific Ocean	Stratigraphic Range
	+	+		+		L. Eocene L. Cretaceous—M. Eocene Cretaceous—Recent L. Eocene—M. Eocene Eocene
		+		+	+	Paleocene—L. Eocene Eocene Paleocene—Oligocene
	+	+			+	U. Eocene M. Eocene
	+	+				L. Eocene M. Eocene
		+	+	+		M. Eocene—U. Eocene Paleocene—U. Eocene M. Eocene
		+				M. Eocene L. Eocene—M. Eocene L. Eocene M. Eocene—U. Eocene L. Eocene
	+	+	+		+	L. Eocene Paleocene—Oligocene M. Eocene—U. Eocene M. Eocene
		+		+	+	Eocene
+					+	L. Eocene U. Eocene Eocene—Oligocene M. Eocene—U. Eocene L. Eocene M. Eocene M. Eocene U. Eocene

Table 3 (cont.)

LOCALITIES SPECIES						
	New Zealand (Oamaru)	Syria	USSR (Russian Platform & Caucasus)	Austria	Germany	France (Paris Basin & Donzacq)
<i>Discolithina macropora</i>	+				+	
<i>D. multipora</i>	+		+		+	+
<i>D. noëlae</i>						+
<i>D. obliquipons</i>	+		+		+	
<i>D. ocellata</i>						
<i>D. panaria</i>						+
<i>D. pectinata</i>						
<i>D. plana</i>						+
<i>D. pulchra</i>					+	+
<i>D. pulchraoides</i>	+				+	
<i>D. punctosa</i>						
<i>D. rectipons</i>					+	
<i>D. rimosa</i>						+
<i>D. solida</i>						+
<i>D. spinosa</i>	+					+
<i>D. stella</i>						+
<i>D. tecta</i>						+
<i>D. versa</i>						
<i>D. vesca</i>						
<i>Ellipsolithus distichus</i>						+
<i>E. macellus</i>						+
<i>Ericsonia alternans</i>						
<i>E. fenestrata</i>	+				+	
<i>E. hesslandi</i>		+				
<i>E. occidentalis</i>						
<i>E. ovalis</i>	+	+			+	
<i>Fasciculithus involutus</i>						+
<i>Goniolithus fluckigeri</i>	+				+	+
<i>Helicosphaera euphratis</i>		+				
<i>H. seminulum</i>	+	+				+
<i>Heliolithus helianthus</i>						+
<i>H. riedeli</i>						+
<i>Heliorthus fallax</i>						
<i>Ilseolithina iris</i>	+			+		

Table 3 (cont.)

Atlantic Ocean	Mississippi (Yazoo Formation)	California	Texas	West Indies and Mexico	Pacific Ocean	Stratigraphic Range
		+				U. Eocene
						U. Eocene—Miocene
		+				L. Eocene
						U. Eocene
		+				L. Eocene—M. Eocene
			+			M. Eocene
		+	+			L. Eocene—M. Eocene
	+	+	+			Eocene
		+				M. Eocene—U. Eocene
		+				Eocene
		+				L. Eocene
						U. Eocene
		+				Paleocene—M. Eocene
						M. Eocene
						M. Eocene—U. Eocene
						L. Eocene
						M. Eocene
		+				L. Eocene—M. Eocene
		+				Eocene
		+				Paleocene—L. Eocene
+		+		+		Paleocene—M. Eocene
						M. Eocene
						U. Eocene
+						U. Eocene
+						M. Eocene
						M. Eocene—U. Eocene
		+				Paleocene—L. Eocene
						U. Eocene—Oligocene
		+	+			U. Eocene
						Eocene
		+				L. Eocene
				+		Paleocene—L. Eocene
				+		L. Eocene
						U. Eocene

Table 3 (cont.)

LOCALITIES SPECIES						
	New Zealand (Oamaru)	Syria	USSR (Russian Platform & Caucasus)	Austria	Germany	France (Paris Basin & Donzacq)
<i>Lophodolitus mochlophorus</i>						+
<i>L. nascens</i>						+
<i>L. reniformis</i>						
<i>Micrantholithus attenuatus</i>						+
<i>M. basquensis</i>						+
<i>M. bramlettei</i>						
<i>M. bulbosus</i>						+
<i>M. crenulatus</i>						
<i>M. flos</i>						+
<i>M. inaequalis</i>						+
<i>M. laterlis</i>						
<i>M. parisiensis</i>						+
<i>M. vesper</i>			+		+	+
<i>Pemma acutum</i>						+
<i>P. angulatum</i>					+	
<i>P. pappillatum</i>						
<i>P. rotundum</i>					+	
<i>Pyrocyclus inversus</i>					+	
<i>Reticulofenestra dupouyi</i>	+	+	+			+
<i>R. oamaruensis</i>	+		+		+	
<i>R. placomorpha</i>	+		+	+	+	+
<i>Rhabdosphaera crebra</i>						+
<i>R. hayi</i>	+					
<i>R. inflata</i>						+
<i>R. marionum</i>						+
<i>R. perlonga</i>					+	+
<i>R. pingia</i>						+
<i>R. recta</i>	+				+	+
<i>R. rudis</i>						
<i>R. scabrosa</i>						+
<i>R. spinula</i>						
<i>R. splendens</i>						+
<i>R. tenia</i>						
<i>R. truncata</i>						+

Table 3 (cont.)

Atlantic Ocean	Mississippi (Yazoo Formation)	California	Texas	West Indies and Mexico	Pacific Ocean	Stratigraphic Range
		+				M. Eocene
		+				Paleocene—M. Eocene
		+				L. Eocene—M. Eocene
						Paleocene—L. Eocene
						L. Eocene
		+				L. Eocene
						M. Eocene
		+				Paleocene—M. Eocene
						M. Eocene
		+				L. Eocene
						Eocene
		+				M. Eocene
		+				M. Eocene—U. Eocene
						M. Eocene
						U. Eocene
+	+	+		+		M. Eocene—U. Eocene
						U. Eocene
						U. Eocene
						Eocene
						U. Eocene
	+					Eocene—Miocene
						M. Eocene
						U. Eocene
						M. Eocene
						M. Eocene
						M. Eocene—U. Eocene
						M. Eocene
						M. Eocene—U. Eocene
		+				L. Eocene
						M. Eocene
	+					U. Eocene
						M. Eocene
		+				M. Eocene—U. Eocene
		+				L. Eocene

Table 3 (cont.)

LOCALITIES SPECIES	New Zealand (Oamaru)	Syria	USSR (Russian Platform & Caucasus)	Austria	Germany	France (Paris Basin & Donzacq)
<i>Rhabdosphaera vitrea</i>						+
<i>Rotalithus teutonicus</i>					+	
<i>Scapholithus fossilis</i>						
<i>Stradnerius daviesi</i>					+	
<i>S. dictyodus</i>	+	+	+		+	+
<i>Tetralithus nitidus</i>						+
<i>Tessellatolithus dentatus</i>					+	
<i>Thoracosphaera deflandrei</i>					+	+
<i>Tiarolithus obscurus</i>			+			+
<i>Umblicosphaera arena</i>						+
<i>Zygolithus aureus</i>	+			+		
<i>Z. connicus</i>						
<i>Z. crux</i>						+
<i>Z. dubius</i>						+
<i>Z. laffittei</i>						+
<i>Z. protenus</i>						+
<i>Zygrhablithus bijugatus</i>	+		+	+	+	+
<i>Z. simplex</i>						+
Incertae sedis						
<i>Clathrolithus ellipticus</i>						+
<i>C. minutus</i>						+
<i>C. spinosus</i>						+
<i>Discoaster aecus</i>						
<i>D. aeocenicus</i>			+			
<i>D. aster</i>						
<i>D. binodosus</i>					+	
<i>D. bramlettei</i>					+	
<i>D. bronimanni</i>						
<i>D. corniger</i>			+			
<i>D. crassus</i>					+	
<i>D. cruciformis</i>					+	
<i>D. deflandrei</i>						+

Table 3 (cont.)

LOCALITIES SPECIES						
	New Zealand (Oamaru)	Syria	USSR (Russian Platform & Caucasus)	Austria	Germany	France (Paris Basin & Donzacq)
<i>Discoaster diatypus</i>						+
<i>D. distinctus</i>					+	
<i>D. durusradiatus</i>			+			
<i>D. elegans</i>						
<i>D. falcatus</i>						+
<i>D. gemmifer</i>				+		
<i>D. geometricus</i>						
<i>D. germanicus</i>					+	
<i>D. helianthus</i>						+
<i>D. heptaradiatus</i>					+	
<i>D. lenticularis</i>						+
<i>D. limbatus</i>						
<i>D. lodoensis</i>				+	+	+
<i>D. martinii</i>						
<i>D. mediosus</i>						
<i>D. membranaeformae</i>			+			
<i>D. minimus</i>						
<i>D. mirus</i>						+
<i>D. molaris</i>						
<i>D. monstratus</i>						+
<i>D. munitus</i>						
<i>D. nivalis</i>						+
<i>D. nonradiatus</i>					+	
<i>D. plebeius</i>					+	
<i>D. septemradiatus</i>				+		
<i>D. stradneri</i>				+		
<i>D. strictus</i>						
<i>D. sublodoensis</i>						+
<i>D. tani</i>	+				+	+
<i>D. trinus</i>				+		
<i>D. uncinatus</i>						
<i>D. unguineus</i>			+			
<i>Discoasteroides kuepperi</i>				+	+	
<i>D. megastypus</i>						

Table 3 (cont.)

Atlantic Ocean	Mississippi (Yazoo Formation)	California	Texas	West Indies and Mexico	Pacific Ocean	Stratigraphic Range
		+		+		L. Eocene U. Eocene U. Eocene L. Eocene—M. Eocene Paleocene—L. Eocene M. Eocene L. Eocene Eocene Paleocene—L. Eocene Eocene Paleocene—L. Eocene Paleocene—L. Eocene L. Eocene—M. Eocene L. Eocene Paleocene—L. Eocene U. Eocene L. Eocene M. Eocene M. Eocene M. Eocene M. Eocene L. Eocene Eocene U. Eocene U. Eocene M. Eocene M. Eocene M. Eocene M. Eocene—U. Eocene M. Eocene L. Eocene U. Eocene Paleocene—Eocene Paleocene—L. Eocene
		+				
		+		+		
		+		+		
		+				
		+				
		+		+		
		+		+		
		+				
		+				
				+		
+				+		
		+				
		+				

Table 3 (cont.)

LOCALITIES SPECIES	New Zealand (Oamaru)	Syria	USSR (Russian Plateform & Caucasus)	Austria	Germany	France (Paris Basin & Donzacq)
<i>Guttolithion cassum</i>					+	
<i>Heliodiscoaster fenestratus</i>			+			
<i>Isthmolithus claviformis</i>						
<i>I. recurvus</i>	+		+		+	
<i>I. unipons</i>						
<i>Lanterithus minutus</i>				+		
<i>Lithostromation obscurum</i>					+	
<i>L. vasrum</i>						+
<i>Lucianorhabdus dispar</i>				+		
<i>Marthasterites riedeli</i>						
<i>M. tribachiatas</i>				+		
<i>Microrhabdulus rugosus</i>						+
<i>Nannotetraster alatus</i>					+	
<i>N. fulgens</i>						
<i>N. insignitus</i>						+
<i>N. spinosus</i>				+		
<i>N. swasticoides</i>				+	+	
<i>Rhomboaster cupis</i>						
<i>Trochoaster austriacus</i>				+		
<i>T. conglobatus</i>				+		
<i>T. cristatus</i>					+	
<i>T. gracilis</i>					+	
<i>T. hobensis</i>					+	
<i>T. mexicanus</i>						
<i>T. operosus</i>	+					+
<i>T. pappi</i>						
<i>T. simplex</i>					+	+

Table 3 (cont.)

Atlantic Ocean	Mississippi (Yazoo Formation)	California	Texas	West Indies and Mexico	Pacific Ocean	Stratigraphic Range
	+	+		+		U. Eocene M. Eocene—U. Eocene L. Eocene U. Eocene L. Eocene U. Eocene Eocene U. Eocene M. Eocene L. Eocene L. Eocene M. Eocene U. Eocene L. Eocene L. Eocene—M. Eocene L. Eocene—M. Eocene Eocene Paleocene—L. Eocene M. Eocene U. Eocene U. Eocene U. Eocene U. Eocene L. Eocene M. Eocene—U. Eocene L. Eocene U. Eocene
		+				
				+		
				+		
		+		+		
				+		
				+		

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PLATES

PLATE I

- Fig. 1. General view of an unshadowed carbon-replica of a suspension not treated with sodium-hexametaphosphate before evaporation. Dark patches are grains of clay. Negative D 950. Approximately $\times 2,300$.
- Fig. 2. General view of a platinum shadowed carbon-replica of the same suspension as in fig. 1, but treated with sodium-hexametaphosphate to dissolve the particles of clay and other silicate particles. Negative E 330. Approximately $\times 2,000$.
- Fig. 3. Electronmicrograph of a fragment to show the effect of double shadowing, one with platinum at a low angle and the other with carbon at a high angle, to achieve a better three dimensional effect. $\times 5,000$
- Fig. 4. Transmission electronmicrograph of *Ericsonia ovalis* BLACK, 1964, proximal view. Negative E 895. $\times 10,400$.
- Fig. 5. Photomicrograph of *Ericsonia ovalis*. Positive phase-contrast, proximal view. $\times 3,100$.
- Fig. 6. Same as fig. 5. Negative phase-contrast. $\times 3,100$.
- Fig. 7. Transmission electronmicrograph of *Ericsonia ovalis*, distal view. Negative E 471. $\times 8,800$.
- Fig. 8. Photomicrograph of *Ericsonia ovalis*. Positive phase-contrast, distal view. $\times 3,100$.
- Fig. 9. Same as fig. 8. Negative phase-contrast. $\times 3,100$.
- Fig. 10. Transmission electronmicrograph of *Ericsonia fenestrata* (DEFLANDRE and FERT) STRADNER, 1967, proximal view of a corroded specimen. Negative D 964. $\times 11,300$.
- Fig. 11. Photomicrograph of *Ericsonia fenestrata*. Positive phase-contrast, proximal view. $\times 3,100$.
- Fig. 12. Same as fig. 11. Negative phase-contrast. $\times 3,100$.

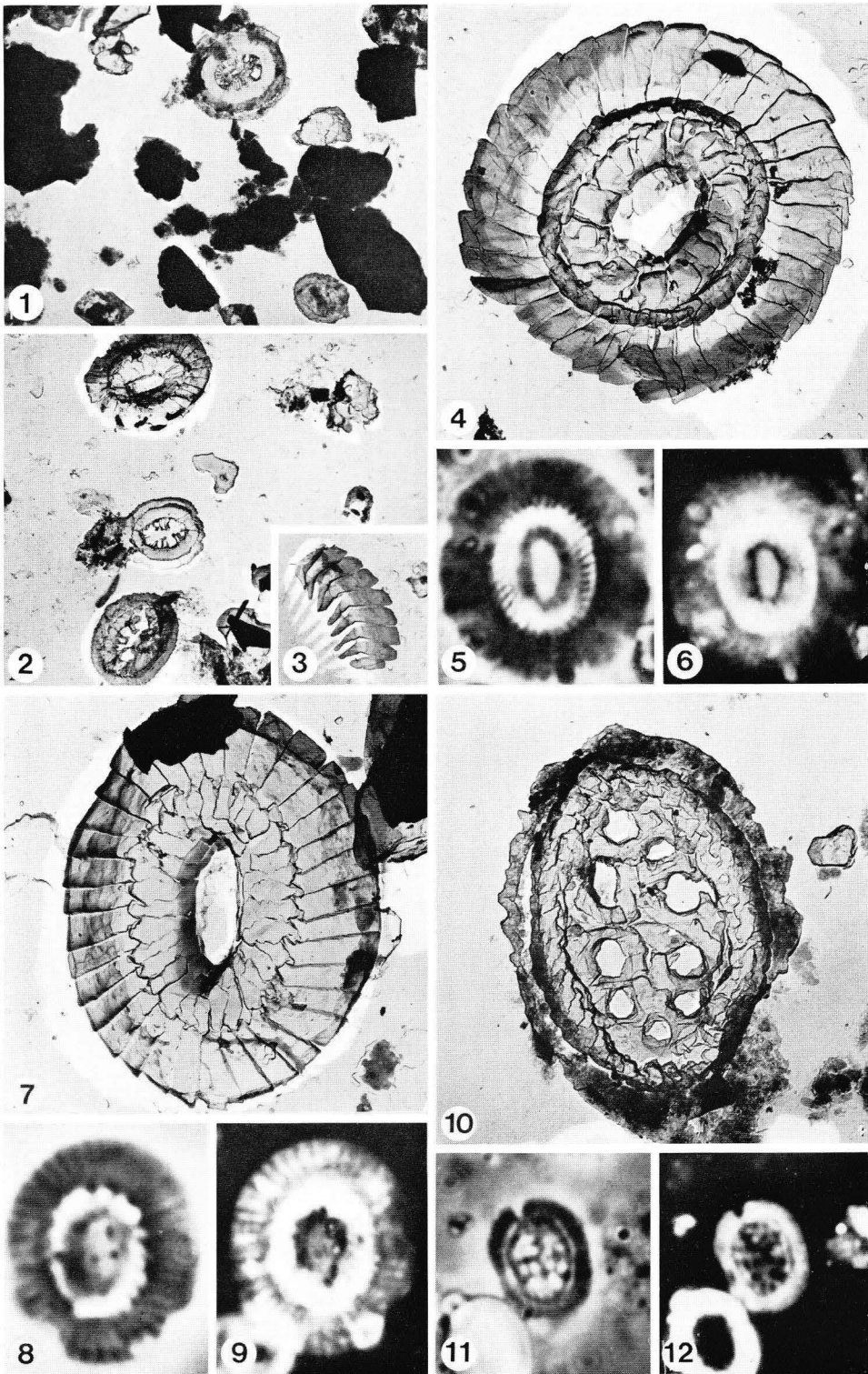


PLATE II

- Fig. 1. Scanning electronmicrograph of *Ericsonia ovalis* BLACK, 1964, distal view. Negative SM/A 15. $\times 7,600$.
- Fig. 2. Transmission electronmicrograph of *Ericsonia ovalis*, distal view. Negative E 416. $\times 8,100$.
- Fig. 3. Scanning electronmicrograph of *Ericsonia ovalis*, proximal view. Negative SM/A 23. $\times 7,000$.
- Fig. 4. Transmission electronmicrograph of *Ericsonia ovalis*, proximal view. The carbon-replica is transparent and shows the internal structure of the rings and the distal shield. Negative E 427. $\times 7,800$.
- Fig. 5. Scanning electronmicrograph of *Stradnerius dictyodus* (DEFLANDRE and FERT) HAQ, n. comb. Proximal view of a slightly broken specimen. Negative SM/AO 4. $\times 8,500$.
- Fig. 6. Transmission electronmicrograph of *Stradnerius dictyodus*. Proximal view of a slightly broken specimen. Negative E 305. $\times 7,500$.
- Fig. 7. Scanning electronmicrograph of *Stradnerius dictyodus*, n. comb. Distal view. Central area covered with a lid of crystals. Negative SM/A 17. $\times 6,700$.
- Fig. 8. Transmission electronmicrograph of *Stradnerius dictyodus*. Distal view of specimen similar to fig. 7. Negative E 907. $\times 6,600$.

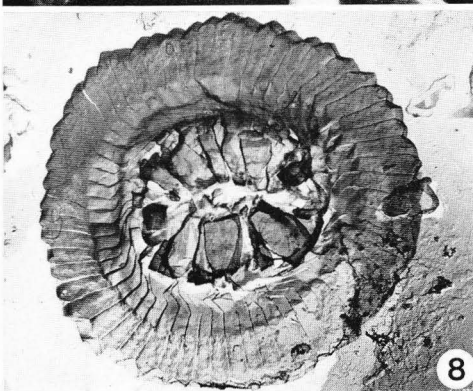
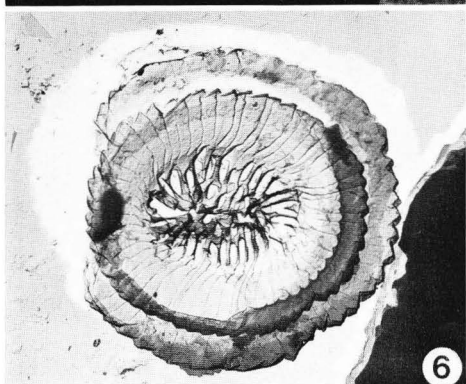
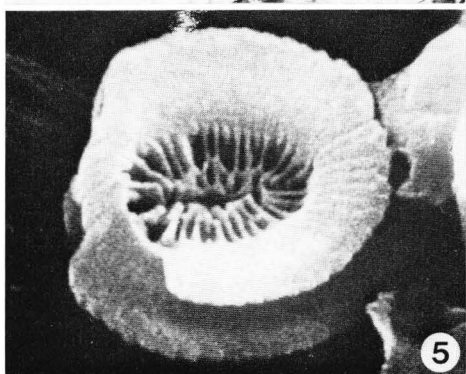
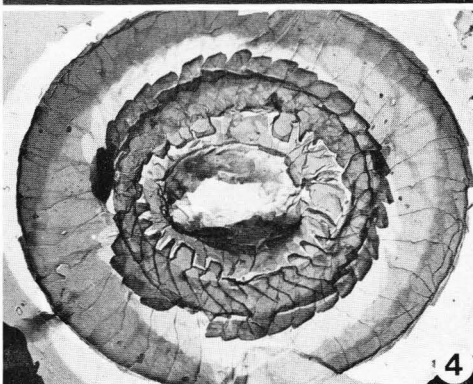
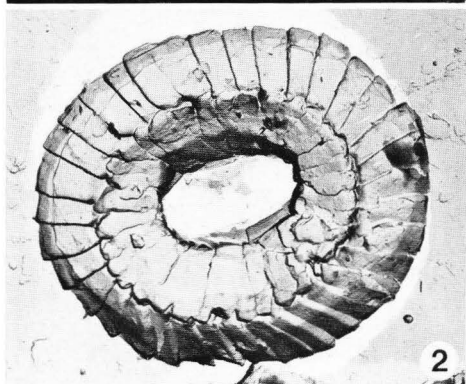
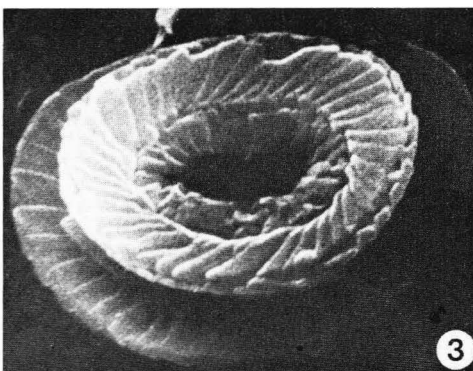
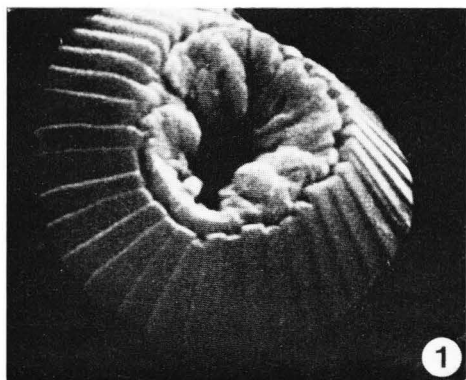


PLATE III

- Fig. 1. Transmission electronmicrograph of *Stradnerius dictyodus* (DEFLANDRE and FERT) HAQ, n. comb. Proximal view of a well preserved specimen. Negative E 908. $\times 12,600$.
- Fig. 2. Transmission electronmicrograph of *Stradnerius dictyodus*, n. comb. Proximal view, showing the vertical septa extending from each crystal-ray into the centre. Negative E 973. $\times 6,600$.
- Fig. 3. Transmission electronmicrograph of the central area of *Reticulofenestra placomorpha* (KAMPTNER) STRADNER, 1967. Proximal view, for comparison with the central area of *Stradnerius dictyodus*. Negative E 545. $\times 11,200$.
- Fig. 4. Transmission electronmicrograph of *Stradnerius dictyodus*, n. comb. Distal view. Central area covered with a lid of crystals. Negative E 313. $\times 7,500$.
- Fig. 5. Photomicrograph of *Stradnerius dictyodus*. Positive phase-contrast, distal view; same as fig. 4. $\times 3,100$.
- Fig. 6. Same as fig. 5. Negative phase-contrast.
- Fig. 7. Scanning electronmicrograph of *Stradnerius dictyodus*, n. comb. Distal view of a specimen in which the central area is surrounded by a ring of crystals. Negative SM/A 30. $\times 8,100$.
- Fig. 8. Transmission electronmicrograph of *Stradnerius dictyodus*. Distal view of a specimen similar to fig. 7. Negative E 306. $\times 6,900$.

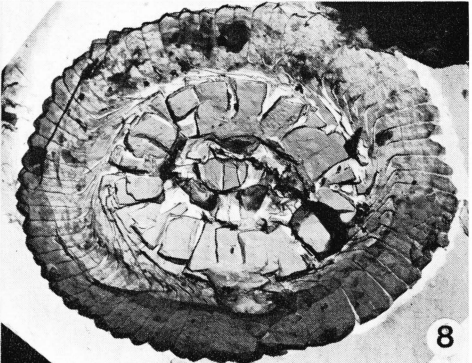
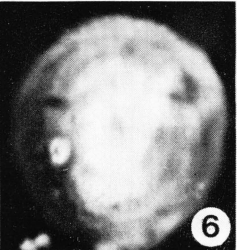
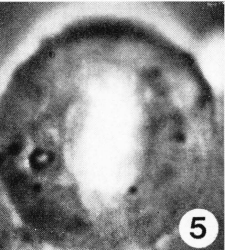
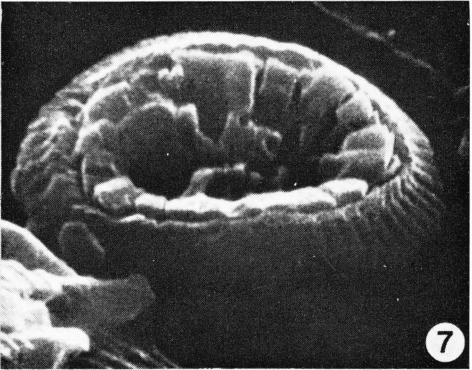
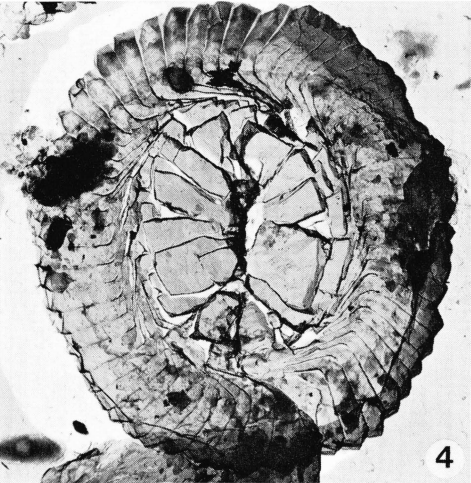
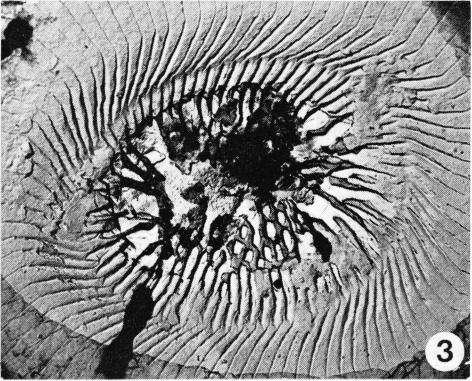
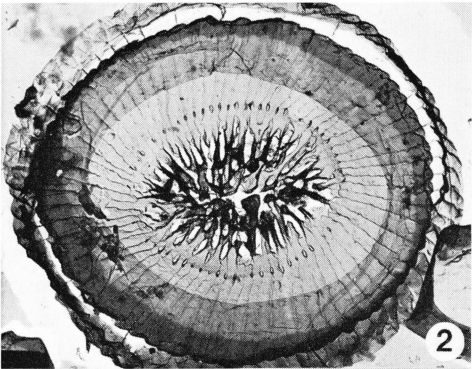


PLATE IV

- Fig. 1. Scanning electronmicrograph of a corroded specimen of *Ericsonia ovalis* BLACK, 1964, showing the innermost ring of the proximal side to be a derivate of the distal shield and the ring of the distal shield to be derived from the second ring of the proximal side. Negative SM/B 22. $\times 11,500$.
- Fig. 2. Scanning electronmicrograph of *Ericsonia ovalis*, confirming observations made in fig. 1. Negative SM/A34. $\times 14,200$.
- Fig. 3. Scanning electronmicrograph of *Stradnerius dictyodus* (DEFLANDRE and FERT) HAQ, n. comb. Proximal view of a specimen with a well preserved central area. Negative SM/B 32. $\times 9,600$.
- Fig. 4. Scanning electronmicrograph of *Stradnerius daviesi* HAQ, n. sp., proximal view. Holotype negative SM/B 33. $\times 8,200$.
- Fig. 5. Scanning electronmicrograph of *Stradnerius daviesi*, distal view. Negative SM/B 14. $\times 9,100$.
- Fig. 6. Scanning electronmicrograph of *Stradnerius dictyodus*, n. comb., proximal view. Negative SM/B 40. $\times 10,000$.
- Fig. 7. Scanning electronmicrograph of *Cycloplacolithella blacki* HAQ, n. sp., distal view of a partly covered specimen. Negative SM/B 36. Approximately $\times 9,100$.
- Fig. 8. Scanning electronmicrograph of *Cycloplacolithella blacki*, proximal view. Holotype negative SM/B 18. $\times 8,200$.
- Fig. 9. Scanning electronmicrograph of *Cycloplacolithella blacki*, distal view. Negative SM/B 20. $\times 10,000$.

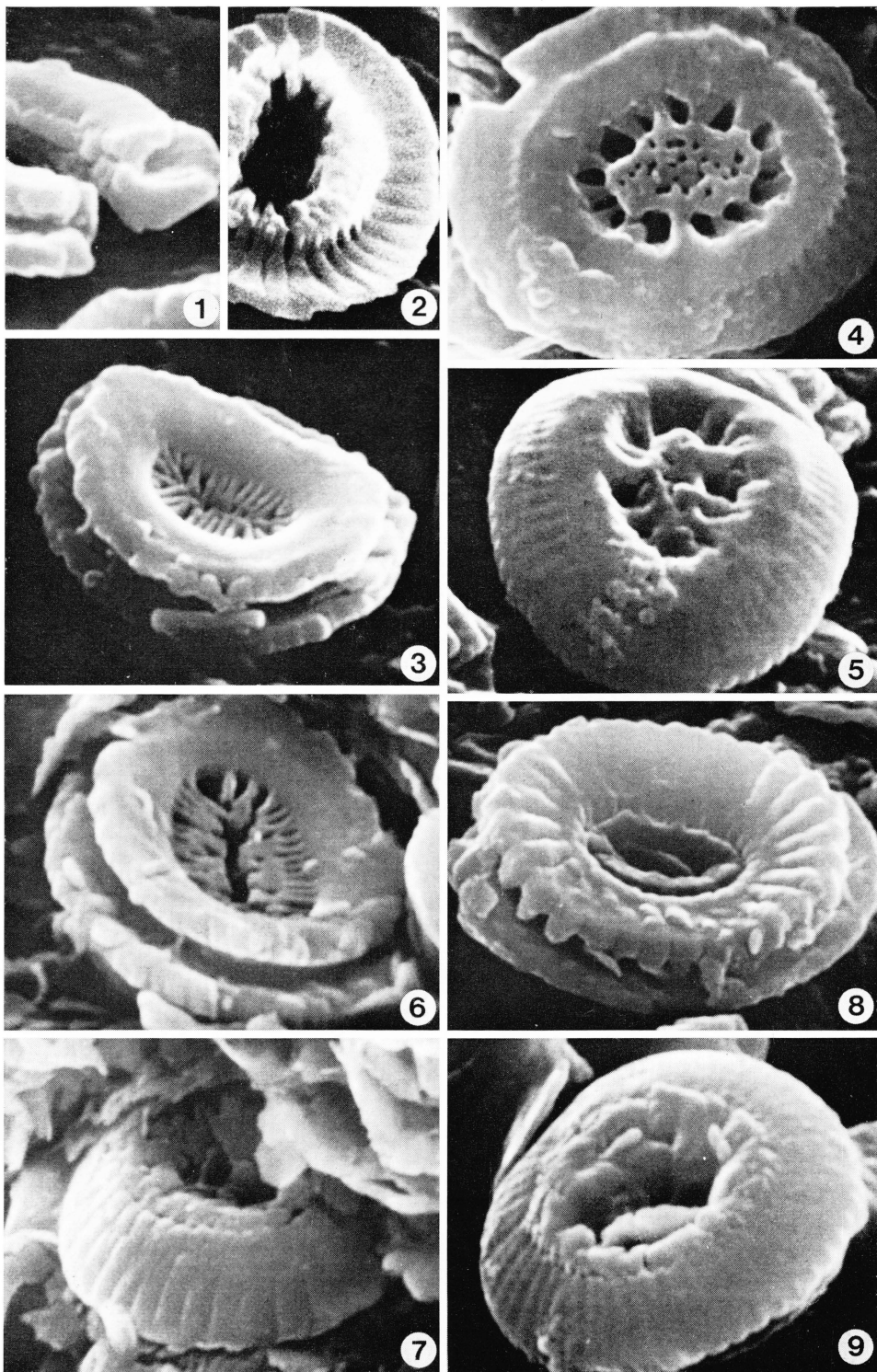


PLATE V

- Fig. 1. Transmission electronmicrograph of *Reticulofenestra placomorpha* (KAMPTNER) STRADNER, 1967. Proximal view of a specimen with central reticulate membrane partly preserved. Negative E 411. $\times 8,300$.
- Fig. 2. Transmission electronmicrograph of *Reticulofenestra placomorpha*. Distal view with central reticulate pattern completely broken away. Negative E 536. $\times 5,100$.
- Fig. 3. Scanning electronmicrograph of *Reticulofenestra placomorpha*, showing the central reticulate pattern. Negative SM/AO 3. $\times 6,000$.
- Fig. 4. Transmission electronmicrograph of *Reticulofenestra placomorpha*. Proximal view with part of the central reticulate membrane present. Negative E 335. Ca $\times 6,600$.
- Fig. 5. Scanning electronmicrograph of *Reticulofenestra placomorpha*. Distal view with reticulate membrane missing, showing the relative depth of the central tube. Negative SM/A 24. $\times 5,900$.
- Fig. 6. Transmission electronmicrograph of a highly magnified fragment of *Reticulofenestra oamaruensis* (DEFLANDRE) STRADNER, 1967, showing rows of numerous triangular pores. Negative E 465. $\times 12,900$.
- Fig. 7. Photomicrograph of *Reticulofenestra oamaruensis*. Normal light; proximal view. $\times 3,100$.
- Fig. 8. Same as fig. 7. Crossed nicols.

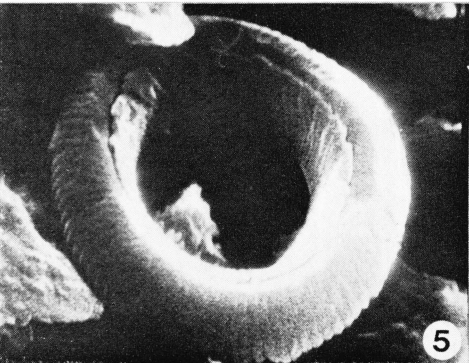
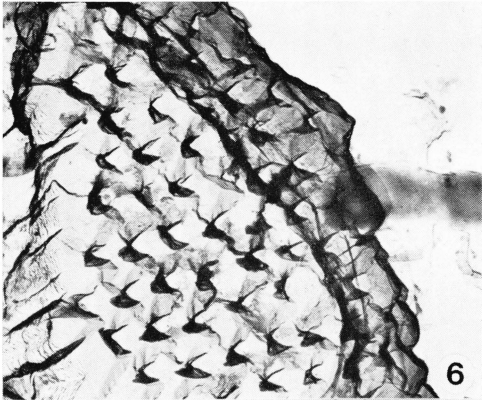
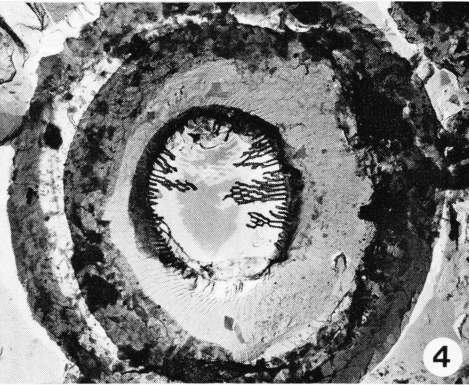
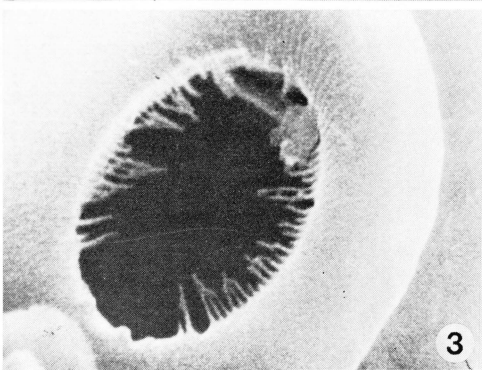
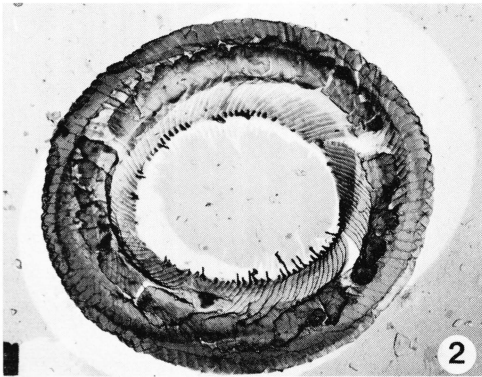


PLATE VI

- Fig. 1. Transmission electronmicrograph of a well preserved specimen of *Coccolithus perforatus* HAQ, n. sp., proximal view. Holotype negative E 337. $\times 10,300$.
- Fig. 2. Transmission electronmicrograph of *Coccolithus perforatus*, proximal view. Paratype negative E 276. $\times 8,200$.
- Fig. 3. Transmission electronmicrograph of *Coccolithus perforatus*, proximal view. Negative E 464. $\times 7,500$.
- Fig. 4. Transmission electronmicrograph of *Discolithina multipora* (KAMPTNER) MARTINI, 1965, distal view. Negative D 931. $\times 7,800$.
- Fig. 5. Photomicrograph of *Discolithina multipora*. Positive phase-contrast, probably proximal view. $\times 3,100$.
- Fig. 6. Same as fig. 5. Negative phase-contrast.
- Fig. 7. Transmission electronmicrograph of *Discolithina multipora*, distal view. The kind of specimen pictured here was formerly known as *Discolithina vigintiforata* (KAMPTNER) LOEBLICH and TAPPAN, 1963, but is now considered only a variety of *D. multipora*. Negative E 986. $\times 10,700$.
- Fig. 8. Photomicrograph of *Discolithina multipora* ex *Discolithina vigintiforata*. Positive phase-contrast, distal view. $\times 3,100$.
- Fig. 9. Same as fig. 8. Negative phase-contrast.

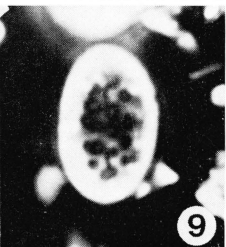
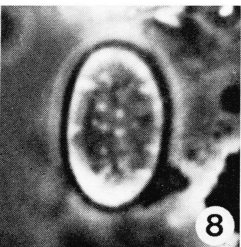
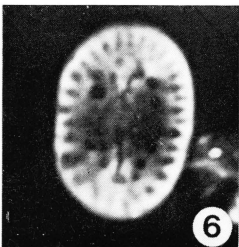
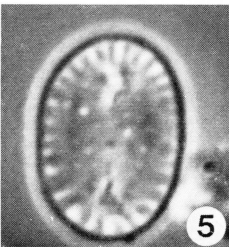
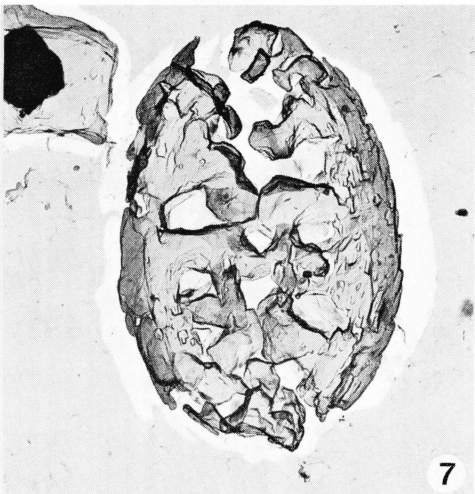
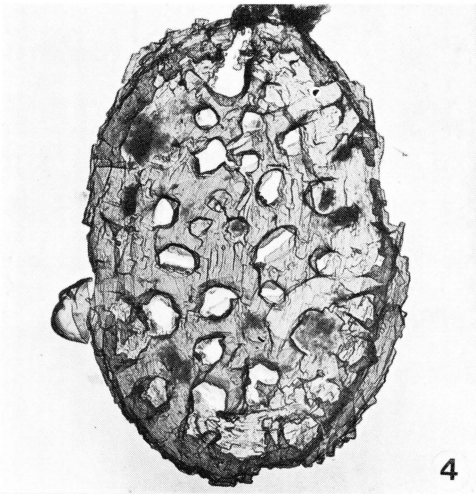
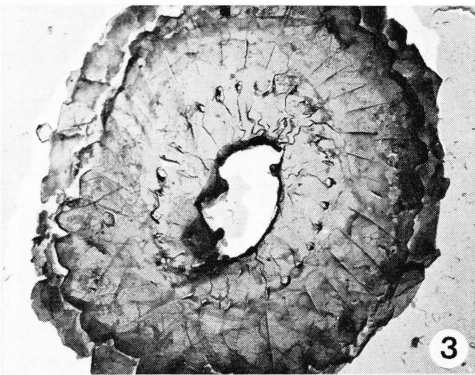
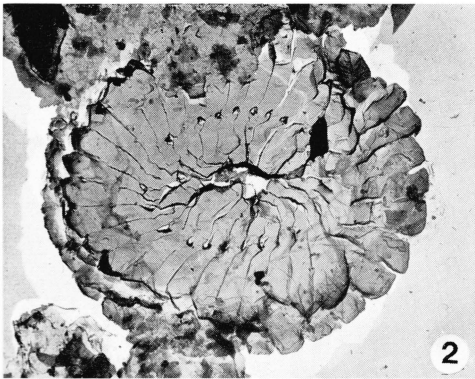
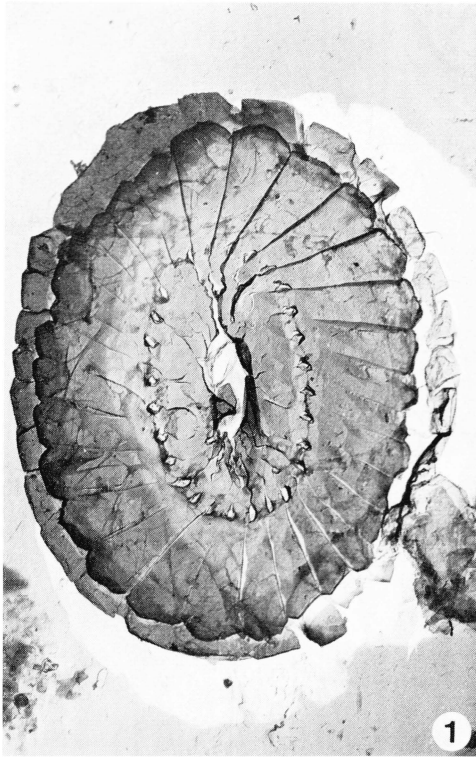


PLATE VII

- Fig. 1. Transmission electronmicrograph of *Discolithina pulcheroides* (SULLIVAN) STRADNER, 1967, distal view. Negative E 540. Approximately $\times 8,200$.
- Fig. 2. Photomicrograph of *Discolithina pulcheroides*. Positive phase-contrast, distal view. $\times 3,100$.
- Fig. 3. Same as fig. 2. Negative phase-contrast.
- Fig. 4. Transmission electronmicrograph of *Discolithina obliquipons* (DEFLANDRE) STRADNER, 1967 of an unshadowed carbon-replica, distal view. Negative D 989. $\times 8,800$.
- Fig. 5. Photomicrograph of *Discolithina obliquipons*. Positive phase-contrast, distal view. $\times 3,100$.
- Fig. 6. Same as fig. 5. Negative phase-contrast.
- Fig. 7. Transmission electronmicrograph of *Discolithina rectipons* HAQ, n. sp., distal view. Holotype negative E 461. $\times 8,800$.
- Fig. 8. Photomicrograph of *Discolithina rectipons*. Positive phase-contrast, distal view. $\times 3,100$.
- Fig. 9. Same as fig. 8. Negative phase-contrast.
- Fig. 10. Photomicrograph of *Zygrhablithus bijugatus* (DEFLANDRE) DEFLANDRE, 1959. Axial view, polarized light. $\times 3,100$.
- Fig. 11. Transmission electronmicrograph of a single crystal of *Micrantholithus vesper* DEFLANDRE, 1954. Negative E 988. $\times 9,400$.
- Fig. 12. Transmission electronmicrograph of *Marthasterites* cf. *tribrachiatatus* (BRAMLETTE and RIEDEL) DEFLANDRE, 1959. Negative E 967. $\times 6,300$.

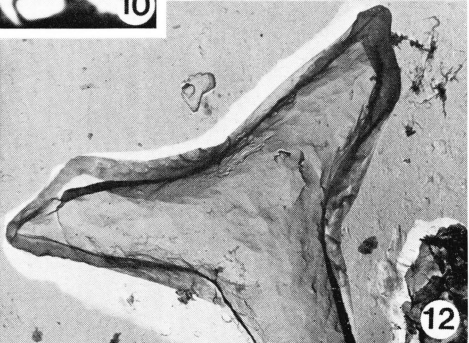
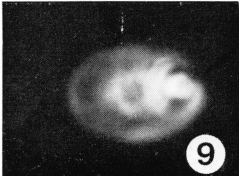
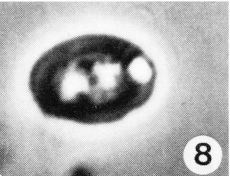
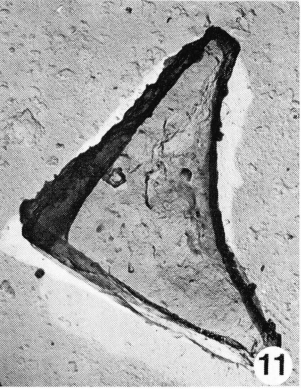
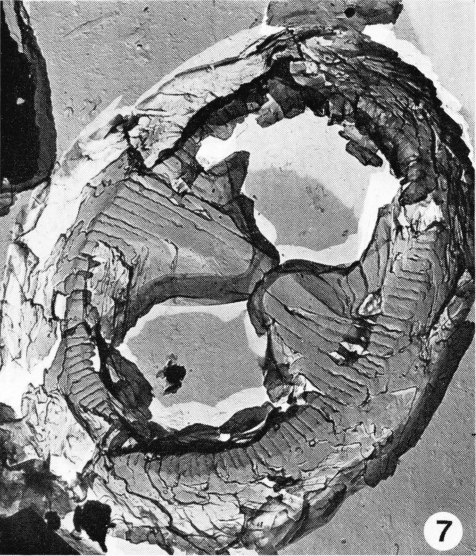
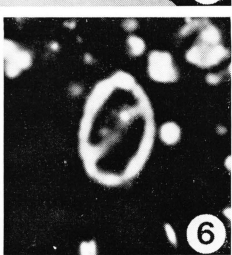
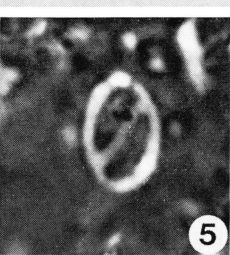
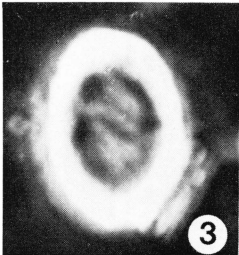
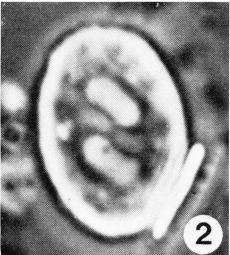
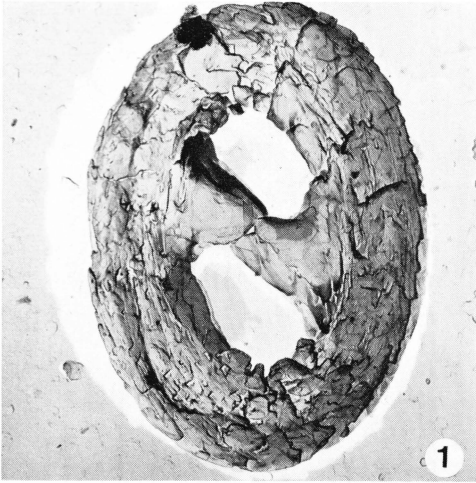


PLATE VIII

- Fig. 1. Transmission electronmicrograph of *Cyclococcolithus inversus* (DEFLANDRE) HAY, MOHLER and WADE, 1966. Proximal view of a specimen with proximal shield almost completely broken away. Negative E 982. $\times 6,900$.
- Fig. 2. Transmission electronmicrograph of a juvenile form of (?) *Cyclococcolithus inversus*, distal view. Negative E 984. $\times 8,200$.
- Fig. 3. Transmission electronmicrograph of *Cyclolithella inflexa* (KAMPTNER) LOEBLICH and TAPPAN, 1963. Probably distal view. Negative EO 36. $\times 7,500$.
- Fig. 4. Photomicrograph of *Cyclolithella inflexa*. Positive phase-contrast. $\times 3,100$.
- Fig. 5. Same as fig. 4. Negative phase-contrast.
- Fig. 6. Transmission electronmicrograph of *Rotalithus teutonicus* HAQ, n. gen., n. sp., distal view. Holotype negative E 459. $\times 7,800$.
- Fig. 7. Transmission electronmicrograph of *Rotalithus teutonicus*. Proximal view of partly corroded specimen. Negative E 302. $\times 10,300$.
- Fig. 8. Transmission electronmicrograph of *Cycloplacolithella simplex* HAQ, n. gen., n. sp., proximal view. Negative E 326. $\times 10,300$.
- Fig. 9. Photomicrograph of *Cycloplacolithella simplex*. Positive phase-contrast, proximal view. $\times 3,100$.
- Fig. 10. Same as fig. 9. Negative phase-contrast.

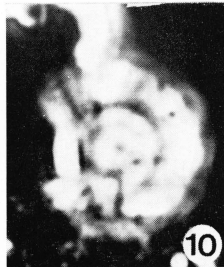
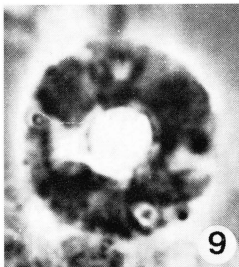
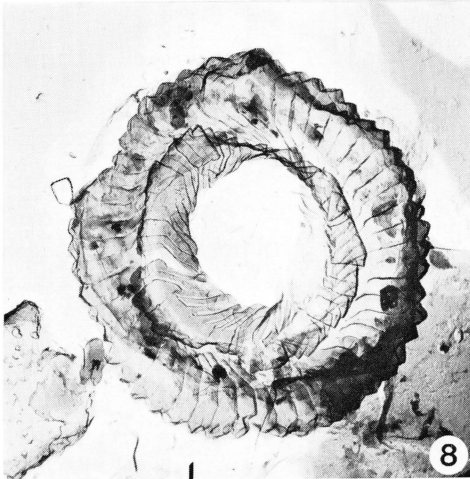
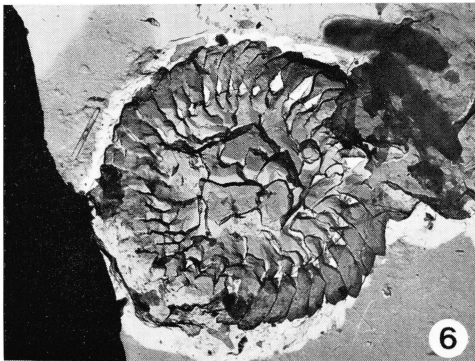
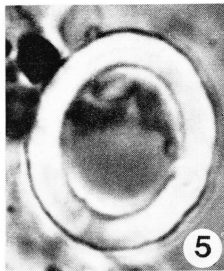
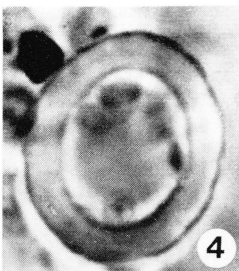
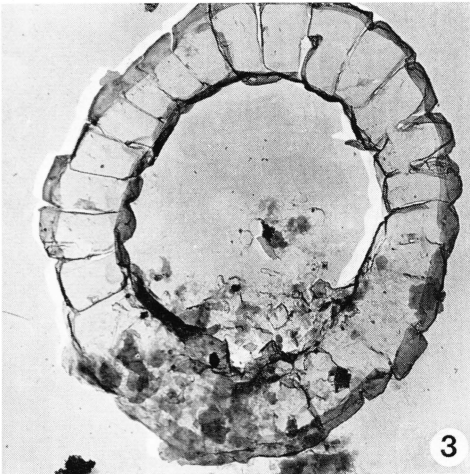
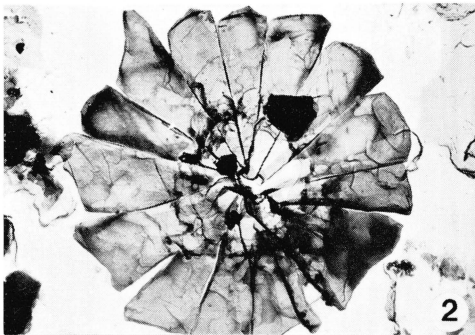
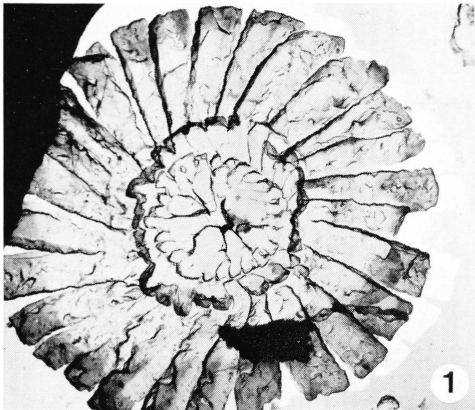


PLATE IX

- Fig. 1. Scanning electronmicrograph of *Isthmolithus recurvus* DEFLANDRE, 1954. Top view of partly broken specimen. Negative SM/B 27. $\times 8,200$.
- Fig. 2. Scanning electronmicrograph of *Isthmolithus recurvus*. Top view of specimen with one longitudinal wall broken off. Negative SM/A 33. $\times 7,500$.
- Fig. 3. Transmission electronmicrograph of *Isthmolithus recurvus*, top view. Negative E 543. $\times 7,800$.
- Figs. 4—5. Phase-contrast micrographs of *Isthmolithus recurvus*, side view. Fig. 4, positive. Fig. 5, negative. $\times 3,100$.
- Figs. 6—7. Phase-contrast micrographs of *Isthmolithus recurvus*, top view. Fig. 6, positive. Fig. 7, negative. $\times 3,100$.
- Fig. 8. Transmission electronmicrograph of *Rhabdosphaera recta* (DEFLANDRE). Axial view of a specimen in which the outer ring of the basal shield is completely broken away. Negative E 898. $\times 12,300$.
- Fig. 9. Transmission electronmicrograph of an unshadowed carbon-replica of *Microrhabdulus* sp. Negative D 962. $\times 7,400$.
- Fig. 10. Transmission electronmicrograph of a side view of *Zygrhablithus bijugatus* (DEFLANDRE) DEFLANDRE, 1959, part of test broken away. Negative E 903. $\times 10,000$.
- Fig. 11. Transmission electronmicrograph of *Zygrhablithus bijugatus*. Side view of a similar specimen as fig. 10. Negative E 949. $\times 7,800$.

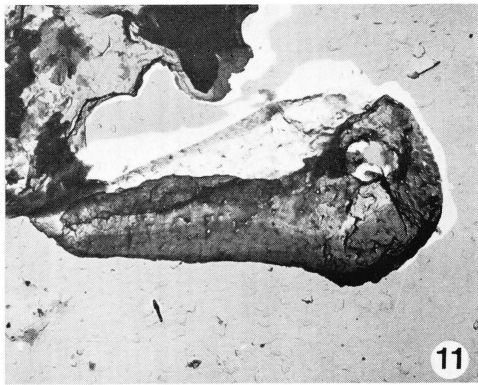
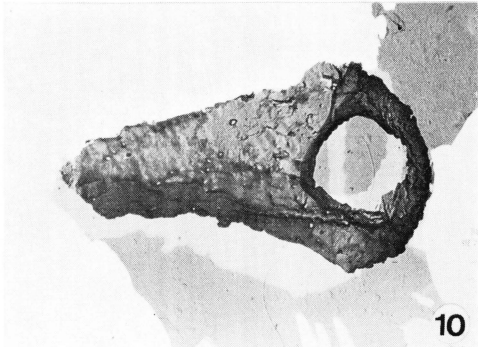
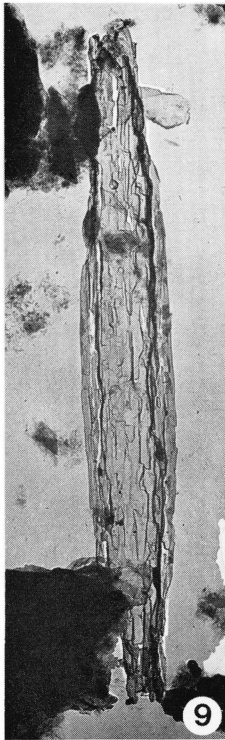
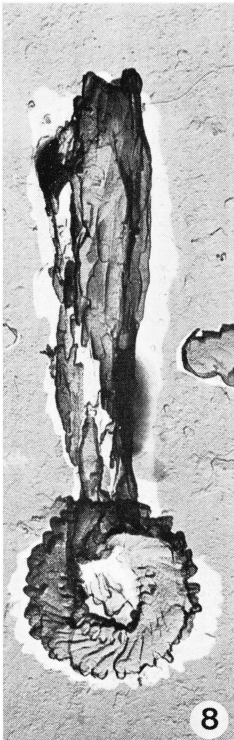
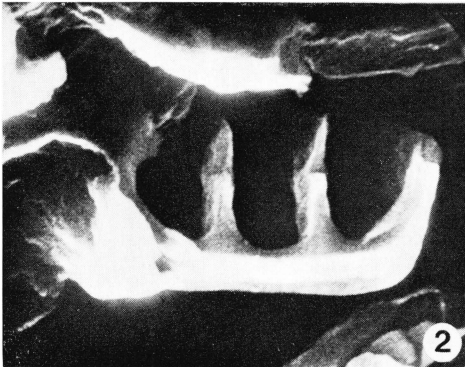
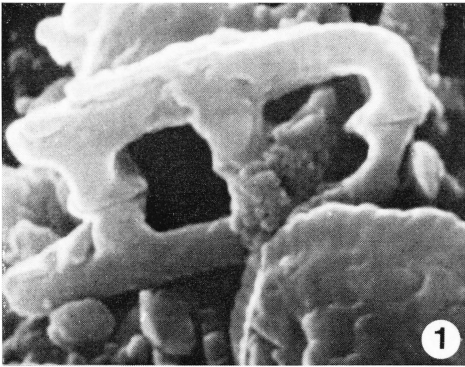


PLATE X

- Fig. 1. Transmission electronmicrograph of *Thoracosphaera deflandrei* KAMPTNER, 1956. Almost complete specimen. Negative E 457. $\times 6,900$.
- Fig. 2. Transmission electronmicrograph of a highly magnified fragment of *Thoracosphaera deflandrei*, showing the mosaic of irregularly shaped but almost equi-dimensional crystals. Negative E 902. $\times 17,300$.
- Fig. 3. Transmission electronmicrograph of *Tessellatolithus dentatus* HAQ, n. gen., n. sp. Holotype negative E 981. Approximately $\times 6,100$.
- Fig. 4. Transmission electronmicrograph of a highly magnified fragment of *Tessellatolithus dentatus*, showing the dentate outlines of the mosaic crystals. Negative E 546. $\times 9,400$.
- Fig. 5. Transmission electronmicrograph of *Discoaster multiradiatus* BRAMLETTE and RIEDEL, 1954. Specimen partly corroded. Negative EO 35. Approximately $\times 6,600$.
- Fig. 6. Transmission electronmicrograph of *Discoasteroides kuepperi* (STRADNER) BRAMLETTE and SULLIVAN, 1961, showing the heliolithic stem remnant. Negative E 962. $\times 7,700$.
- Fig. 7. Scanning electronmicrograph of *Discoaster tani nodifer* BRAMLETTE and RIEDEL, 1954, laevogyra view. Negative SM/A 27. $\times 4,400$.
- Fig. 8. Scanning electronmicrograph of (?) *Discolithina macropora* (DEFLANDRE), 1954, distal view. Negative SM/BO 2. $\times 6,600$.

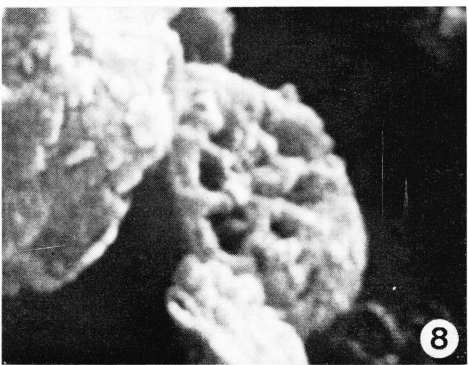
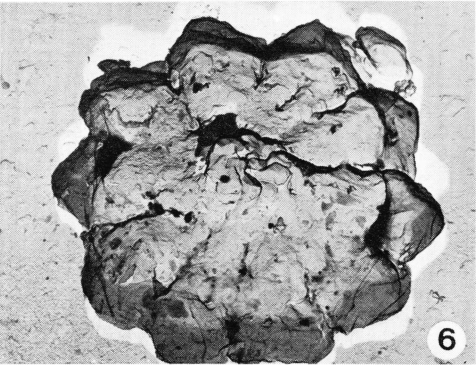
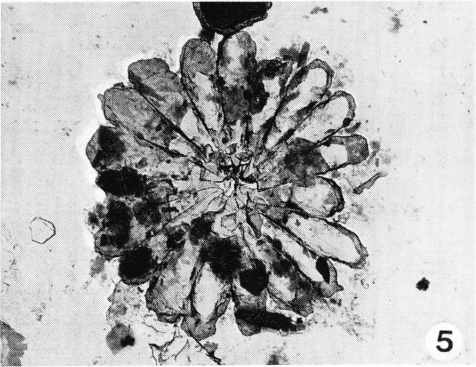
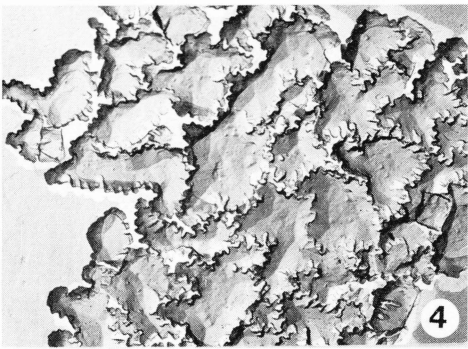
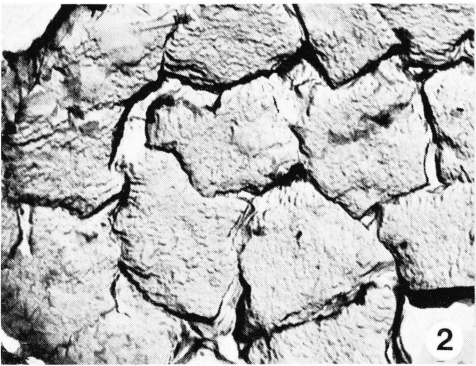
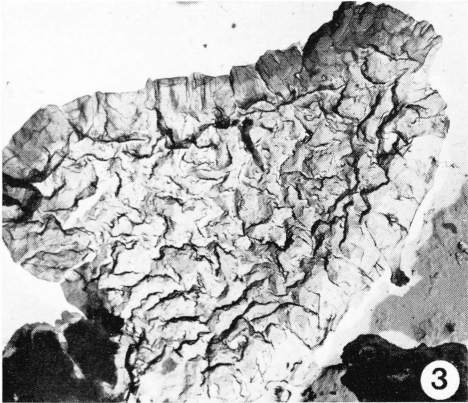
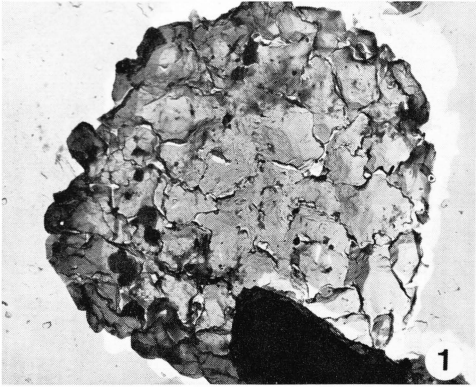


PLATE XI

- Fig. 1. Scanning electronmicrograph of *Discolithina rectipons* HAQ, n. sp., distal view. Negative SM/B 39. $\times 12,800$.
- Fig. 2. Scanning electronmicrograph of *Discolithina obliquipons* (DEFLANDRE) STRADNER, 1967, proximal view. Negative SM/B 16. $\times 9,100$.
- Figs. 3—4. Phase-contrast photomicrographs of *Braarudosphaera bigelowi* (GRAN and BRAARUD) DEFLANDRE, 1947. Fig. 3, positive phase-contrast; Fig. 4, negative phase-contrast. $\times 3,100$.
- Figs. 5—6. Phase-contrast photomicrographs of *Braarudosphaera* sp. Fig. 5, positive phase-contrast; Fig. 6, negative phase-contrast. $\times 3,100$.
- Figs. 7—8. Phase-contrast photomicrographs of *Trochoaster simplex* KLUMPP, 1953. Fig. 7, positive phase-contrast; Fig. 8, negative phase-contrast. $\times 3,100$.
- Figs. 9—10. Photomicrographs of *Rhabdosphaera* sp. Fig. 9, positive phase-contrast; Fig. 10, negative phase-contrast. $\times 3,100$.
- Figs. 11—12. Photomicrographs of *Discolithina macropora* (DEFLANDRE). Fig. 11, positive phase-contrast; Fig. 12, negative phase-contrast. $\times 3,100$.
- Fig. 13. Photomicrograph of *Deflandrius* sp., crossed nicols. $\times 3,200$.
- Fig. 14. Photomicrograph of *Cretarhabdus* sp., negative phase-contrast. $\times 3,100$.
- Figs. 15—16. Photomicrograph of *Rhabdosphaera* sp. Fig. 15, positive phase-contrast; Fig. 16, negative phase-contrast. $\times 3,100$.
- Figs. 17—18. Photomicrograph of *Rhabdosphaera recta* (DEFLANDRE), axial view. Fig. 17, positive phase-contrast; Fig. 18, negative phase-contrast. $\times 3,100$.
- Fig. 19. Photomicrograph of *Rhabdosphaera perlonga* (DEFLANDRE) BRAMLETTE and SULLIVAN, 1961. Axial view, negative phase-contrast. $\times 3,100$.

