LEIDSE GEOLOGISCHE MEDEDELINGEN, Deel. 35 blz. 1-44, separate published 1-9-1965

COCCOLITHS AND DISCOASTERS FROM ADRIATIC BOTTOM SEDIMENTS

BY

C. L. D. COHEN [1]

CONTENTS

[1] Geological Institute of the University of Groningen, The Netherlands.

ABSTRACT

The presence of coccoliths and discoasters in Adriatic bottom sediments is established. Both recent and fossil or allochthonous forms can be distinguished. The grab samples are located in sections across the sea.

A consistent decrease of land-derived forms and an increase of recent forms can be observed in the composition of the species in the samples at increasing distances from the Italian coast. It is thought that these land derived forms are allochthonous, originating from the mountains of the Italian peninsula and brought down by rivers to the sea-shore from where they were swept out to the open sea by currents. These forms are indicative of Upper Cretaceous and Tertiary sediments and many are shown in polarized light to be in a recrystallized state. The supply of material from the eastern or Yugoslavian side of the sea turned out to be negligible.

A relation was found between the composition of the samples and the pattern of sea currents.

It was concluded, however, that their strong tendency to be reworked resulting from easy transportation over great distances, together with their little effect of solution, must be considered a serious drawback in stratigraphic use. As a result the reworked forms can not easily be distinguished from those in situ.

The study further includes a systematic description of some of the more common forms. The techniques used are shortly mentioned and the technical difficulties when using both light and electron microscopes are briefly discussed.

INTRODUCTION

As part of an extensive geological investigation of the Adriatic by staff members of the Geological Institute of the University of Groningen, a number of grab samples were examined as to their content of coccoliths and discoasters.

The samples were collected during an expedition in the summer of 1962 with the Italian fishing boat "Nuovo San Pio" and the "Horizon" of Scripps Institution of Oceanography at La Jolla, California, U.S.A.

A total of 39 samples were selected for the present purpose. Although the amount of clastic material was considerable (especially in samples from locations near the Italian coast), the organic part of the fine fraction contained abundant coccoliths and discoasters. Besides, diatoms and a few silicoflagellates were found.

A great number of coccoliths and discoasters belonging to many different species were counted in each sample. The data are combined in a table (see table I) which demonstrates the differences in composition of the samples. A systematic description of the most characteristic species is included in this report.

ACKNOWLEDGEMENTS

The author is greatly indebted to Prof. Ph. H. Kuenen, director of the Geological Institute of the University of Groningen, The Netherlands, for giving the opportunity to do this investigation; his critical remarks are also gratefully acknowledged here. He wished to extend his sincere thanks also to Mr. B. J. Spit, Technical Physics Department of T.N.O. & T.H., Stieltjesweg 1, Delft, The Netherlands, and his assistants fot their dedication to provide the author with a great number of electron micrographs of excellent quality.

Prof. G. Deflandre of the Laboratoire de Micropaléontologie in Paris was so kind to place his card-system at the disposal of the author; his valuable advice with respect to the identification of some forms is gratefully acknowledged here. The author is grateful to Prof. L. M. J. U. van Straaten of the Geological Institute of the University of Groningen, for providing the bottom samples and to Prof. J. R. van der Fliert and Mrs. Prof. E. Gallitelli, respectively connected with the Free University of Amsterdam (The Netherlands) and the University of Modena (Italy) for providing the author with a great number of land samples from Italy. A grant from Shell Oil helped to finance the work and is gratefully acknowledged.

NATURE OF COCCOLITHS AND DISCOASTERS

Coccoliths are the calcareous plates covering the cell of the Coccolithophoridae. The Coccolithophoridae are planktonic unicellular algae, which have calcareous skeletal elements, the coccoliths. These are embedded in or located on the hyaline membrane around the cell, the cell surface. They are circular or elliptical in plan view, but they can also be trumpet-like or have the form of a bar located on a basal plate. Their size ranges generally from 1 to 11 microns. The size of the complete form having many coccoliths on the cell surface ranges generally from 5 to 35 microns.

After death the cell-wall desintegrates and the plates sink individually down through the water column to the bottom contributing to a large extent to the formation of the bottom sediment. Modern oozes, like Globigerina- and pteropod ooze have been found to consist for a large part of these tiny plates. They have also been found to form a large integral part in a variety of ancient marine sediments, some as old as the Jurassic.

The living plants have been grouped into families and genera mainly on the basis of the structure of their coccoliths. The fossil coccoliths are nearly always found as isolated lime-bodies. They can not be related in the majority of cases to living genera or species. Because each coccolith forms only a small part of the cell surface around the organism, taxonomy can not be done according to a natural system. An artificial system of form genera and higher categories has to be used purely based on the morphology.

The Coccolithophoridae are nearly exclusively marine and have been found in all seas and oceans; however, there seems to be a preference for the warmer waters of low latitudes. It was found further, that in Lower Tertiary marine sediments of California with abundant calcareous nannoplankton, the sea depths of the depositional environment was not necessarily bathyal or abyssal, but of various depths ranging from littoral to abyssal; this was deduced from enclosed benthonic foraminifers and mollusks (Sullivan, 1965, p. 17).

The discoasters are related forms. These star or rosette-like lime-bodies form probably the skeletal elements of organisms, which are largely if not completely extinct. As yet they have never been found as an integral part of a fossil or living organism. Their systematic position is therefore uncertain. They are primarily found in ancient marine sediments, in particular Tertiary.

TECHNIQUES OF INVESTIGATION

The samples which have been stored in air-tight plastic bags for more than a year, desintegrated easily in distilled water. A few drops of the suspension were brought on a microscope slide and dried. Three hundred specimens were identified in each sample. Their numbers are given in table I.

A Zeiss standard polarization microscope has been used for this study. The slides were examined with a magnification of 1200×. Both ordinary and polarized light were used; also phase-contrast illumination. The photographs, made with a Zeiss camera with an Agfa 35 mm Agepan film mounted on the microscope, turned out to be good. Some samples were also studied with a Philips 100 kV electron microscope. A great number of electron micrographs were made using the carbon replica technique. A short résumé of this technique will follow next (communicated by Mr. B. Spit).

"A small quantity of the sample was treated with 30 % hydrogenperoxyde in order to oxidize the organic parts and to clean the coccoliths from small clay particles; it was expected that in this way it would prove easier to bring them into suspension. This treatment was done on a water bath at about 95°C for 30—45 minutes.

The samples were suspended, using ultrasonics (40 kHz) and centrifuged several times in distilled water in order to get rid of the H_2O_2. Aceton was used to remove any fatty material.

The larger particles were removed next by wet sedimentation for ½—1 minute. The finest particles (less than 1 μ) were removed by settling for a period of 17 hours, after which the fluid above the sediment was poured off. The sediment was suspended again and spread evenly on a warm microscope slide.

After drying, a replica was made using the following technique:

(1) the sediment was shadowed with platinum under an angle of 60°;

(2) a thin film of carbon (ca. 500 Å) was deposited;

(3) a great number of squares (3×3 mm) were cut;

(4) the carbon with the sediment was removed from the slide using ± 5 % hydrofluoric acid;

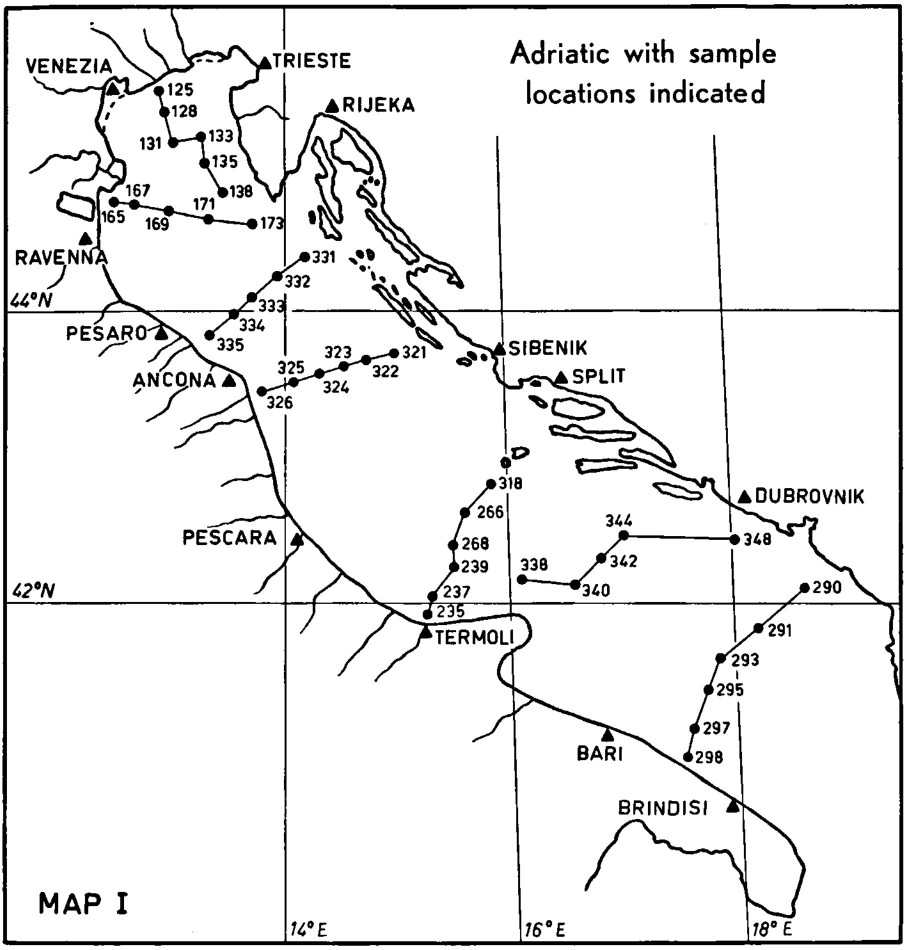
(5) the particles on the film were dissolved in 40 % hydrofluoric acid and 10 % hydrochloric acid; the first was used to dissolve the clay minerals and other silicates, the second to remove the calcitic coccoliths;

(6) after washing with distilled water, the squares were picked up on an electron microscope support screen for viewing.

The above mentioned treatment gave a better result for the samples from locations, far from the coast, than for those taken closer in-shore; evidently the first group contained much fine clay, while the in-shore samples left a nearly clear fluid above the sediment after the period of long sedimentation, which points to the absence of ultrafine material. The samples 291, 295 and 298 have been treated in this way. Many electron micrographs were made; among these stereoscopic pairs. Sample no. 165 contained very few coccoliths and no pictures could be made of this sample.

The photographs are so-called positive prints. These have been made from a rephotographed film, resulting in a dark shadow; in this way a more plastic image was obtained".

For the present investigation seven cross-sections, each consisting of five or six bottom samples, were selected from a total 360 samples. These cross-sections, which are shown on map I, were chosen, because it was supposed to be the most simple way to demonstrate any variation in regional distribution of the coccoliths and discoasters in the surface layer of the bottom sediment. As a result, differences in the

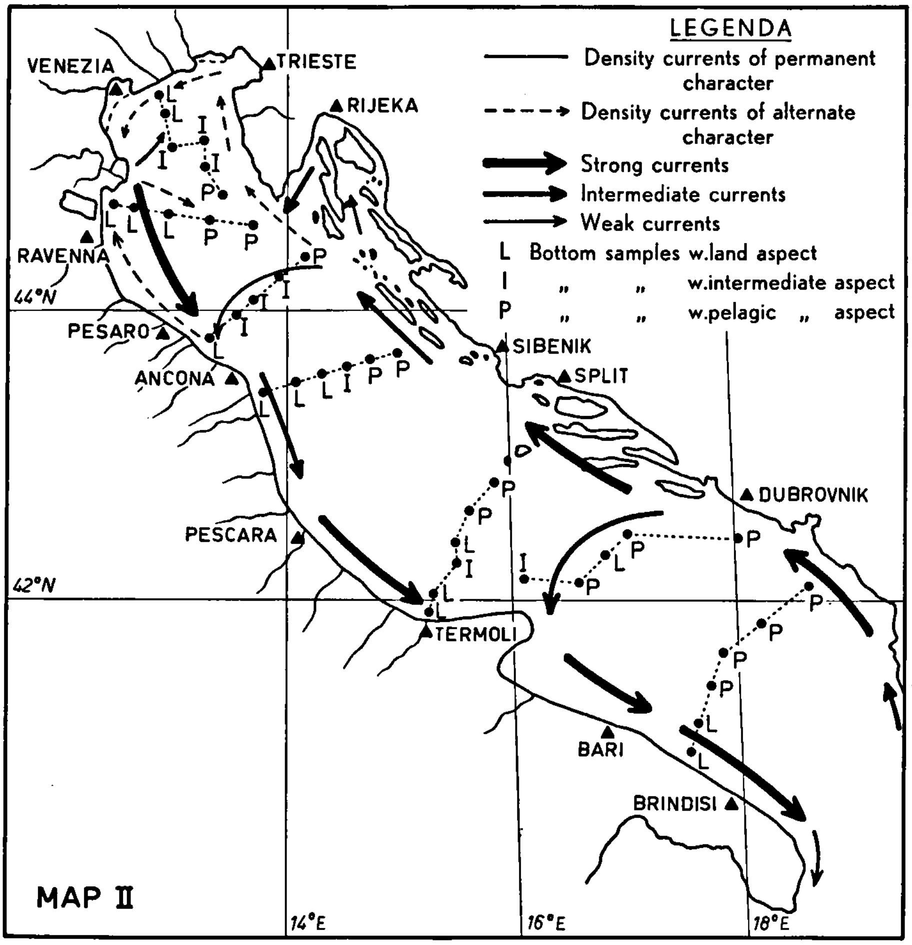


composition of the species in the samples could be correlated with the distance from the (Italian) coast. Next, the relation between the species distribution and the marine current pattern in the area could be considered (see map II).

Table I presents a list of the selected samples with the distribution of the species. The figures are the actually counted numbers of each species or group of species. Table II gives a list of samples, their exact geographical location and depth below sea-level. The general aspect of each sample is obtained by way of a simple procedure, in which the relative amounts of the coccoliths and discoasters are considered in relation to their source areas: from land or from the sea surface, respectively fossil or (sub)recent. This point will be treated more extensively below.

Identification difficulties

A number of unexpected difficulties were met when the samples were observed with the light and electron microscopes. The counting procedure with the light microscope was handicapped by the fact that a great number of coccoliths were observed with (sub)elliptical outline, in the size range from 5–18 μ, without distin-



guishable characteristics. They were all lumped together and tabulated under the heading *Coccolithus* ? sp. The electron micrographs of some of these forms are being described under the genera *Coccolithus*, *Coccolithites* and *Syracosphaera*. As was concluded earlier (and can be checked in table I) many of these forms are land-derived.

When in-shore samples were observed with the electron microscope very few coccoliths and discoasters were found. This was surprising, because the light microscope showed a great variety of fossil forms. The reason is probably that most of the forms were covered with a layer of secondary(?) $CaCO_3$, obscuring every structural detail, making the forms indistinguishable from mineral particles. A form like *Helicosphaera carteri* could only be detected in these samples by the flange sticking out from a massive roughly elliptical mass. It is thought by the present author, that this layer must have been precipitated on the particle when still on land, before, during or after diagenesis. During transportation to the coast and after, this precipitate was not or only partly removed. The strong basicity of the Adriatic sea water prevented it from being dissolved. On the other hand precipitation of lime on the sea bottom must be considered unlikely. As a result it was impossible to secure one single electron micrograph of such samples as 165 and only a few were made from 298, the latter being unusually "clean", probably as a result of its location where only few rivers debouch into the sea. Swift surface currents (see map II) must have brought most of the material of this sample from locations farther north, loosing on its way south most of its sand-sized particles.

Generally it can be said that the smooth and clean looking forms when observed in the electron microscope are of recent origin, which had settled from the sea surface, such as the forms pictured on plate 17, fig. d, plate 18, fig. e, plate 19, figs. a and b, plate 21, figs. c and d and plate 25, figs. a, b, c and f. Forms like those in fig. a of plate 11, fig. a of plate 17, fig. d of plate 19 (all three probably with a layer of secondary $CaCO_3$) and fig. c of plate 19, fig. e of plate 24 and fig. e of plate 25 show a very rough surface with corrosion marks; these are probably allochthonous. Plate 11, fig. a is particularly instructive in that it shows a hole in the secondary $CaCO_3$ layer, with the original, smooth surface of the form visible (see enlarged detail plate 11, fig. b).

Most of the discoasters, which were observed in the electron microscope, showed secondary lime deposition between the rays. The use of the more sophisticated technique in preparing the carbon replicas described earlier, resulted in obtaining "cleaner" samples; especially, the long settling period proved to be essential to get rid of the smallest particles. Still, only a few discoasters could be detected and not a single specimen of such characteristic genera as: *Zygolithus*, *Zygrhablithus*, *Cribrosphaerella*, *Micula*, *Fasciculithes* and *Lucianorhabdus* of which the allochthonous character is indisputable, could be photographed, in spite of the considerable time spent at the electron microscope. As a result, from only a limited number of species both electron and light microscope pictures are being presented. Most electron micrographs were made from samples 291 and 295, both having a pelagic aspect and which can be considered therefore to be very "clean".

Technical imperfections

There is as yet no trustworthy technique for moving specimens from the light to the electron microscope although some work in this field has been done in Oslo (Halldal, Markali & Naess, 1954). Hence, one can never be absolutely sure of correlations of species viewed by the two types of instrument (Bramlette & Martini, 1964, p. 293). Therefore, although the present author thinks he has good reasons for the present correlations, they still should be considered with some reserves. The counting and tabulation of the samples with the light microscope before moving to the electron microscope made the process of identification with the latter easier, because a rough idea existed as to which species could be expected in a certain sample.

When comparing a specimen photographed with the light and electron microscopes one has to realize that the depth of focus in the electron microscope is much greater than in the light microscope resulting in a completely "in focus" electron micrograph and a partly "in focus" light micrograph. With the light microscope at very high magnification, one can only focus a certain level of the form, but can never get the whole specimen at the same time in focus. Therefore we can not simply compare photographs made by both instruments.

Further, when working with electron micrographs we have projections of the form on the screen; if the position of a specimen was originally not horizontal, a circular plate may show up as elliptical on the negative. This might be the case with pl. 21, figs. c and d showing the basal plate of *Rh. stylifer*, which appears to be elliptical but should be circular.

		allochthonous	allochthonous	intermediate	intermediate	intermediate	pelagic	allochthonous	allochthonous	allochthonous	pelagic	pelagic	allochthonous	intermediate	intermediate	intermediate	pelagic
Sample number:		125	128	131	133	135	138	165	167	169	171	173	335	334	333	332	331
Rhabdosphaera claviger	x	1				1	5		1						1	5	21
Rhabdosphaera stylifer	x	9	12	18	24	52	66		1	14	88	120	1	40	34	22	65
Rhabdosphaera sp.	?													5	1	1	1
Discosphaera tubifer	x					1											2
Helicosphaera carteri	?		4	1	6	8	10	9	19	9	4	1	28	17	16	19	11
Scapholithus sp.	x		1	4	2	4	5	1			5	16		9	11	11	30
Ceratolithus cristatus	x						2			1	1	2		3	3	3	
Discolithus antillarum	x																
Cyclococcolithus leptoporus	x		1	1	1		5	2	1	1	1		7	11	6	13	4
Cyclococcolithus cf. formosus	a	14	10	3	9	4	2	9	6	6		2	7	8	4	9	7
Cyclococcolithus mirabilis	x												1				
Discolithus macroporus	x			2	1	2	1				2	2		2	4	3	8
Syracosphaera dalmatica	x			3		2	5				5	9		7	6	6	21
Discolithus cf. distinctus	?					1			1		1		1				
Coccolithus atlanticus	x	17	21	41	43	43	50	2	4	15	83	88	2	28	20	32	62
Cricolithus jonesi	x	4	3	22	18	20	40			4	15	12		6	3	7	13
Discoaster barbadiensis	a			2				2			1		2		3	1	1
Discoaster deflandrei	a							1					1	1	2		
Discoaster challengeri	a					1			1					1			
Group of discoasters	a	10	7	2			2	5	5	4	3	1	7	7	7	9	1
Zygrhablithus bijugatus / Deflandrius intercisus	a		1	3		3		4	7	4			6	4	2	3	
Cribosphaerella ehrenbergi	a			2	1	3		2		3		1	4	1			
Group of fossil coccoliths	a	24	13	15	25	17	5	35	20	18	7	3	19	11	5	2	1
Coccolithus pelagicus	?	118	54	41	40	30	13	47	45	54	26	10	102	57	66	59	16
Coccolithus ? sp.	?	80	147	123	112	96	78	159	168	156	52	30	105	62	80	81	31
Thoracosphaera heimi	x																
? Thoracosphaera imperforata	?																
Micula decussata	a		3	2	3	4		11	6	2	2		3	2	3	2	2
Braarudosphaera bigelowi	?									1			1	1	4	1	2
? Pemma rotundum	a														2		
Sphenolithus radians	a	3	3	2	3	1	3	1	1		1			3	1	2	
Sphenolithus ? sp.	a	16	14	10	11	7	7	7	7	3	2	3	3	12	11	8	
Lithostromation perdurum	a																
Fasciculithes involutus	a							1	3	1							
Lucianorhabdus cayeuxi	a	3	3					1	2	3	1				4	1	
Isthmolithus recurvus	a								1								
Microrhabdulus	a				1		1	1	1	1					1		
Micrantholithus sp.	a	1	1														
Discolithus planus	?													2			
Pontosphaera scutellum	?		2	3													

		allochthonous	allochthonous	allochthonous	intermediate	pelagic	pelagic	allochthonous	allochthonous	intermediate	allochthonous	pelagic	pelagic	intermediate	pelagic	allochthonous	pelagic	pelagic	allochthonous	allochthonous	pelagic	pelagic	pelagic	pelagic
Sample number:		326	325	324	323	322	321	235	237	239	268	266	318	338	340	342	344	348	298	297	295	293	291	290
Rhabdosphaera claviger	x			1		5	1		1	2	3	11	7	6	12	6	19	8		3	12	15	19	4
Rhabdosphaera stylifer	x		2	26	62	54	71	1	8	16	4	46	46	41	27	2	44	41	10		59	61	61	56
Rhabdosphaera sp.	?					1					1					2					1			
Discosphaera tubifer	x					1						4	3	1	1	1	7	2			2	9	8	2
Helicosphaera carteri	?	14	11	17	14	12	24	25	23	24	42	45	31	29	44	41	41	33	20	20	23	27	31	20
Scapholithus sp.	x		4	10	28	37	31		1	6	2	44	38	14	21	1	24	30	2	1	32	34	33	41
Ceratolithus cristatus	x			1	1		6				1	2	2			2	1	2			1	2	1	
Discolithus antillarum	x													1				2			2	2	2	
Cyclococcolithus leptoporus	x	2	4		3	13	11	14	11	8	14	17	10	4	7	7	9	16	9	3	9	13	9	4
Cyclococcolithus cf. formosus	a	6	5		1		4	11	2	7	6	3	1	1	2	3		1	11	14	9	7	10	3
Cyclococcolithus mirabilis	x					4			1				3								2	1	5	3
Discolithus macroporus	x			1	3	3	3			5	1	10	9	2			5	1	1	2	3	7		6
Syracosphaera dalmatica	x			3	3	8	5		1	3		10	4	4	3		4	3	2		8	5	6	9
Discolithus cf. distinctus	?		2		1		1		1	3		1	1			2	2	1	2		1	1	2	3
Coccolithus atlanticus	x	2	13	24	56	68	91	2	7	26	13	46	79	32	54	21	69	68	16	2	76	69	65	71
Cricolithus jonesi	x		3	3	13	8	8		1	3		14	14	8	23	4	14	12	1	1	14	10	9	13
Discoaster barbadiensis	a			1	1			1	3	2	2					2				4		1		1
Discoaster deflandrei	a		2		1			1	1	1									1					
Discoaster challengeri	a			1	1			1	1	1				1			1		1					
Group of discoasters	a	10	6	3	2	1		12	11	7	11	5	1	4	3	4	2	2	5	10			3	
Zygrhablithus bijugatus / Deflandrius intercisus	a	3	2	2				3	1		3	1	1		1		2		4	4				
Cribosphaerella ehrenbergi	a	1			2			2		6	3			1	1	1			3					
Group of fossil coccoliths	a	9	9	8	4	2	2	10	6	7	6	3		4	5	4	3	1	9	11	1			1
Coccolithus pelagicus	?	60	60	42	28	16	11	97	71	94	77	23	17	45	21	44	15	15	62	114	9	13	17	26
Coccolithus ? sp.	?	165	157	135	66	55	25	108	134	78	98	12	25	89	64	138	32	52	127	97	29	21	13	29
Thoracosphaera heimi	x					1			1			1	1				2	1					1	1
? Thoracosphaera imperforata	?																				1	1		
Micula decussata	a	2	2	1	2	2	1	1	1		4	1		1		1			5	2				1
Braarudosphaera bigelowi	?				1	1							1		1								1	1
? Pemma rotundum	a																							
Sphenolithus radians	a	1	2	2	1	1		1							1	2	1		2					
Sphenolithus ? sp.	a	19	9	11	3	6		9	8		2			10	5	9	2	8	3	12	4	1	3	3
Lithostromation perdurum	a								1															
Fasciculithes involutus	a	1	4	5	2				1		4		3	1					1					
Lucianorhabdus cayeuxi	a	2	1				2		1															
Isthmolithus recurvus	a								1															
Microrhabdulus	a			1			1	1																
Micrantholithus sp.	a						2												2					
Discolithus planus	?		1		1					1	3	1	3		2		1	1	1					1
Pontosphaera scutellum	?	3	1	2		1			1					1	2	3					2		1	1

Another point was brought up by Bramlette (Bramlette & Martini, 1964, p. 294, first section) in which the validity of electron micrographs was questioned when it is not indicated if the pictured specimens are the normal or mirror image of the form. This of course is true with respect to the direction of inclination of the sutures and the imbrication of the plates. We feel that one should be very careful in handling the film and bringing it on the electron microscope with the shadowed side of the film to the viewing screen. However, there are at the present so many other question marks in this field, that this problem seems to be a minor one.

Some of the descriptive terms proposed by Hay & Towe (1962, p. 499) were used.

Since the specimens themselves were destroyed in the preparation of the carbon replicas, the holotype and paratypes(s) of each species described in this paper is a photographic negative identified by a serial number in the collection of electron micrographs at the Technical Physics Department of T.N.O. & T.H. at Delft; this also holds for the electron micrographs of the hypotypes. The author has designated also a number of specimens as hypotypes in the microscope slides observed in transmitted light; these slides have been deposited at M. Deflandre's Laboratoire de Micropaléontologie, Rue de Buffon 8, in Paris under the numbers BF 78-BF 83.

SYSTEMATIC DESCRIPTIONS

Family COCCOLITHOPHORIDAE Lohmann, 1902.

Genus COCCOLITHUS Schwarz, 1894.

Coccolithus atlanticus Cohen, spec. nov.

Pl. 2, figs. l—o; Pl. 15, figs. c—e; Pl. 17, fig. f.

Derivatio nominis: atlanticus from Atlantic (ocean).

Description: Two elliptical plates pressed closely together, which are slightly curved in side view. The extinction figure in polarized light between crossed nicols is characteristic in that the outer marginal area gives a well-defined image, while the central area remains vague.

The carbon replicas show that each plate consists of about 36 counter-clock-wise curved elements. The outer edge is regularly serrate. There is only one cycle of elements with a small irregular opening in the center, sometimes reduced to a small hole or narrow slit. Not all elements forming the outer margin continue to the central area; some wedge out half way.
Length: $3\frac{1}{2}$–9 μ; width: $3\frac{1}{2}$–6 μ.

Remarks: A regular central elliptical opening is lacking distinguishing this form from *C.* cf. *atlanticus* (Cohen, in press). *Ellipsoplacolithus productus* Kamptner (1963) shows similarity in structure and form especially with the specimen shown on pl. 15, fig. e. However, *E. productus* is smaller, has fewer elements in a plate and appears to be flatter.

Distribution: Abundant in samples far from the coast. Probably cosmopolitan today.

Coccolithus brambatii Cohen spec. nov.

Pl. 11, figs. a, b.

Derivatio nominis: in honor of Dr. A. Brambati, Pescara, Italy, for his valuable help with respect to storage and transportation of material.

Description: Elliptical form consisting of a single plate, made up to two cycles of elongate elements. An outer cycle with about 36 elements curved slightly counter-clockwise, appears to partly cover a second more centrally located cycle of elements. The latter are arranged around a central elliptical opening, with fragments of what once must have been a grille.
Length: $4\frac{1}{2}$ μ; width: $3\frac{3}{4}$ μ.

Remarks: The upper surface appears to be very irregular and grooved. This is probably due to the deposition of a layer of secondary lime with subsequent corrosion. The detail pictured in fig. b shows a hole in the secondary lime cover, revealing the smooth, original surface. The outer margin, although corroded has been originally regularly indented.

Distribution: Unknown. This is one of the many forms lumped together in table 1 under the heading of *Coccolithus* ? sp.

Coccolithus huxleyi (Lohmann 1902)

Pl. 8, 9, 10; P. 11, figs. c—e; Pl. 12, figs. a, b, ? c.

1902 *Pontosphaera huxleyi* Lohmann, p. 130, pl. 4, figs. 1—6, pl. 6, fig. 69
1941 *Pontospaera huxleyi* (Lohm.), Kamptner, p. 79, pl. 2, fig. 27, pl. 3, figs. 29, 30, p. 99.
1943 *Coccolithus huxleyi* (Lohm.), Kamptner, p. 44.
1952 *Coccolithus Huxleyi* (Lohm.), Kamptner, p. 234, figs. 7—9.
1954 *Coccolithus Huxleyi* (Lohm.), Kamptner, pp. 67—69.
1956b *Coccolithus Huxleyi* (Lohm.), Kamptner var. *typica* Kpt. and var. *tenuis* Kpt., p. 178, pl. 1, figs. 1—3.
1961 *Coccolithus huxleyi* (Lohm.) Kamptner, Black and Barnes, pp. 141—142, pls. 20, 21.

Remarks: When observing the samples with the electron microscope it turned out that this species was by far the most abundant. Its small size prevented us from giving a picture in transmitted light. This form was not counted and therefore is not included in table I.

The electron micrographs turned out to be good. In addition to the excellent description of Black and Barnes (1961) we should like to make a few remarks.

Plates 8 and 9 give a number of top views from the distal (or upper) plate and the distal end of the tubular ring connecting both plates. The distal ends of the rays might be in contact with each other (see pl. 12, fig. a) or not (pl. 9, figs. a, b and c), which is probably a result of corrosion. The grille in the center appears to be in fact a continuation of the rays via the central tube; this part is often badly preserved, except in pl. 10, fig. f and pl. 12, fig. b.

If we compare pl. 8, figs. a, b and e with pl. 9, figs. a, c, d and e, there appears to be some variation in the structure of the distal end of the central elliptical tube. Pl. 9, figs .a, d and e shows, that a cycle of peculiarly shaped, closely fitting (possibly overlapping) rounded elements, which are slightly raised, is located between the proximal ends of the distal rays and the central elliptical area. This raised area is not always distinguishable, as for instance in pl. 9, fig. c; this is also true of the specimen shown in pl. 8, fig. d., Pl. 8, figs. a, b, c and e are similar to those given by Black; they do not have an additional cycle of elements between the proximal ends of the rays and the central area. Pl. 11, fig. e shows a specimen with club-shaped distal ends of the rays and very wide proximal ends; the rays are bounded by an additional cycle of elements arranged around the central opening. The structural build-up of this specimen is clearly exposed subsequent to corrosion, resulting in the absence of a grille. Evidently this is quite different from "... a faint suture, causing separation of the ray from the central ring ..." (Black, 1961, p. 141). The obliquely located prisms forming the wall of the central tube can be seen in pl. 8, fig. c.

Pl. 10, figs. a–f, pl. 11, fig. d and pl. 12, fig. b show the proximal (or lower) plate, which is smaller than the distal. It appears that the rays of both plates are similar in the same individual, though this is not always the case, as appears from pl. 12, fig. c (see Black, 1961, p. 142). In the majority of cases we observe that the rays continue into the central grille via a curved segment, and without intermediate elements.

Pl. 12, fig. c shows an aberrant form. A grille is absent, but instead there are a number of small pores. The plates are of the same size; the slender rays of the upper disc are quite different from those of the lower disc, which are in contact throughout their length (except for a few elliptical holes, which are probably the result of corrosion). The proximal ends of the slender rays form a frame around the central elliptical area; there are no intermediate elements. Dimorphy of the rays was described earlier by Black (1961) and Kamptner (1952, fig. 10; 1954, p. 69). A new species was proposed by Kamptner: *Coccolithus foliatus*. We think this should not be done in view of the gradation of the rays mentioned by Black; this also holds for *C. Huxleyi* (Lohm.) Kpt. var. *tenuis* Kpt. (1943, 1956b).

The number of rays of the distal plate ranges from 25 to 42; the number of intermediate elements in the distal plate corresponds to that of the rays with some irregularities at the short sides of the ellipse. In the proximal plate 29 to 38 rays were counted. The number of rays in both plates of the same form are about the same. Pl. 11, fig. c shows the central tube of a strongly corroded specimen; this is evidently the most durable part of the form.
Length ranging from 3–5 μ; width: 2–4 μ.

Distribution: In all samples observed in the electron microscope, this species was the most abundant one. Probably cosmopolitan today.

Coccolithus pelagicus (Wallich, 1877)

Pl. 1, figs. a—c.

1877 *Coccosphaera pelagica* Wallich, p. 348, pl. 17, figs. 1, 2, 5, 11, 12.
1930 *Coccolithus pelagicus* (Wall.), Schiller, p. 246 (pro parte).
1954 *Coccolithus pelagicus* (Wall.) Schiller, Kamptner, pp. 20, 21, figs. 14, 15.
1963b *Coccolithus pelagicus* (Wall.) Schiller, Stradner, p. 156, 157.

Remarks: Elliptical form consisting of two plates, with the distal larger than the proximal. It appears in side view, that the central area is structurally united with the proximal plate, the distal one being a separate unit (see pl. 1, fig. d). The central elliptical area gives a well-defined extinction figure in polarized light between x-nicols in contrast to the outer area, which remains vague (see pl. 1, fig. b); this was felt to be a good characteristic, distinguishing this form from similar elliptical forms of the same size range (see Bramlette and Martini, 1964, p. 298). Form, size and arrangement of the pore(s) were not felt to be important systematic characters.
There is no carbon replica available for description.
Length: 5–16 μ or more.

Distribution: Abundant to very abundant in the bottom samples, especially from inshore locations. Reported from strata as old as the Middle Jurassic (Stradner, 1963a) to recent. Recorded in sediments from Upper Eocene, Oligocene and Miocene age from the northern Apennines. Probably cosmopolitan today.

Coccolithus aff. *sarsiae* Black, 1962

Pl. 13, figs. c, d.

1962 *Coccolithus sarsiae* Black, p. 125, 126, pl. 8, fig. 2, pl. 9, figs. 2—6.

Remarks: Pl. 13, fig. c shows the distal side of the upper(?) shield. This (sub)elliptical plate consists of about 30 straight-sided and flat-faced elements (40 in *C. sarsiae*), which are sinistrally overlapping with clockwise inclined sutures. A second cycle of about 17 short rhombohedral crystals is located between the outer cycle and a central area of which the structure is not disclosed. The central area appears not to be depressed like in *C. sarsiae* and *C. pelagicus* (Wall.). Fig. d shows the proximal side of the plate, but the structure is less well exposed.
Length: 6½–7½ μ; width: 5½–7 μ.

Distribution: This form has been included within the group *Coccolithus* ? sp. in table 1.

Coccolithus ? sp.

Pl. 1, figs. d—i.

Remarks: Under this heading we have collected the many (sub)circular and (sub) elliptical forms, either single or double-plated, which make up about one-fourth to more than one-half of all specimens counted in some samples. They are nearly all concave-convex in side view. Especially in in-shore samples this group turned out to be the most numerous (see table 1) which points to the great number of allochthonous forms included. This conclusion is strengthened by the fact that many forms showed signs of corrosion and fragmentation.

Some of the forms included showed well-defined extinction figures, others did not; the extinction lines covered the whole plate in some forms like pl. 1, figs. h, j and k, in others only the central area. The curving of the extinction lines was pronounced in some forms but not in others; it should have been an interesting thing to check Stradner's (1961, p. 80, and personal communication) remark, that Mesozoic forms have a more straight-lined extinction figure, while Tertiary forms display a more strongly curved extinction figure. This should be a point of interest for future work.

Forms like *Coccolithus placomorphus* (Kamptner) (see Stradner, 1963b, pl. 23, figs. 4, 5) figured on pl. 1, figs. k, l and *Coccolithus crassus* Bramlette and Sullivan (1961, p. 139, pl. 1, fig. 4a–d) were observed in the samples and are included within this group.

The length of the many different forms included within this group varied between 4 and 18 μ.

Some more forms are being referred to this group. The electron micrographs of these have been assigned to various genera; they can be found in the systematic descriptions under *Coccolithus*, *Coccolithites* and *Syracosphaera*.

Genus DISCOLITHUS Kamptner, 1948

Discolithus aff. *histricus* Kamptner

Pl. 24, fig. a.

1964 *Discolithus histricus* (Kamptner) Cohen, p. 236, pl. 1, fig. 2a—g; pl. 2, fig. 1.

Remarks: This elliptical forms has a spine (or what is left of it) in the center. About 33 triangular openings located along the periphery of the central area at regular intervals are present. The rest of the central area consists of a great number of elongate elements, radially arranged. The outer edge consists of a double ring of about 35 closely fitting elements; the edge is relatively thick and raised above the central area. A side view is not available, so that we do not know whether or not another cycle of elements is present in the edge below the one exposed. This does not seem to be very likely.

Discolithus histricus is larger and does not have openings in the central area; there are also more elements in the central area, with the outer edge consisting of a single row of 50.

Length: $3\frac{1}{2}$ μ; width: $2\frac{1}{2}$ μ.

Distribution: Rare in bottom samples. This form was not included in the count.

Discolithus planus Bramlette and Sullivan, 1961

Pl. 2, figs. p—s.

1961 *Discolithus planus* Bramlette and Sullivan, p. 143, pl. 3, figs. 7a—c.
1962 *Discolithus planus* Bramlette and Sullivan, Stradner, p. 180.
1964 *Discolithus crassus* Deflandre, Cohen, p. 236, fig —e.

Remarks: Single, thick elliptical plate with the out edge not at all or only slightly raised. Two fine slits in the direction of the long axis present. A number of marks (pores ?) which often do not penetrate the unusually thick plate are often irregularly placed; they may also be located more or less regularly along the outer edge. Un usually high interference colors in polarized light between x-nicols are a result of the thickness of the disc. In side view the distal side is more strongly curved than the proximal.

The particular specimen presented on plate 2 shows markings at regular intervals along the outer margin. These should not be seen as an important characteristic of this species, but rather as a rarely observed phenomenon. Time does not permit us to present a better example.

Length: 7–10 μ; width: 5–6½ μ; thickness: 2½–3 μ.

A carbon replica of this form has been presented before (Cohen, in press), but incorrectly under the name of *Discolithus crassus* Deflandre.

Distribution: Rare in the bottom samples. Reported from the Paleocene, Lower and Middle Eocene of the U.S.A., the Middle Eocene of France and the Flysch of Istria. Recorded in Pleistocene and (sub)recent sediments of deep-sea cores.

Discolithus aff. *ponticulus* Deflandre, 1954

Pl. 24, figs. e, f.

1954 *Discolithus ponticulus* Deflandre and Fert, p. 144, pl. 13, figs. 18, 19; text-figs. 32, 54.

Remarks: There is no picture in transmitted light available for description. Pl. 24, figs. e and f form a stereoscopic pair. We observe an elliptical plate with two subcircular pores. One perforates the disc completely, the other has a flat bottom; this is probably a peculiarity of this particular specimen, also in view of the regular screw-like arrangement of the crystal plates.

About 27 strongly sinistrally imbricate rhombohedral elements form a wide outer margin. The outer edge is deeply notched at the small sides of the ellipse, at the long sides it is rather smooth, depending on the angle at which the elements hit the outer edge. The pores are separated by a bridge-like structure made up of a number of small ill-defined elements placed without apparent regularity. No slits or nerves appear to be present as in *Discolithus pulcher* Deflandre (1954, p. 142). The dimensions fit those of the holotype of *Discolithus ponticulus* very well, except for the bilateral symmetry.

Length: 7 μ; width: 5 μ.

Distribution: Very rare in the bottom samples. This and similar forms with two large perforations were found exclusively in in-shore samples. All these forms were included within the group of fossil coccoliths. Recorded in the Senonian of France and Poland, and the Tertiary of North Africa.

Discolithus macroporus Deflandre, 1954

Pl. 3, fig. u.

1954 *Discolithus macroporus* Deflandre and Fert, p. 138, pl. 11, fig. 5.
1961 *Discolithus macroporus* Deflandre, Baldi Beke, p. 166, pl. 1, figs. 1, 2.
1962 *Discolithus macroporus* Deflandre, Stradner, p. 365, pl. 1, figs. 1—13.
1964 *Discolithus macroporus* Deflandre, Cohen, p. 236, pl. 3, fig. 5 a—c, pl. 4, fig. 6 a—b.

Remarks: Small elliptical plate with 10 to 13 pores all of the same size. The form pictured by Stradner (1962, fig. 12) corresponds to the form found by us. His figs. 1–11 show forms never found by us and the relationship to the form shown in his fig. 12 is to be considered doubtful.

A description of this form in transmitted light together with a presentation of the electron micrograph has been given before (Cohen, 1964).
Length: 3–5 μ; width: 2–3 μ.

There appears to be a strong resemblance with *Syracosphaera schilleri* Kamptner (1927, p. 179, figs. 4, 5; 1941, p. 82, pl. 5, figs. 52–54). Dimension and pore location are similar.

Distribution: Rare in in-shore but rather common in samples far from the coast. Reported form the Oligocene of New Zealand, the Upper Eocene and Upper Miocene of Austria. Found living in the Adriatic.

Discolithus cf. *distinctus* Bramlette and Sullivan, 1961

Pl. 3, figs. r—t.

1961 *Discolithus distinctus* Bramlette and Sullivan, p. 141, pl. 2, figs. 8a—b, 9 a—c.
1964 *Discolithus distinctus* Bramlette and Sullivan, Sullivan, p. 182, pl. 4, fig. 4a, b.

Remarks: Large elliptical plate with a distinct, slightly elevated rim. In side view curved: the distal side more so than the proximal. Forty to fifty pores, of which the outer two or three rows are placed in concentric arrangement parallel with the outer edge, are piercing the plate. Their position in the center is less regular and they appear to be less distinct there.
Length: 6–10 μ; thickness: 2–2½ μ.

Both forms have a longitudinal line (or are there actually two slit-like pores ?) in the basal plate. However, our form is much smaller than the holotype, and number and pore arrangement are different. Besides, our form is thinner with a narrow outer rim. The form shown in pl. 2, fig. 8 (Bramlette and Sullivan, 1961) has not been found by us. A carbon replica of this or a closely related form will be presented in a forthcoming publication (Cohen, in press).

Discussion: There appeared to exist many forms showing smaller and larger variations with the characters described above, which makes a re-examination of this and similar forms necessary (M. Deflandre, personal communication).

The variation in width of the outer rim and the number and the arrangement of the pores showed considerable variation. Pore-dimorphism was observed in some forms. *Discolithus multiporus* Kamptner (Stradner, 1964, p. 3, fig. 8), *Discolithus pachymorphus* Kamptner (1955, p. 15, fig. 27) and *Discolithus deflandrei* Kamptner (1955, p. 16, fig. 141) show pore-dimorphism and have been observed in our samples.

Discolithus trematotus Kamptner (1955, p. 15, fig. 24) and *Discolithus multiporus* Kamptner (1948, p. 5, pl. 1, fig. 9) are similar forms with all pores of same size. The latter form, however, is "breit-elliptisch", while our forms were nearly exclusively "normal-elliptisch" to "schmal-elliptisch" (Kamptner, 1954, p. 12); number, pore arrangement and size of this form resemble those of our forms very closely.

Distribution: Not uncommon in the bottom samples; preferably at locations far from the coast. Reported from the Middle Eocene of the U.S.A., Trinidad and France and the Paleocene of California.

Genus CRICOLITHUS Kamptner, 1963

Cricolithus adriaticus Cohen spec. nov.

Pl. 16, fig. e.

Derivatio nominis: adriaticus from Adriatic (sea).

Description: The electron micrograph shows one cycle of curved, elongate elements forming a (sub)circular structure. There is a large central opening around which the elements form a tightly fitting structure. The outer margin is deeply indented, which is probably the result of corrosion. There appears to be considerable depth in the form which is accentuated by the strong curvature of the 45 elements composing the ring. Diameter: 4 μ; central opening about $1\frac{3}{4}$ μ.

Remarks: Cycloplacolithus amerensis Kamptner (1963, p. 167, pl. 6, fig. 34) shows a resemblance with the present form. The presence of a second, smaller ring and the fact that this form has only 36 elements are points of difference. The size of both forms appears to be about the same. This can also be said of small specimens of *Cyclococcolithus mirabilis* (Lohmann) Kamptner (Cohen, 1964, p. 237, pl. 6, fig. 3 f) which shows a remarkable resemblance with Kamptner's fig. 34.

Distribution: Unknown. This species was not recorded in transmitted light.

Cricolithus jonesi Cohen spec. nov.

Pl. 2, figs. j, k; ? Pl. 16, figs. a, b or c.

Derivatio nominis: in honor of Dr. J. I. Jones, The Marine Laboratory, Miami, Florida.

Description: Single, rather thick, elliptical ring of simple appearance. The smooth and sharp outline is characteristic, and is probably due to the unusual thickness of the form. The extinction figure in polarized light between x-nicols is very clear and sharp, making this form readily distinguishable.
Length: 2–3 μ; width $1\frac{1}{2}$ μ; thickness approx. 1 μ.

Remarks: In transmitted light, the small and narrow elliptical ring appears to be slightly curved. The unusual thickness of the form is reflected in the clear and well-defined extinction figure.

Because we are as yet not able to move specimens from the light microscope to the electron microscope (see p. 8), we are not sure which of the forms of pl. 16 is the form wanted (there are probably even more similar structures to be found in the samples !).

Pl. 16, figs. a and b form a stereoscopic pair. The specimen shows a single cycle of 33 elements separated by strongly curved sutures. Both inner and outer edges are regularly notched. The form is fairly thick, but not abnormally so and consists of one elliptical ring.

The form of fig. c consists of two cycles of elements: an inner cycle of about 23 elements (in imbricate arrangement ?) separated by slightly curved sutures and an outer cycle of about the same number of elements, which are strongly dextrally imbricate and of flat, rhombohedral form. The inner edge is regularly and deeply indented; the outer edge regularly serrate. The form is fairly thick, but not unusually so.
Length about $2\frac{1}{2}$ μ; width about $1\frac{3}{4}$ μ.

Discussion: The specimen shown in fig. c shows a resemblance with *Hymenomonas (Syracosphaera) Carterae* Braarud and Fagerland (Braarud, 1954, p. 3, pl. 2 a–d). Without a side view, we can not make a comparison between the two forms.

Pl. 4, figs. 5 and 6 (Cohen, in press) present also forms consisting of simple rings but of different structural build-up and larger size.

Distribution: Rather common in the bottom samples, but with a preference for those located far from the coast. Probably cosmopolitan today.

Cricolithus scabrosus Cohen spec. nov.

Pl. 16, fig. d.

Derivatio nominis: scabrosus (lat.) = rough.

Description: An elliptical ring composed of (probably) one cycle of (about 35) crystal plates. The sinistral imbrication of the elements is particularly well demonstrated at the outer edge; the sutures show a clockwise inclination. The structure of the area immediately bordering the large central opening is not fully disclosed, probably partly as a result of the depostion of secondary(?) lime on the specimen (see p. 7).

Although the structure of the form is probably partly hidden by $CaCO_3$ deposition, the form gives the impression of being of coarse making.
Length: $6\frac{1}{2}$ μ; width: 5 μ.

Distribution: Unknown. This form was not included in the count.

Genus CYCLOLITHUS Kamptner, 1948

? *Cyclolithus rotundus* Kamptner, 1948

Pl. 16, fig. f.

1948 *Cyclolithus rotundus* Kamptner, p. 6, pl. 12, fig. 19.

Remarks: Circular form composed of two cycles of elements. The outer cycle consists of about 40 curved elements in imbricate arrangement. There appear to be fewer elements in the inner cycle, but their exact number and structural arrangement is not fully revealed. The specimen shown seems to be slightly corroded. The form is tentatively identified as *Cyclolithus rotundus* Kamptner. This latter form, however, is much larger and has a horizontal constriction and 50 notches, which roughly agrees with the number of elements in the form under discussion. As long as we can not present a side view, a correlation between both forms remains unsafe.
Diameter about $3\frac{1}{2}$ μ, about half of Kamptner's form.

The present form is also much smaller than *Cyclolithus* ? *robustus* Bramlette and Sullivan (1961, p. 141), which has an inner rim and consists of two rings pressed closely together.

Distribution: Unknown. This form was not included in the count.

Genus UMBELLOSPHAERA Paasche, 1955

Umbellosphaera tenuis (Kamptner, 1937) emend. Paasche, 1955

Pl. 13, figs. e, f.

1937 *Coccolithus tenuis* Kamptner, pp. 311, 312, pl. 17, figs. 41, 42.
1954 *Coccolithus tenuis* Kamptner, Deflandre and Fert, p. 152, pl. 3, figs. 1—5; pl. 8, figs. 6, 7.
1955 *Umbellosphaera tenuis* (Kamptner) emend. Paasche, In: Markali and Paasche, pp. 96, 97, pl. 1, 2.

Remarks: Pl. 14, fig. e shows what appears to be an elliptical shield with an elliptical opening in the center. Actually it is the broad funnel-shaped macro-coccolith, with the central tubular part gradually widening into the convex, umbrella-like outer brim (Paasche, 1955, p. 97). About 21 of what appear to be raised ridges (25 radial stripes according to Paasche) situated between the central opening and the outer edge are located at more or less regular intervals around the plate. They are wedge-formed, with minor ridges branching off when approaching the outer edge (see also fig. f). The ridges are clockwise curved; the outer edge faintly undulated. The plate seems to be slightly arched.

According to Paasche (1955): "Micro-structure very coarse, made up of more or less parallel stripes, often running at angles to the radii, their ends protruding at the edge of the coccolith".
Length: 4–5½ μ; width: 3–4 μ.

Kamptner (1937) mentioned 24 radially arranged grooves, counter-clockwise curved; because he looked at the proximal side of the shield he observed grooves, which are actually ridges with a clockwise curvation.

Distribution: Unknown. This form has been included within the group *Coccolithus* ? sp. in table 1. Reported from the Mediterranean and Atlantic (Gulf Stream). According to Deflandre (1954) this species has not been found yet as a fossil.

Genus PONTOSPHAERA Lohmann, 1902

Pontosphaera scutellum Kamptner, 1954

Pl. 15, figs. a, b.

1950 *Discolithus scutellum* Kamptner, p. 153 (nomen nudum).
1954 *Pontosphaera scutellum* Kamptner, pp. 12—16, figs. 1—7.

Remarks: Because we cannot present a picture of this form in transmitted light, a few general remarks are given. The form which we tentatively assign to this species has an elliptical plate, which appears to be smooth and flat, with a very narrow outer edge. Two fine slits according to the long axis are present. No pores or marks of any kind were found. The form shows some resemblance to *Discolithus planus* (Bramlette and Sullivan) but *P. scutellum* is much thinner.
Length about 8½ μ; width about 6 μ.

The electron micrographs which are tentatively assigned to this species show flat elliptical plates. There is an outer cycle of a great number of extremely narrow, elongate elements, curved slightly counter-clockwise, separated by finely serrated sutures. The central area is made up of elements of the same form separated by serrate sutures; they are nearly straight and converge on a line (which is called Längsraphe by Kamptner, 1954, p. 12) bisecting the form according to the long axis. There appear to be a number of small perforations (possibly the result of corrosion) in this area.

Kamptner's detailed discussion of the form and subsequent construction of the micro-crystalline texture is not being contradicted by the structure as depicted by our electron micrographs. His fig. 7 is comparable with the mirror image of our fig. b. The presence of an outer cycle of elements in our forms is not contradicted by Kamptner's statement: "ohne Differenzierung einer Randpartie" (p. 12), because the differentiation between the outer cycle (of elements) and the central area seems to be very concise, with most elements continuing from the outer edge to the line bisecting the form in the centre. In plain and polarized light, this break might not be discernable, because there seems to be only a slight change in the direction of the elements (see in particular pl. 15, fig. b).
Length: 7–9 μ; width: 5–7 μ.

Distribution: Rare in the bottom samples.

Genus SYRACOSPHAERA Lohmann, 1902

Syracosphaera dalmatica Kamptner, 1927

Pl. 3, fig. v; Pl. 24, figs. b—d.

1927 *Syracosphaera dalmatica* Kamptner, p. 178, fig. 2.
1930 *Syracosphaera dalmatica* Kamptner, Schiller, pp. 202, 203, fig. 86.
1941 *Syracosphaera dalmatica* Kamptner, p. 81, pl. 4, figs. 46—48, p. 104.
1951 *Syracosphaera dalmatica* Kamptner, Lecal-Schlauder, Ann. Inst. Océanogr., Vol. 26, p. 324, pl. 10, fig. 10.

Remarks: This small, elliptical form shows in transmitted light six to eight depressions (pores in the corroded specimens of pl. 24, figs. c and d) placed along the outer edge. One or two are sometimes located more in the center, where a culmination is located, of which the structural characteristics are not disclosed in transmitted light. In polarized light between x-nicols the disc behaves as one single calcite crystal (ortholithid characteristic).

The electron micrographs disclose the extremely irregular surface (in particular of fig. b), without well-defined crystal faces. The culmination in the central area agrees with "eine buckelartige Erhebung" (Kamptner, 1941, p. 81). The depressions along the outer edge correspond to the pores of figs, c. and d. It is likely that the depressions show up as pores in transmitted light. The culmination in fig. d seems to consist of a number of flat plates, one on top of the other.
Length: $2\frac{1}{2}$–3 μ; width: $1\frac{1}{2}$–2 μ.

Discussion: Size, pore arrangement and other structural details seem to correlate very well with *S. dalmatica* Kamptner. This form has been found in the Adriatic. The peculiar notched structure is not understood as yet. Some resemblance with the calcite rhombohedrons (micro-crystals) pictured by Gaarder (1962, pl. 4, fig. c) is noticed.

Prof. Kamptner (personal communication) suggested, that the structure perhaps could be a result of recrystallization, which placed the very small crystallites in a diffuse, irregular arrangement, resulting in the disappearance of the extinction figure.

Distribution: Fairly common in most samples, but preferably at locations far from the coast. Reported living in the Mediterranean and Adriatic.

Syracosphaera pulchra Lohmann, 1902

Pl. 12, fig. d; Pl. 14, figs. a, b.

1902 *Syracosphaera pulchra* Lohmann, p. 134, pl. 4, figs. 33, 36, 36a, 37.
1930 *Syracosphaera pulchra* Lohm., Schiller, pp. 207, 208, figs. 90a, b; figs. 11, 30.
1955 *Syracosphaera pulchra* Lohm., Halldal and Markali, p. 12, pl. 11.

Remarks: The central area consists of a great number of radially arranged elements which converge on a linear area in the center. Halldal and Markali (1955) state: "The central area may be considered an intermediate between a unit with radial perforation, and an area built up of radially arranged ribs." The central area of pl. 12, fig. d seems to be less regular.

The outer margin of pl. 14, fig. a seems to agree with the girdle shown in pl. 11, fig. 2 (Halldal and Markali, 1955) when seen in top view. The outer margin of pl. 14, fig. b appears to be wider, less regular and structurally different. As to pl. 12, fig. d this wide margin consists of at least one (and probably two) cycles of elements: an inner(?) cycle of about 50 dextrally imbricate angular elements and an outer (?) (or lower) cycle of about the same number of elements which appear to be sinistrally imbricate.

Length: 6–7½ μ; width: 4–5½ μ.

Distribution: Unknown. This form was not identified as such in the light microscope. When present, this large form must have been included within the group *Coccolithus?* sp. Reported from the Adriatic Mediterranean and Gulf Stream today. According to Schiller (1930) cosmopolitan.

Syracosphaera sp.

Pl. 25, fig. f.

Remarks: Small elliptical plate consisting of a central body formed by a great number of sharply-edged, elongate and partly overlapping elements culminating in a central point. The exact form of each individual element is not evident. Together they seem to form a large unit, which is connected with the elements of the outer rim by approximately 25 narrow, elongate and radially arranged elements. The outer rim is formed by about 20 flat, rhombohedral crystals separated by slightly curved sutures. The specimen shown looks extremely fresh and clean and is probably of recent origin.

Length: 2μ; width: 1½ μ.

Discussion: There appears to be a strong resemblance with discoliths of the genus *Syracosphaera* (Deflandre and Fert, 1954, pl. 4, figs. 1, 5). *Pontosphaera variabilis* Halldal and Markali (1955, pl. 12) shows a similar culminating central area in an elliptical disc of the same size.

Distribution: Unknown. This form or another, very similar to it, was found in the samples, but was not included in the count.

Genus HELICOSPHAERA Kamptner, 1954

Helicosphaera carteri (Wallich, 1877)

Pl. 3, figs. o—q; Pl. 17, figs. a—d.

1877 *Coccosphaera carteri* Wallich, p. 348, pl. 17, figs. 3, 6, 7, 17.
1954 *Helicosphaera carteri* (Wallich) nov. comb. Kamptner, p. 21, figs. 17—19.
1961 *Helicosphaera carteri* (Wallich) Kamptner, Black and Barnes, pp. 139, 140, pl. 22, 23.
1964 *Helicosphaera carteri* (Wallich) Kamptner, Cohen, pp. 238, 240, pl. 3, fig. 2 a—f, pl. 4, fig. 1 a—c).

Remarks: There appears to be no variation in groundplan: a central, elliptical, perforate lower surface surrounded by a spiral flange, which flares out to form a wing-like expansion. There is, however, considerable variation in size, form, number of pores and flange dimensions (see Cohen, 1964), although this is not considered to be of systematic importance.

The electron micrographs show the structure in detail. Little needs to be added to the excellent description of Black (1961). Fig. a shows a strongly corroded fossil (?) specimen with a narrow flange but a pronounced wing-like expansion. Fig. d gives a very fresh modern(?) form. Fig. c shows the lower surface with two slit-like pores and tangentially arranged crystals.
Length: 6–13 μ.

Distribution: Abundant to very abundant in most bottom samples. There is no preference for either in-shore samples or for those far from the coast. Reported from the Middle Eocene of Istria, the Lower and Middle Miocene of the northern Apennines, and the Miocene of Austria. Recorded in Pleistocene and (sub)recent deep-sea cores. Probably cosmopolitan today.

Genus KAMPTNERIUS Deflandre, 1959

Kamptnerius magnificus Deflandre, 1959

Pl. 17, fig. e.

1959 *Kamptnerius magnificus* Deflandre, p. 135, pl. 1, figs. 1—4.
1963 *Kamptnerius magnificus* Deflandre, Stradner, p. 7, pl. 2, figs. 2, 2a.
1963 *Kamptnerius magnificus* Deflandre, Gorka, p. 16, pl. 1, figs. 7—10, text pl. 3, figs. 1—3.

Remarks: Elliptical form with fringe consisting of what are probably calcite lamellae, which do not show the characteristic strong asymmetric development at one side of the ellipse; the width remains about constant all around the (bottom) plate. This flat central part appears to be corroded to some extent; the striae so characteristic in transmitted light seem to correspond with the linear directions, which probably reflect the sutures of the elongate elements forming the basal plate. These lines appear to converge on a longitudinal line according to the long axis of the plate. There appears to be a strong resemblance between the structure of this part of *K. magnificus* and that of the flat elliptical shield of *H. carteri*. However, the exact form of the calcite elements in the plate and fringe are not fully disclosed in the (corroded) specimen pictured in fig. e.

A little gap in the fringe at the (right) short side of the ellipse makes us suspicious that we might still have here a specimen of *H. carteri* with a very small wing (or

no wing at all); the absence of an asymmetrical fringe makes a decision between the two forms even more difficult. However, M. Deflandre (personal communication) the creator of the species, assigned this specimen to the genus *Kamptnerius.*
Total length 8 μ; length of the basal ellips 6 μ; width of the basal ellips $4\frac{1}{2}$ μ.

Distribution: Upper Cretaceous of U.S.A., Australia, Poland and France. Very rare in the bottom samples. According to Stradner (1963a) characteristic for the Upper Cretaceous.

Genus RHABDOSPHAERA Haeckel, 1894

Rhabdosphaera claviger Murray and Blackman, 1898

Pl. 3, figs. a—c; Pl. 22, figs. a, b; Pl. 23, fig. e.

1898 *Rhabdosphaera claviger* Murray and Blackman, pp. 438, 439, pl. 15, figs. 13—15.
1964 *Rhabdosphaera claviger* Murray and Blackman, Cohen, pp. 240, 242, pl. 5, fig. 2 a—g; pl. 6, fig. 1.

Remarks: There have been identification problems between this form and *Rhabdolithus perlongus* Deflandre (Ann. Pal. Vol. 40, p. 158) and *Rhabdolithus pinguis* Deflandre, although these last two forms are rare (see also *Rhabdospaera perlonga* Bramlette and Sullivan, p. 146). There are also intermediate forms between *R. claviger* and *R. stylifer,* which make a proper identification in transmitted light difficult.

The electron micrographs did not show the regular imbricate arrangement of the calcite rhombs (see Cohen, 1964, pl. 6, fig. 1) but offer a more confuse image; the elements in the stem appear to be very narrow; their exact form and placing is not fully disclosed. The robust stem with the abrupt termination of the distal end and the circular basal plate at the proximal end are characteristic for the species. The outer edge of the basal plate shown in pl. 23, fig. e is formed by about 32 elements placed without appreciable overlap. The structure of the central part is not fully disclosed but there seems to be a great number of elements present.
Dimensions: Length: $5\frac{1}{2}$–13 μ; width of basal plate: $3\frac{1}{2}$–4 μ.

Distribution: Rare to very rare in the northern part of the Adriatic; common in the southern part with a preference in samples far from the coast. Reported in Pleistocene and (sub)recent deep-sea cores and living in the Mediterranean and Atlantic. Probably cosmopolitan today.

Rhabdosphaera stylifer Lohmann, 1902

Pl. 3, figs. d—f; Pl. 21, figs. c—f; Pl. 23, figs. b?, c, d,

1902 *Rhabdosphaera stylifer* Lohmann, p. 143, pl. 5, fig. 65.
1941 *Rhabdosphaera stylifer* Lohm., Kamptner, p. 96, pl. 15, figs. 148, 149, p. 115.
1955 *Rhabdosphaera stylifer* Lohm., Halldall and Markali, p. 16, pl. 20.
1964 *Rhabdosphaera stylifer* Lohmann, Cohen, p. 242, pl. 6, fig. 2.

Remarks: In transmitted light this form is much smaller than *R. claviger*; at the dista end of the straight stem a faint widening can be observed (pl. 3, fig. d).

Pl. 21, figs. c and d forming a stereoscopic pair show a stem which is not exactly straight and appears to be hollow at the transition to the basal plate. Four wing-like folds can be seen (the fifth is at the back side: see Kamptner, 1941, p. 96); these appear to form extensions of the structural elements forming the stem. A blunt point at the distal end of the stem sticks out from between the folds (see pl. 23, figs. c, d). Narrow, elongate elements form the stem; they appear to be placed in imbricate arrangement (see pl. 23, fig. c).

The lamellae in the basal plate are arranged in curved, radial lines. The arrangement appears to be similar to those of pl. 23, fig. b, a structure only tentatively assigned to *R. stylifer*. This plate seems to be elliptical (like in pl. 21, figs. c and d; see also p. 8), and should have a central opening. A great number of diversified units form a tightly-fitting mosaic surrounded by about 23 rhombohedral elements, which form the outer edge (= a flat segmented ring of lamellae, Halldal and Markali (1955, p. 16).

Pl. 21, figs. e, f forming a stereoscopic pair, shows probably the same species; corrosion must have broken off the folds.
Length: 2½–6 μ; width basal plate: 1½–4 μ.

Distribution: Rare to fairly common in in-shore samples; (very) abundant in samples far from the coast. Reported from Pleistocene and (sub)recent deep-sea cores. Living in the Mediterranean; probably cosmopolitan today.

Rhabdosphaera vatricosa Cohen spec. nov.

Pl. 21, figs. a, b.

Derivatio nominis: vatricosa (lat.) = club-footed.

Description: Figs. a and b, forming a stereoscopic pair, show a rhabdolith-like form with circular basal plate and straight stem with a club-like structure at the distal end. The basal plate consists of a great number of angular elements surrounded by about 26 roughly rectangular units, which are rounded at the outer edge probably as a result of corrosion. They are arranged in a single peripheral row. The stem consists of a great number of elongate elements, usually found to be present in the stem of forms like this. The club-like protrusion at the distal end of the stem is most unusual, because this is definitely different from the wing-like folds shown by *R. stylifer*. However, the structure of this part is not fully revealed in the specimen shown. Length about 4½ μ; width about 3½ μ.

Distribution: Unknown, because this form is probably difficult to distinguish from other rhabdoliths in transmitted light. The form must have been included with *R. stylifer* in table I.

? *Rhabdosphaera* sp.

Pl. 22, figs. c, d.

Description: This form is only provisionally assigned to the genus *Rhabdosphaera*; the unusual structure and the irregularly shaped "elements" form a reason of doubt. The round protrusion at one end of the stem could be the basal plate; secondary lime deposition has possibly made this part unrecognizable. This also holds for the slightly tapering stem, a detail of which is shown (enlarged) in fig. d. The composing elements show an extreme irregularity both in form and placement. The author does not think it impossible that this is a fragment of the skeleton of some invertebrate.
Length: 11 μ; width: 4½ μ.

Distribution: Unknown. This form was not recognized in transmitted light.

Genus DISCOSPHAERA Haeckel, 1894

Discosphaera tubifer Murray and Blackman, 1898

Pl. 3, figs. g—i; Pl. 23, fig. a.

1898 *Discosphaera tubifer* Murray and Blackman, pp. 438, 439, pl. 15, figs. 8—10.
1955 *Discosphaera tubifer* (Murr. and Blackm.) Lohm., Halldal and Markali, p. 17, pl. 22.
1964 *Discosphaera tubifer* Murr. and Blackm., Cohen, pp. 242, 244, pl. 5, fig. 3 a—c, pl. 6, fig. 3 a—e.

Remarks: This fragile form consists of a trumpet-like appendix with a basal plate (vaguely shown in pl. 3, fig. g). The recurvature of the edge of the trumpet seems in our form to be less than indicated in the original designs (Murray and Blackman, 1898).

The electron micrograph shows a discosphaera-like cup with the outer edge recurving to some extent. The straight sides of the cup are somewhat unusual; this might be the result of corrosive action.
Length: 5–5½ μ; width: 3½–4 μ.

Distribution: Very rare in the northern part of the Adriatic, but fairly common in the southern part; preferably in samples far from the coast. Recorded in Pleistocene and (sub)recent deep-sea cores. Reported from the Atlantic (Gulf Stream) and Mediterranean.

? *Discosphaera thomsonii* Ostenfeld, 1899

Pl. 12, fig. e.

1874 *Rhabdolithus* Murray and Thomson, p. 38, pl. 3, fig. 4.
1899 *Discosphaera Thomsonii* Ostenfeld, p. 436.
1930 *Discosphaera Thomsonii* Ostenfeld, Schiller, pp. 254, 255, fig. 134.

Remarks: This cup-shaped discosphaera is tentatively identified as *D. thomsonii.* The cup placed at the distal end of the stem is a hollow structure composed of curved elements of irregular form. The build-up of this part of the form remains undisclosed partly as a result of the poor quality of the replica. The long, straight stem terminates abruptly at the proximal end. The exact form and placement of the elements forming the stem are not revealed.
Length: 5 μ; width: 2½ μ.

Distribution: This form was not recognized as such during the counting and has probably been included with *R. stylifer* because both forms have a narrow, straight stem and are about of same size. Reported from the (sub)tropical waters and bottom sediments of the oceans; probably present in the Mediterranean and Adriatic (Schiller, 1930).

Genus SCAPHOLITHUS Deflandre, 1954

Scalpholithus sp. Deflandre

Pl. 3, figs. j—l; Pl. 25, figs. a—d.

1953 *Calciosolenia* Gran, Deflandre. In: Deflandre and Fert, p. 310, pl. 1, fig. 5.
1954 *Scapholithus fossilis* types *scalae* and *alternans* Deflandre and Fert, pp. 129, 164, 165, pl. 7, figs. 1—9; pl. 8, figs. 12—17.
1964 *Scapholithus fossilis* Deflandre, Cohen, p. 244, pl. 3, fig. 4 a—f, fig. 2 a—c.

Remarks: The rhombic form is the only observable character, which can be seen in transmitted light. Insufficient resolution prevents the observation of additional structural details (see Deflandre and Fert, 1954).

The electron micrographs of pl. 25, figs. a and b form a stereoscopic pair and show the type *scalae* in which singular bars (about 13 in our specimen) form "the bottom" of the structure. The sides appear to be thin and smooth on the outside, but show irregular lime sedimentation on the inside. Each flank appears to be one structural element. Fig. c shows the form from the other side. The flanks form a sharp ridge; each ridge consists of a great number of structural elements, which probably help in fastening the ribs to the sides. The wide, rounded, middle part of the flanks can be observed. Fig. d shows the type *alternans*; the flanks are straight and not rounded or wider in the middle part.
Length: $3\frac{1}{2}$–9 μ.

Distribution: Rare in in-shore samples; abundant in samples far from the coast (observe the difference between the samples 297 and 295). Recorded in Pleistocene and(sub)recent deep-sea cores. Reported from the Eocene of California and the Late Tertiary of North Africa. Found living in the Adriatic and the (sub)tropical Atlantic.

Genus CYCLOCOCCOLITHUS Kamptner, 1954

Cyclococcolithus leptoporus (Murray and Blackman, 1898)

Pl. 2, figs. h, i; Pl. 18, figs. a—e; Pl. 19, figs. a, b; Pl. 20, figs. a, b.

1898 *Coccosphaera leptopora* Murray and Blackman, p. 430, pl. 15, figs. 1—7.
1954 *Cyclococcolithus leptoporus* (Murr. and Blackm.), Kamptner, p. 23, 24, fig. 20.
et multis auctoribus.

Remarks: In transmitted light this strictly circular form shows a circular central part with a small pore in the centre surrounded by a ring of curved striae (see Bramlette and Martini, 1963, pl. 102, figs. 4, 5). Pl. 2, fig. h gives a proximal view, with clockwise curved lamellae. There is considerable variation in the number, curvation and thickness of the lamellae (see Kamptner, 1955, figs. 67–69 and 72–74).

Both discs are well exposed in the electron micrographs of pl. 18, fig. e and pl. 19, figs. a, b. The sutures between the elements are distinctly curved in the first but nearly straight in pl. 19, fig. b. The number of elements forming the discs are the same in one individual. Pl. 18, figs. a, b and c and pl. 20, fig. a show only one plate with a clockwise curvation of the elements: they represent probably the proximal side of the distal(?) plate (see Kamptner, 1941, pl. 13, fig. 139; Deflandre, 1952, fig. 343 G). From 24 to 32 elements have been counted in the plates.

Pl. 18, fig. d has only 17 elements, placed in sinistral imbrication around a small central hole. There appears to be some similarity in the number and curvature of the elements, with those of *C. fragilis* Lohmann (see Deflandre and Fert, 1954, pl. 6, figs. 1–3), but the central, circular opening of *C. fragilis* is not present in the form presented.

The specimens shown in pl. 19, figs. a and b are smooth; those shown in pl. 18, figs. a and b and pl. 20, fig. a (see also detail in fig. b) are grooved and look worn. The smooth forms are probably modern forms, the grooved, fossil specimens. Pl. 18, fig. e shows in the slightly depressed central area of the proximal plate, an intricate pattern of sutures, which probably indicates a great many small elements to be present there; together they form a circular area separated from the large curved plates forming the rest of the disc, by a circular groove.

Discussion: The importance of the curvature of the sutures between the plates has been mentioned before (Deflandre and Fert, 1954, p. 150). The importance of the direction of curvature is as yet unknown. We should like to mention in this connection *Cyclococcolithus leptorus* var. *inversus* Deflandre and Fert (1954), a form with inverse curvation of the striae. This name might be applicable to some of the specimens shown by us, like pl. 18, fig. e and pl. 20, fig. a.
Diameter distal plate: $7\frac{1}{2}$–$13\frac{1}{2}$ μ; proximal plate: 4–$8\frac{1}{2}$ μ.

Distribution: Common in the bottom samples, with no apparent preference as to sample location. Reported from Pleistocene and (sub)recent deep-sea cores. Reported from the Pacific, Atlantic and Mediterranean. Similar forms have been found as far back as the Jurassic.

Cyclococcolithus cf. *formosus* Kamptner, 1963

Pl. 2, figs. a—g; Pl. 19, figs. c—e.

1963 *Cyclococcolithus formosus* Kamptner, pp. 163, 164, pl. 2, fig. 8, text-fig. 20.

Remarks: In plan view large central pore with two concentric rings around it; these rings correspond with the edges of the two plates. In side view we observe a large, curved distal plate connected via a central tube with a smaller, circular, proximal plate or ring. In plan view distinctly different from *C. leptoporus* in having a large central pore and rings around it (see also Stradner, 1963b, pl. 24, figs. 3, 4).

Kamptner (1963) in his description of *C. formosus* indicates, that about 50 straight-edged elements are found in the distal plate. We are not able to count their number in our forms, but the elements appeared not to be straight, but curved. The electron micrographs of forms comparable to those seen in transmitted light have only 16 and 20 (counter-clockwise curved) elements. The extinction cross in polarized light between x-nicols corresponds with that of Kamptner's form: the arms of the cross have a constant thickness from the outer edge to the central pore.

It appeared, that there were many transitional forms between this species and *C. leptoporus* (observe the difference in structural dimensions between figs. c and f of pl. 2). There is little doubt that this is an allochthonous form (both Kamptner's and Stradner's specimens originated from Lower Tertiary strata); the corroded state of the carbon replicas points in the same direction. Pl. 19, fig. c shows a remnant from what once might have been a circular form; this specimen has no central pore.
Diameter: 4–9 μ.

Distribution: Rather common in most bottom samples, but preferably found in samples from locations near the coast. Reported from the Lower Tertiary of Austria. Found in Upper Eocene, Oligocene and Lower Miocene strata of the northern Apennines.

Genus ZYGOLITHUS Kamptner, 1949

Zygolithus dubius Deflandre, 1954

Pl. 4, fig. f.

1954 *Zygolithus dubius* Deflandre and Fert, p. 149, text-figs. 43, 44, 68.
1956 *Coccolithus tetracellus eleganticus* Chamray and Lazareva, p. 713, pl. 1, no. 5.
1957 *Zygolithus dubius* Deflandre, Gorka, p. 267, pl. 1, fig. 6.

Remarks: Smooth elliptical form with a structure in the central area in the form of the letter H. There is no electron micrograph available for description.
Length about: 8 μ.

Distribution: Very rare in the bottom samples. Reported from the Jurassic of North Africa; the Upper Cretaceous of Poland and the Eocene of the U.S.S.R., France, Germany, Czechoslovakia and the Miocene of Hungary.

Genus ZYGRHABLITHUS Deflandre, 1959

Zygrhablithus ? turriseiffeli (Deflandre, 1954)

Pl. 4, fig. g.

1954 *Zygolithus turriseiffeli* Deflandre and Fert, p. 149, pl. 13, figs. 15, 16, text-fig. 65.
1964 *Zygrhablithus ? turriseiffeli* (Deflandre), Bramlette and Martini, p. 304, pl. 3, figs. 18—21; pl. 4, figs. 1—2.

Remarks: Elliptical form of which the structure especially of the basal plate, has not been fully revealed in ordinary light. Polarized light and x-nicols shows a characteristic extinction pattern according to the structural elements present (see fig. g). A stem has not been observed (probably broken off).

We have also observed, in polarized light between x-nicols, an image like that shown by Stradner (1963a, pl. 5, fig. 9), which seems contradictory to our fig. g (see also Deflandre, 1954). Possibly the proximal and distal sides of the plate have a different structure, resulting in different extinction patterns.
Length about: 9 μ.

Distribution: Rare in the bottom samples; only at in-shore locations. This form seems to be characteristic for the upper part of the Upper Cretaceous.

Zygrhablithus bijugatus Deflandre, 1959

Pl. 4, figs. h—m.

1954 *Zygolithus bijugatus* Deflandre and Fert, p. 148, pl. 11, figs. 20, 21, text-fig. 59.
1954 *Rhabdolithus costatus* Deflandre and Fert, p. 157, pl. 11, figs. 8—11, text-figs. 41, 42, 77—79.
1959 *Zygrhablithus bijugatus* (Deflandre), Deflandre, pp. 135, 136.
1962 *Zygrhablithus bijugatus* (Deflandre), Hay and Towe, p. 502, pl. 2, fig. 2.

Remarks: Single elliptical plate with the central (open) area bridged by two cross bars with a stem in the centre. The four open areas between the bars may be straight-sided but they may also have a more rounded form. If also reduced in size, they are like pores (see fig. k). The lenght of the stem could only measured occasionally, because this part was nearly always broken off. A description of the electron micrograph of this form has been given by Hay and Towe (1962).
Length: 7–9 μ; width: 6–8 μ.

Distribution: Rare in the bottom samples, preferably in samples near the coast. Reported from Oligocene of New Zealand and the Eocene of France.

Genus DEFLANDRIUS Bramlette and Martini, 1964

Deflandrius intercisus (Deflandre, 1954)

Pl. 4, figs. c—e.

1954 *Rhabdolithus intercisus* Deflandre and Fert, p. 159, pl. 13, figs. 12, 13, text-figs. 91, 92.
1959 *Zygrhablithus intercisus* (Deflandre), Deflandre, p. 136, pl. 1, figs. 5—20.
1964 *Deflandrius intercisus* (Deflandre), Bramlette and Martini, p. 301, pl. 2, figs. 13—16.

Remarks: In plan view the (sub)circular basal plate shows an outer margin of about 20 rounded peripheral elements with two diagonal cross bars in the central opening. The basal plate is robust when seen in side view; it is curved and bears a long stem which has extensions at the far end. The latter are often broken off probably as a result of corrosion. The stem is thick and consists of many distinct, calcite elements, giving a "broken" pattern in polarized light between x-nicols (see fig. c). There is no electron micrograph available for description.
Diameter basal plate: 6–9 μ; length stem: 9–11 μ.

Distribution: Rather common in samples near the coast. Reported from the Upper Cretaceous of many parts of the world and reworked in Tertiary strata. According to Stradner (1963a) characteristic for the period of Upper Turonian to Maestrichtian.

Genus COCCOLITHITES Kamptner, 1955

Coccolithites dissitus Cohen spec. nov.

Pl. 11, fig. f.

Derivatio nominis: dissitus (lat.) = apart.

Description: Elliptical shield consisting of a central raised area and a flat outer part with slightly raised edge. The structure appears to be slightly curved with the convex side facing us. A large elliptical opening is present in the centre.

The plate consists of about 70 narrow, elongate elements which are slightly counter-clockwise curved and fit tightly together; the elements appear to be tilted and twisted in the central, raised area and show a dextral overlap there. The outer edge has a regular serration.

There is no picture of this form available in transmitted light.
Length: 7½ μ; width: 6 μ.

Distribution: Unknown. This form has been included within the group *Coccolithus* ? sp. in table I.

Coccolithites viriosus Cohen spec. nov.

Pl. 14, figs. c—e.

Derivatio nominis: viriosus (lat.) = strong, robust.

Description: In plan view, flat, elliptical shield consisting of a central, elliptical area and wide outer edge. In the central area a great number of elongate somewhat wedge-shaped elements (slab-like in fig. c) can be seen, which are roughly radially arranged and converge on a central line according to the long axis (see fig. d). The outer edge is composed of one cycle of roughly rombohedral elements placed in imbricate arrangement. It appears, that these latter are resting on the elements of the central area, obscuring part of the marginal structure of the central plate. It may

very well be, that there is a second structure (plate?) below the one exposed to view, if we consider the "fold" (fig. e, left side) and other "irregularities" near the outer edge.
Length: 5–7½ μ; width: 4–5½ μ.

The three specimens look rather worn, which is probably a result of corrosion; they are probably fossil forms.

Distribution: Unknown. This form was not recognized in transmitted light and has been included within the group *Coccolithus* ? sp. in table I.

Coccolithites kueneni Cohen spec. nov.

Pl. 14, fig. f.

Derivatio nominis: in honor of Prof. Dr. Ph. H. Kuenen, Geological Institute of the University of Groningen.

Description: Single elliptical plate consisting of a central area surrounded by a cycle of peripheral elements. The central area is composed of about 40 roughly wedge-shaped elements imbricately placed and converging on a central, high point. Twenty-six rhombohedral elements, some with a more irregular shape, form the periphery; they are placed dextrally imbricate. There is no picture of his form available in transmitted light.
Length about: 4 μ; width about: 3 μ.

The specimen appears to have been attacked by corrosion; it is probably a fossil form.

Distribution: Unknown. This form was not recognized in transmitted light and has been included within the group *Coccolithus* ? sp. in table I.

Coccolithites repletus Cohen spec. nov.

Pl. 13, fig. a.

Derivatio nominis: repletus (lat.) = filled.

Description: Single, flat elliptical plate consisting of a wide outer margin and a slightly depressed central (structureless?) area. This central area appears to be solidly filled with (secondary ?) $CaCO_3$; it may have been originally an open area, in which case the form shows some resemblance with *Cricolithus scabrosus* (see p. 17). The outer margin is composed of one cycle of about 24 sinistrally imbricate elements. There is no picture of this form available taken with transmitted light.
Length about: 4 μ; width about: 3 μ.

The texture of the specimen appears to be very coarse; in view of the fact, that the central elliptical area might have originally been open, it seems likely, that the whole form is covered by a layer of secondary(?) lime, obscuring the finer details (see p. 7). This is probably also a fossil form.

Distribution: Unknown. This form was not recognized in transmitted light and has been included within the group *Coccolithus* ? sp. in table I.

Coccolithites mendicus Cohen spec. nov.

Pl. 13, fig. b.

Derivatio nominis: mendicus (lat.) = poor.

Description: Small, elliptical disc consisting of one(?) cycle of curved, radially arranged, elements and an irregular slit-like opening in the center. About thirty plates separated by counter-clockwise inclined sutures are present forming a nearly flat disc. It is not likely, that a second (smaller) disc is present below the one exposed, if we consider the thickness of the structure. In the center, a slit-like opening is present, but the structure of the area around it is not fully revealed; it is evident that corrosion (and secondary lime deposition) has disfigured the form, obscuring some structural details.

There is no picture of this form available taken with transmitted light.
Length about 3 μ; width: $2\frac{1}{2}$ μ.

Distribution: Unknown. This form was not recognized in transmitted light and has been included within the group *Coccolithus* ? sp. in table I.

Genus CRIBROSPHAERELLA Deflandre, 1952

Cribrosphaerella ehrenbergi (Arkhangelsky, 1912)

Pl. 4, figs. a, b.

1912 *Cribrosphaera Ehrenbergi* Arkhangelsky, p. 412, pl. 6, figs. 19, 20 (?).
1952 *Cribrosphaerella ehrenbergi* (Arkh.) Deflandre, p. 466, figs. 362 N, O.
1957 *Cribrosphaerella ehrenbergi* (Archangelsky), Gorka, p. 280, pl. 4, fig. 12.

Remarks: Elliptical form ("breit-elliptisch", Kamptner, 1954, p. 12) composed of two discs (M. Deflandre, personal communication). In the central area there are a great number of pores placed at regular intervals along the outer margin and some more in the center. The outer margin shows what appear to be incisions at regular intervals. Most specimens found showed an irregular outline with deep indentations; these latter are probably the result of corrosion during transport.

There is no electron micrograph available for a description.
Length: 6–11 μ; width: 4–7 μ.

Discussion: Stradner (1963a, pl. 2, figs. 1, 1a) indicates this species to be a discolith with one plate. Bramlette (Bramlette and Martini, 1964, p. 301) also shares this view Deflandre (1952) thinks of a placolith-like structure consisting of two plates. Neither Gorka (1957) nor Manivit (1958, p. 20, figs. 8, 9) indicates the number of plates. We do not want to give an opinion yet before additional work has been done.

Distribution: Common in the bottom samples but preferably in samples near the coast. Reported from the Upper Cretaceous of Poland and Russia. Also found in the Eocene of North Africa and France (reworked!). Recorded in Upper Cretaceous and Tertiary sediments of the northern Apennines. According to Stradner (1963a) characteristic for the Upper Cretaceous.

Family THORACOSPHAERIDAE Kamptner, 1927
Genus THORACOSPHAERA Kamptner, 1927

Thoracosphaera heimi (Kamptner, 1927),

Pl. 5, fig. f.

1927 *Thoracosphaera pelagica* Kamptner, pp. 180—184, fig. 6.
1954 *Thoracosphaera Heimi* (Lohm.) Kamptner, pp. 40—42, figs. 41, 42.
1961 *Thoracosphaera heimi* Kamptner, Stradner, p. 8, fig. 75.

Remarks: The poroliths are angular and fit tightly together. Each porolith has a small central pore. There may be an opening at one of the poles, although this seems not always to be the case (Stradner, 1961).
Diameter: 10–20 μ.

Distribution: Rare; preferably in samples far from the coast in the southern part of the Adriatic. Reported from the Mediterranean, Atlantic and Pacific. Probably cosmopolitan but preferably at lower latitudes.

? *Thoracosphaera imperforata* Kamptner, 1946

Pl. 5, fig. g.

1946 *Thoracosphaera imperforata* Kamptner, pp. 100—103.
1955 *Thoracosphaera imperforata* Kamptner, p. 37, pl. 8, fig. 98.
1961 *Thoracosphaera imperforata* Kamptner, Stradner, p. 8, fig. 76.
1964 *Thoracosphaera* cf. *T. imperforata* Kamptner, Bramlette and Martini, p. 305, pl. 5, figs. 1, 2.

Remarks: The units of the shell form a mosaic of irregularly curving and undulating elements closely resembling Stradner's (1961) text-fig. 71 of *T. saxea.* There appears also to be a resemblance with Kamptner's (1955, fig. 98) schematic drawing of *T. imperforata.* Because the forms we found are probably living in the sea today, we tentatively assign these to *T. imperforata.* There is evidently much confusion as to the systematics of this genus making additonal study necessary (see Bramlette and Martini, 1964, p. 305).
Diameter sphere: 10–30(?) μ.

Distribution: Rare in the bottom samples; only found at locations in the southern part of the Adriatic.

Family BRAARUDOSPHAERIDAE Deflandre, 1947

Genus BRAARUDOSPHAERA Deflandre, 1947

Braarudospaera bigelowi (Gran and Braarud)

Pl. 6, figs. a—d.

1935 *Ponthosphaera bigelowi* Gran and Braarud, p. 389, text-fig. 67.
1947 *Braarudosphaera bigelowi* (Gran and Braarud) Deflandre nov. comb., p. 439, text-figs. 1—5.
1961 *Braarudosphaera bigelowi* (Gran and Braarud) Deflandre, Martini, pp. 335—339.
et multis auctoribus.

Remarks: Some pentaliths are angular (figs. a, b), others are rounded (figs. c, d). This probably depends on the degree of corrosion.

There is no electron micrograph available for description (see Hay and Towe, 1962, p. 426, fig. 1).
Diameter: 8–12 μ.

Distribution: Rare in the bottom samples. Only one specimen was found in the Caribbean Pleistocene and (sub)recent deep-sea cores out of a total of many thousands. Reported from strata as old as the Jurassic. It is probably a cool-water form (Martini, 1961).

Genus PEMMA Klumpp, 1953

? *Pemma rotundum* Klumpp, 1953

Pl. 6, fig. e.

1953 *Pemma rotundum* Klumpp, p. 381, pl. 16, figs. 3, 4; text-fig. 2, no. 3.
1962 *Pemma rotundum* Klumpp, Hay and Towe, p. 427, figs. 4, 5.

Remarks: Nearly round plate composed of 5 parts each with a depression. Every part behaves as a singular calcite crystal in polarized light between x-nicols.

An electron micrograph of this form has been given by Hay and Towe (1962). Diameter about 17 μ.

Distribution: Very rare in the bottom samples. Reported from the Eocene of France, Austria and Germany.

INCERTAE SEDIS

Genus DISCOASTER Tan Sin Hok, 1927

Discoaster barbadiensis Tan Sin Hok, 1927

Pl. 7, figs. a—d.

1892 "*Crystalloids*" Jukes-Browne and Harrison, p. 178, figs. 4—6.
1927 *Discoaster barbadiensis* Tan Sin Hok (pro parte), p. 119.
1954 *Discoaster barbadiensis* Tan sens. emend., Bramlette and Riedel, pp. 398, 399, pl. 39, figs. 5a, b.
1962 *Discoaster barbadiensis* Tan Sin Hok, Hay and Towe, p. 515, pl. 10, figs. 3, 5.

Remarks: There is some variation in number and termination of the rays. The variability of the form can not be properly evaluated, because all forms found were corroded to some extent: the tips of the rays were often broken and the stem when observed in side view was partly or completely destroyed. From ten to twelve rays were counted; some with pointed, others with rounded tips.

An electron micrograph of this form has been published by Hay and Towe (1962).
Diameter: 10–17 μ.

Distribution: Common in in-shore samples. Reported from the Upper Cretaceous (?) and Paleocene of some areas; common in the Eocene of many parts of the world. Recorded in the Oligocene of the northern Apennines.

Discoaster challengeri Bramlette and Riedel, 1954

Pl. 7, figs. e—g.

1927 *Discoaster molengraaffi* var. γ Tan Sin Hok, p. 121, text-fig. 2, fig. 11.
1954 *Discoaster challengeri* Bramlette and Riedel, p. 401, pl. 39, fig. 10.
1963 *Discoaster challengeri* Bramlette and Riedel, Bramlette and Martini, p. 851, pl. 103, figs. 11, 12.

Remarks: The parallel sides of the rays and the relatively small central area can be seen best in fig. g. The central area in fig. e appears to be somewhat larger. Fig. f is problematical and resembles in some aspects *Discoaster variabilis* Bramlette and Martini (1963, p. 854, pl. 104, figs. 4–9): a large central area with a structure in the center, the tips of which extend to the margin between the rays. Our specimen is not resting exactly horizontal, which makes a proper identification difficult. There is no electron micrograph available for description.

Diameter: 9–18 μ.

Distribution: Rare in the bottom samples, but preferably in samples near the coast. Reported from the Upper Oligocene (?) and Miocene of Trinidad and Late Tertiary of many parts of the world. This species is generally considered to be characteristic for the Late Tertiary.

Discoaster deflandrei Bramlette and Riedel, 1954

Pl. 7, fig. h.

1954 *Discoaster deflandrei* Bramlette and Riedel, p. 399, pl. 39, fig. 6; text-fig. 1a—c.

Remarks: A relatively large central area with usually six bifurcating rays is characteristic for this species. The sides of the rays are not parallel as in *D. challengeri* and the areas between the rays are rounded. The bifurcating ends in our forms were often rounded or had been broken off.

No electron micrograph is available for description.

Diameter: 9–15 μ.

Distribution: Very rare in the bottom samples; preferably in samples near the coast. Reported from the Eocene of Austria and California; the Oligocene and Miocene of Mexico, Trinidad and many parts of the world.

Discoaster surculus Bramlette and Martini, 1963

Pl. 7, figs. i, j.

1961 *Discoaster brouweri* Tan Sin Hok, Stradner, In: Stradner, H. and Papp, A., pl. 20, figs. 2, 3, 6: (non *D. brouweri* Tan Sin Hok, 1927).
1963 *Discoaster surculus* Bramlette and Martini, p. 854, pl. 104, figs. 10—12.

Remarks: The trifurcation with one spine out of plane with the other two is characteristic.

Diameter about 15 μ.

Distribution: Very rare in samples near the coast. Reported from the Pliocene of the experimental Mohole drilling (Pacific).

Discoaster ? lodoensis Bramlette and Riedel, 1954

Pl. 25, fig. e.

1954 *Discoaster lodoensis* Bramlette and Riedel, p. 398, pl. 39 figs. 3a, b.

Remarks: The electron micrograph shows the central area of a strongly corroded Discoaster which could be that of *D. lodoensis*. The curvation of the Lineae interradiales is not revealed but it seems that the convex side is facing us (see Stradner, 1961, p. 54, table 3).

Genus MICULA Vekshina, 1959

Micula decussata Vekshina, 1959

Pl. 6, figs. f—m.

1959 *Micula decussata* Vekshina, p. 71, pl. 1, fig. 6; pl. 2, fig. 11.
1963 *Micula decussata* Vekshina, Maslov, In: Osnovy Paleontologii, fig. 23, p. 157.
(See further Bramlette and Martini, 1964, p. 318 for a more complete synonymy).

Remarks: There appears to be some variation in size and form of this species. We found small forms with concave sides, being more spinose (see figs. f and g) like those figured by Stradner & Papp (1961, p. 102, 103, pl. 31, fig. 1 a–d), called *Nannotraster concavus*; but we found also more voluminous and less well defined, more massive forms (figs. h–m), like Stradner's figs. 2–4 (1961, pl. 31, pp. 101, 102).

The peculair behaviour in polarized light between x-nicols indicates that this form has a heliolithid structure contrary to the ortholithid structure of *Rhomboaster cuspis* Bramlette and Sullivan (1961, p. 166, pl. 14, figs. 17, 18, 19 a–c) with which *M. decussata* has a superficial resemblance.

The name *Micula staurophora* (Gardet) is being rejected because both the illustration and description (Gardet, 1955, p. 534, pl. 10, fig. 96) of *Discoaster staurophorus* are totally inadequate although accepted by some and considered the prior name. Evidently the North-African form of Gardet has not been found at the original location.

There is no electron micrograph available for description.

Diameter: 4–11 μ.

Distribution: Common in samples near the coast, preferably in the northern part of the Adriatic. Recorded in the Upper Cretaceous of the Rocky Mountains region (Cohen, unpublished thesis University of Utah, 1959) and the Upper Cretaceous and Tertiary of the northern Apennines. Reported from the Upper Cretaceous and Tertiary of widely separated regions from the world such as Europe (France, Denmark, Germany and Austria), Australia, New Zealand, the U.S.A. and Siberia, Earliest occurrence in the Campanian and Santonian (Bramlette and Martini, 1964, p. 320).

Genus LITHOSTROMATION Deflandre, 1942

Lithostromation perdurum Deflandre, 1942

Pl. 6, figs. n—p.

1942 *Lithostromation perdurum* Deflandre, pp. 917—919, figs. 1—9.

Remarks: The large lime body has a characteristic triangular shape. The very irregular surface has many perforations and recesses.

There is no electron micrograph available for description.

Diameter about 12 μ.

Distribution: Very rare in the bottom samples. Reported from the Middle Eocene and later Tertiary sediments of Germany, Austria, Italy and North Africa.

Genus SPHENOLITHUS Deflandre, 1952

Sphenolithus? sp.

pl. 5, figs. h—m.

1963 *Sphenolithus?* sp. Bramlette and Martini, p. 855, pl. 102, figs. 6, 7.

Remarks: In transmitted light this form is indistinct. In polarized light between x-nicols a characteristic black extinction cross indicating the radial arrangement of the component parts can be seen. The exact structural build-up is as yet unknown, mainly because there is no electron micrograph available for description.

The resemblance with *Sphenolithus abies* Deflandre as depicted in pl. 10, figs. 1–4 (Deflandre and Fert, 1954, p. 164) indicates, that a relationship between the two forms is likely.

Diameter: 3–6 μ.

Distribution: Common in the bottom samples, preferably in samples near the coast. Recorded in Upper Eocene, Oligocene and Miocene strata of the northern Apennines. Reported from the Miocene of the Mohole drilling (Pacific).

Sphenolithus radians Deflandre, 1954

Pl. 5, figs. n—p.

1954 *Sphenolithus radians* Deflandre, p. 163 pl. 12, figs. 36—38, text-figs. 109—112.

Remarks: In transmitted light indistinct. In polarized light between x-nicols we distinguished what could be considered as the prismatic basal part having a flat, curved or irregular basis. There appears to be some sort of constriction at the transition to the upper or conical part. The basal part consists of a number of elongate elements placed in radial arrangement. The heliolithid arrangement of the structural parts is evident when turning the microscope stage. The upper or conical part is wedge-shaped and is illuminated at the 45° position.

There is no electron micrograph available for description.

Dimensions: Height: 6–8 μ; width: 2½–3½ μ.

Distribution: Rather common in samples near the coast, preferably in the northern part of the Adriatic. Recorded in Oligocene and Miocene strata of the northern Apennines. Reported from the Eocene of California, France and North Africa.

Genus FASCICULITHUS Bramlette and Sullivan, 1961

Fasciculithus involutus Bramlette and Sullivan, 1961

Pl. 5, figs. q—v.

1961 *Fasciculithus involutus* Bramlette and Sullivan, p. 164, pl. 14, figs. 1a—c, 2a—c, 3a—b, 4a—b, 5a—b.

Remarks: The end view shows in transmitted light a rosette-like structure which appears to be formed by a number of petal-like elements which are arranged around a central area. In polarized light between x-nicols, the heliolithid arrangement of the composing calcite elements is evident; second order interference colors are indicative of its unusual thickness. This is not contradictory to the "fasci-like" structure described by Bramlette (see Bramlette and Sullivan, 1961). Their figs. 4 and 5 of pl. 14 are forms often obversed by us, but their figs. 2a, b. We did not find.

This form has a considerable size range: the central area around which the elements are arranged can be point-like, but is sometimes also a well defined area as in pl. 5, figs. s-v, with the radially placed elements proportionally larger.

There is no electron micrograph available for description.

Diameter: 4½–12 μ.

A close affinity with forms belonging to the genus *Lithastrinus* (Stradner, 1962, pp. 369–372, pl. 2, figs. 6–11) seems likely.

Distribution: Very rare in the bottom samples but rather common in some samples near the coast. Reported from the Paleocene of the U.S.A. and west and central Europe.

Genus LUCIANORHABDUS Deflandre, 1959

Lucianorhabdus cayeuxi Deflandre, 1959

Pl. 5, figs. a—e.

1959 *Lucianorhabdus cayeuxi* Deflandre, pp. 142—143, pl. 4, figs. 11—25.

Remarks: The form presented is tentatively identified as *L. cayeuxi.* We found quite a variety of forms, some like those depicted by Deflandre (1959). Fig. 5e gives an apical or top view of the form; the other half has been broken away, a thing which often happens (M. Deflandre, personal communication). The form pictured in figs. a–c appears to be smaller in size than any form figured by Deflandre (1959). Reworked as they must be, the rest has probably been broken away.

No electron micrograph is available for description.

Length: 6–25 μ; width: 5–10 μ.

Distribution: Not uncommon in samples near the coast; preferably in the northern part of the Adriatic. Reported from the Upper Cretaceous of Europe and Australia. According to Stradner (1963a) characteristic for the Upper Cretaceous.

Genus CERATOLITHUS Kamptner, 1950

Ceratolithus cristatus Kamptner, 1954

Pl. 3, figs. m, n.

1954 *Ceratolithus cristatus* Kamptner, pp. 43—45, figs. 44, 45
1964 *Ceratolithus cristatus* Kamptner, Cohen, p. 246, pl. 5, fig. 5 a—d, pl. 6, fig. 5.

Remarks: Only the smooth and smaller form (Cohen, 1964) was found in the samples. Most of the specimens, however, had rounded and not sharply pointed horns; the horns were generally further apart than in the forms observed earlier (Cohen, 1964). Not a single specimen was found of the more robust type, pictured in pl. 5, figs. 5 b–d and pl. 6, fig. 5 (Cohen, 1964); this form was named *C.* aff. *C. cristatus* by Bramlette (Bramlette and Martini, 1963, p. 854) and seems to be limited to the Pliocene.

There is no electron micrograph available for description.

Length: 6–10 μ; width: 5–9 μ.

Distribution: Not uncommon in samples far from the coast. Recorded in Pleistocene and (sub)recent deep-sea cores. Found living in the Florida Current (Cohen, 1964). Probably cosmopolitan today, but the form may be restricted to (sub)tropical areas.

Unnamed specimen of doubtful generic affiliation

Pl. 15, fig. f.

Remarks: There is no picture of this form in transmitted light available for description.

The electron micrograph shows a structure consisting of two plates (?) closely pressed together and of different size. Each plate appears to consist of three slightly arched sectors separated by inward incurvatures, which seem to continue to a slightly depressed center. The edge of each sector is made up of about 10 elements separated by slightly (clockwise) curved sutures. The bends between the sectors of both plates do not coincide: those of the smaller plate are displaced slightly counter-clockwise in relation to those of the larger plate. The size, the structural build-up of the two plates and the displacement of the incurvatures between the sectors suggest a relationship to the genus *Lithrastrinus* (Stradner, 1962).

Diameter about 7 μ.

Distribution: Unknown. This form was not recognized in transmitted light.

DISCUSSION OF RESULTS

It was obvious even before the counting, that there is a consistent decrease of land-derived material in the samples with increasing distances from the (Italian) coast. The number of discoasters can be considered as a clear indication of this trend (see table I). Obviously, these extinct forms could have been coming only from land.

It soon became evident that there were also many Upper Cretaceous and Cainozoic coccoliths present in the bottom samples. Especially many of the Upper Cretaceous forms showed a peculiar behaviour in polarized light between crossed nicols, in that they did not show the wavy extinction so often found with their (sub) recent relatives. Instead, many showed small well-defined crystalline units with rounded outlines. These forms decreased in number in samples with increasing distances from the coast. They were the same species, which the author had observed before in samples of Upper Cretaceous age (Mancos shale) of the Rocky Mountains region of the central U.S.A. (unpublished master's thesis, University of Utah) with their peculiar pore arrangement and other structural properties.

Many of these forms are described in publications dealing with Upper Cretaceous rocks, such as those of Bramlette & Martini (1964), Vekshina (1959), Gorka (1957, 1963) and others.

It seems very likely that these fossil forms are allochthonous, originating from the mountains of the Italian mainland and transported by rivers down to the coast, from where they were swept out into the open sea by currents. The particular behaviour of some of these Upper Cretaceous forms in polarized light between crossed nicols is probably partly the result of recrystallization during diagenesis, partly that of their original structural properties. As a check a number of samples from the Upper Cretaceous of Italy were investigated. It turned out that they contained numerous species which showed these same pecularities. The fact that in the land samples these forms were abundantly present can be used as an additional proof for the allochthonous aspect of these same species found on the bottom of the sea.

On the other hand a larger number of (sub)recent forms was found at locations farther from the coast. A number of publications dealing with the living forms of this particular area such as those of Kamptner (1927, 1937, 1941) and Schiller (1913, 1925, 1930) together with the author's own experience with Pleistocene and (sub) recent forms in deep-sea cores from the Caribbean (Cohen, 1964, and in press) was felt to be a firm enough basis for deciding whether a form could be considered to be (sub) recent. A subdivision was made of each sample, in discriminating between (sub) recent forms (marked with an asterisk); allochthonous or land-derived forms (marked with an a) and a third group (marked with a question mark) composed of species of mixed or questionable origin. Among this last group are the many forms, which have been lumped together under the heading the *Coccolithus?* sp. in table I and in the systematic descriptions. Most of the forms included in the latter group are probably also land-derived, because this group decreased sharply in number in most cross sections, when the samples were considered with increasing distances from the coast. This subdivision of the taxa in land-derived species, species of (sub)-recent origin and a third group when considered in their relative amounts, formed the basis for the enumeration in the last column of table II of:

1) the samples with allochthonous aspect;

2) the samples with pelagic aspect;

3) those with intermediate aspect.

This result, indicated on map II, shows that the character of the samples coincides with the general circulation pattern in the Adriatic.

There are a few irregularities, such as the land aspect of sample no. 342 and the intermediate aspect of the samples nos. 239 and 338. These discrepancies are easily accounted for by the pecularities of the current system, as described in the

TABLE II

Samples with counted coccoliths and discoasters

No.		*Depth*	*Geographic Location*		*Source area of prevalent constituents*
			lat.	*long.*	
1.	125	15	45°27.0′	12°38.5′	allochthonous aspect
2.	128	23	45°22.0′	12°43.9′	allochthonous aspect
3.	131	30	45°16.1′	12°49.5′	intermediate aspect
4.	133	30	45°11.0′	12°52.0′	intermediate aspect
5.	135	35	45° 9.0′	13° 9.5′	intermediate aspect
6.	138	38	44°51.8′	13°18.1′	pelagic aspect
7.	165	10	44°45.0′	12°20.4′	allochthonous aspect
8.	167	23	44°44.8′	12°30.2′	allochthonous aspect
9.	169	35	44°43.0′	12°52.0′	allochthonous aspect
10.	171	40	44°41.4′	13°14.1′	pelagic aspect
11.	173	40	44°39.6′	13°37.0′	pelagic aspect
12.	335	26	43°50.6′	13°17.2′	allochthonous aspect
13.	334	68	43°57.2′	13°31.7′	intermediate aspect
14.	333	71	44° 3.7′	13°45.6′	intermediate aspect
15.	332	68	44°10.2′	13°57.5′	intermediate aspect
16.	331	64	44°20.5′	14°16.7′	pelagic aspect
17.	326	20	43°25.6′	13°49.7′	allochthonous aspect
18.	325	68	43°37.9′	14° 3.4′	allochthonous aspect
19.	324	88	43°30.4′	14°17.3′	allochthonous aspect
20.	323	84	43°32.6′	14°30.3′	intermediate aspect
21.	322	91	43°37.2′	14°48.2′	pelagic aspect
22.	321	101	43°39.8′	15° 3.8′	pelagic aspect
23.	235	23	42° 2.6′	15° 1.7′	allochthonous aspect
24.	237	75	42° 7.5′	15° 6.1′	allochthonous aspect
25.	239	130	42°18.4′	15°21.0′	intermediate aspect
26.	268	145	42°30.0′	15°25.0′	allochthonous aspect
27.	266	138	42°42.2′	15°36.5′	pelagic aspect
28.	318	99	42°51.6′	15°52.9′	pelagic aspect
29.	338	128	42°12.0′	16° 6.1′	intermediate aspect
30.	340	179	42° 7.0′	16°36.5′	pelagic aspect
31.	342	249	42°16.3′	16°46.5′	allochthonous aspect
32.	344	355	42°24.2′	16°55.8′	pelagic aspect
33.	348	267	42°28.0′	18° 0.0′	pelagic aspect
34.	298	55	40°52.4′	17°32.6′	allochthonous aspect
35.	297	560	41° 3.3′	17°37.6′	allochthonous aspect
36.	295	1161	41°28.2′	17°50.4′	pelagic aspect
37.	293	1198	41°45.3′	18° 9.0′	pelagic aspect
38.	291	302	41°56.9′	18°30.7′	pelagic aspect
39.	290	122	42° 2.8′	18°43.6′	pelagic aspect

section on hydrography, and the sometimes very small differences in species distribution between the samples. The general aspect shows consistently samples with deep-sea aspect along the eastern side of the Adriatic where the incoming current flows from the open Mediterranean. Samples with land aspect occur along the western side. Particularly at the southern end of the west side of the Adriatic, near Bari and Brindisi, where few (Italian) rivers debouch into the sea, relatively strong long-shore currents must have transported land-derived material from the north along the coast, resulting in a marked difference in composition between samples no. 295 and 297. It is also clear that the supply of material from land along the eastern or Yugoslavian side of the sea is negligible: no increase is observed in the number of discoasters or the number of characteristic extinct species such as: *Zygrhablithus? turriseiffeli*, *Deflandrius intercisus*, *Cribrosphaerella ehrenbergi*, *Micula decussata* and *Sphenolithus radians* near that coast.

The cause is probably that the few Yugoslavian rivers, which contain little or no water part of the year, carry very little material into the sea.

Hydrography

As a result of a number of expeditions carried out by the Austrian ship S.M.S. Najade during the years 1911–14, we may present a few observations about the water movements in the Adriatic (Brückner & Grund, 1911–14).

Relatively warm water of high salinity enters the Adriatic at the surface, in the central and eastern part of the Otranto Straits. This water moves in a northerly direction along the Dalmatian coast to the Istrian peninsula and farther north where it makes a turn to the west. On its way north this (main) current gives off secondary branches which cross the Adriatic turning south again on reaching the Italian coast. Therefore relatively cold water of low salinity moves southeast along the Italian side of the Adriatic and escapes through the western part of the Otranto Straits into the Mediterranean (see map II). The low salinity is a result of the considerable quantities of river water from the Po and many other smaller streams flowing into the sea along its western side. This whole circulation pattern is essentially the result of the earth's rotation.

It has further been observed, that the velocity of the water movements at the surface is much greater than down below. For instance, it takes on the average three months for the upper 30 m water along the Dalmatian coast to be renewed, which means that in the meantime, the old water mass has been moved over to the west or Italian side of the sea. It takes twice as long for the upper 30 m of the Adriatic as a whole to be renewed. Down at 50 m it takes a year for the whole Adriatic and at 100 m it takes one and a half year for complete renewal.

At greater depth, we find horizontal (advection) current, which throws the first mentioned general circulation pattern out of balance, which means that this is only applicable to the upper water layers. The influence of climatological factors, such as air temperature, rainfall and last but not least wind direction and wind force, which seem to vary considerably in this area from one year to another, should not be underestimated (see also Jerlov, pp. 235, 237, 241). They appear to exert a strong effect on the water movements.

It became evident that horizontal water movements are the rule, often resulting in a vertical density layering of the water body. Vertical convection currents resulting in a homothermal and homohyaline water column are more the exception than the rule. Especially in the deeper parts, a layer of cold and heavy water with a low oxygen content is often present, which does not mix with water higher in the column, and prevents the forming of a homogeneous water column.

In the spring there exists, especially at locations were many rivers debouch into the sea, such as along the Italian and Albanian coasts, a thin water layer of low salinity at the surface, so-called coastal water, which can be wide or narrow, depending on the fresh water supply and the wind force and wind direction. Branches of this coastal water are mixed with highly saline sea water, forming complicated cyclonic water movements not only at the surface but also far below (see also Jerlov, p. 241). In a year of plentiful supply of river water, a "bridge", which is actually a cyclonic current, of this coastal water can span the Otranto Straits. The highly saline Mediterranean water north of the Otranto Straits is then cut off at the surface from its Ionian source area.

In spring and early summer, cold northern shelf water flows below the surface to the southeast. This water of rather low salinity does not mix with the heavy and cold deep bottom water farther south, which has a higher density, or with the high saline Mediterranean water at the surface moving north. A density layering results, especially in the deeper parts of the sea.

Complicated water movements have been observed during the summer, when strong northeasterly winds (Scirocco) push the warm surface water away from the Dalmatian coast. Cold bottom water takes its place and the warm surface water is first pushed to the west side of the sea, where it sinks down and moves back at thermocline depth (ca. 25 m depth) to the east side where it comes to the surface again. A reversed circulation which takes place at the same time at greater depth moves cold water to higher levels at the west side, while warm water moves down at the east side of the sea. Evidently, apart from the first mentioned surface circulation along the coasts in longitudinal direction, a cross-circulation takes place under favourable circumstances. Concluding we might say, that there is apparently no consistent circulation pattern in the Adriatic, except perhaps for the upper 25 m if we consider long periods of time. Evidently, the circulation at the surface can be quite different from that at greater depth.

The coccoliths and discoasters being flat, calcareous bodies settle very slowly to the bottom. Simple calculations indicate that the settling velocity of particles in the size range of the elements, we are interested in, lies rather in weeks than in days for depths from 25 to 100 m. The dominating horizontal currents in the Adriatic as described above must transport the bodies over long horizontal distances. The inconsistencies of the direction of the currents makes the regular sedimentation pattern as indicated by these small forms the more surprising. The solution of this apparent inconsistency lies probably in the fact that the diameter of the settling particles is considerably increased by the attachment of clay-size clastic particles and organic debris, enlarging the settling velocity 10 to 50 times. The time interval between death and disintegration of the coccolithophorid is possibly also of importance with respect tot the settling velocity. Very little is known about this period of time, but is seems likely that the intact coccolithophorid will reach the bottom sooner than the singular coccoliths.

CONCLUSIONS

As a result of this investigation it could be demonstrated that the organic part of the fine fraction in the bottom samples of the Adriatic near the Italian coast came for a great part from land, in this case the Italian mainland. No supply of material from the Yugoslavian side of the sea could be detected.

Because the samples were selected in cross-sections perpendicular to the coast, the decreasing influence of land-derived material could be clearly demonstrated with increasing distance from the coast by way of the changing composition of the species in the samples. In each of the seven cross-sections, a consistent decrease of allochthonous forms and a consistent increase of forms of (sub)recent origin could be shown. This result conveniently arranged on a map depicting the current system shows clearly that there must exist a relation between the two.

GEOLOGICAL CONSIDERATIONS

It was suggested before by Bramlette (Bramlette and Martini, 1964; Bramlette and Sullivan, 1961), Stradner (1963), Hay (1962), and others, that coccoliths and discoasters might be used for correlation of marine sediments of widely separated regions. Their use for stratigraphic interpretation and their grouping in biostratigraphic zones has been demonstrated already. In particular the sediments of Cretaceous and Lower Tertiary age appear to lend themselves admirably well for this purpose.

It is of much significance that in spite of their minute size these calcareous particles show generally little effect of solution. The rivers and the sea are apparently saturated with respect to lime. However, the strong tendency of these minute bodies to be reworked and transported for great distances, as demonstrated by the present study, must be considered a serious drawback in stratigraphic use. It appears highly doubtful that in exposures of the distant future of the present Adriatic sediments, the contemporaneous and reworked fossil individuals would be distinguishable from each other.

As a result of the present investigation it was shown that these small organisms can be transported over hundreds of miles without loss of distinctive features. Hence, their quality as "tracers" for the identification of transportation routes including rivers and sea currents has been demonstrated. In an earlier publication (Cohen, 1964) some indications to the same effect had already been brought forward. It might very well be, that a more thorough study of the rocks of the Italian mainland as to their coccoliths and discoasters content might give a more precise image concerning the transportation by rivers and marine currents with respect to the finest fractions ($< 62\ \mu$).

REFERENCES

Arkhangelsky, A. D., 1912. Oberkreide-Ablagerungen des osteuropäischen Russland. Mater. Geol. Russl., vol. 25, pp. 1–631, pls. 1–10.

Baldi-Beke, M., 1961. Untersuchungen an Coccolithophoriden aus dem Miozän des Mecsek-Gebriges. Évi jelentése Évröl. 1, pp. 161–173, 2 pls.

Black, M., 1962. Fossil coccospheres from a Tertiary outcrop on the continental slope. Geol. Mag., vol. 99 (no. 2), pp. 123–127, 2 pls.

Black, M., and Barnes, B., 1961. Coccoliths and discoasters from the floor of the South Atlantic Ocean. Journ. Roy. Micr. Soc., vol. 80 (pt. 2), pp. 137–147, pls. 19–26.

Bouché, P. M., 1962. Nannofossiles calcaires du Lutétien du Bassin de Paris. Rev. Micropal., vol. 5 (no. 2), pp. 75–103, pls. 1–4.

Braarud, T., 1954. Coccolith morphology and taxonomic position of *Hymenomonas roseola* Stein and *Syracosphaera carterae* Braarud and Fagerland. Nytt. Mag. Botan., vol. 3, pp. 1-6.

Bramlette, M. N., and Martini, E., 1963. Calcareous nannoplankton from the experimental Mohole drilling. Journ. Paleont., vol. 37 (no. 4), pp. 845–856, pls. 102–105.

—— 1964. The great change in calcareous nannoplankton fossils between the Maestrichtian and Danian. Micropaleontology, vol. 10 (no. 3), pp. 291–322.

Bramlette, M. N., and Riedel, W. R., 1954. Stratigraphic value of discoasters and some other microfossils related to recent Coccolithophores. Journ. Paleont., vol. 28 (no. 4), pp. 385–403, pls. 38–39.

Bramlette, M. N., and Sullivan, F. R., 1961. Coccolithophorids and related nannoplankton of the early Tertiary in California. Micropaleontology, vol. 7 (no. 2), pp. 129–188, pls. 1–14.

Brückner, E., Grund, A., et al., 1911—1914. 12 Terminfahrten der S.M.S. "Najade" in Hochsee der Adria. Mitt. K. K. Geogr. Ges., Wien, vols. 54–57.

Chamrai, I. A., and Lazareva, E. P., 1956. Coccolithophoridae and their stratigraphic importance. Akad. Nauk. S.S.S.R., Doklady, vol. 108, pp. 711–714, 1 pl. (in Russian).

Cohen, C. L. D., 1964. Coccolithophorids from two Caribbean deep-sea cores. Micropaleontology, vol. 10 (no. 2), pp. 231–250, pls. 1–6.

—— (in press). Coccoliths and discoasters from deep-sea core CP 28.

Deflandre, G., 1942. Coccolithophoridées fossiles d'Oranie. Genre *Scyphosphaera* Lohmann et *Thorosphaera* Ostenfeld. Bull. Soc. Hist. Natur. Toulouse, vol. 77, pp. 125–137.

—— 1942. Sur la conservation de microfossiles calcaraires, notamment de Coccolithophoridés dans les silex sahéliens d'Oranie. Acad. Sci., C.R., vol. 214, pp. 804–805.

—— 1947. Braarudosphaera nov. gen., type d'une famille nouvelle de Coccolithophoridés actuels à éléments composites. Acad. Sci., C.R., vol. 225, pp. 439–441.

—— 1952. Classe des Coccolithophoridés. In: Grassé, P.P. (ed.): Traité de Zoologie. vol. 1 (fasc. 1), pp. 439–470, text-figs. 339–364.

—— 1959. Sur les nannofossiles calcaires et leur systématique. Rev. Micropal., vol. 2 (no. 3), pp. 127–152, pls. 1–4.

Deflandre, G., et Fert, C., 1953. Application du microscope électronique à l'étude des Coccolithophoridés. Bull. Soc. Hist. Natur. Toulouse, vol. 88, pp. 301–313, 4 pls.

—— 1954. Observations sur les Coccolithophoridés actuels et fossiles en microscopie ordinaire et électronique. Ann. Pal., vol. 40, pp. 117–176, 15 pls.

Gaarder, K. R., 1962. Electron microscope studies on Holococcolithophorids. Nytt. Mag. Botan., vol. 10, pp. 35–51, pls. 1–12.

Gardet, M., 1955. Contribution à l'étude des coccolithes des terrains néogènes de l'Algérie Publ. Serv. Carte Géol. Algérie, N.S. Bull. 5, pp. 477–550, 11 pls., 1 text-fig.

Gorka, H., 1957. Les Coccolithophoridés du Maestrichtien supérieur de Pologne. Acta Paleont. Pol., vol. 2, pp. 235–284, pls. 1–5.

—— 1963. Coccolithophoridés, dinoflagellés, hystrichosphaeridés et microfossiles incertae sedis du Crétacé de Pologne. Acta Paleont. Pol., vol. 8 (no. 1), pp. 1–90.

GRAN, H. H., and BRAARUD, T., 1935. A qualitative study of the phytoplankton in the Bay of Fundy and the Gulf of Maine. Journ. Biol. Board Canada, vol. 1, pp. 279–467.

HALLDAL, P., and MARKALI, J., 1955. Electron microscope studies on Coccolithophorids from the Norwegian sea, the Gulfstream and the Mediterranean. Norske Vidensk. Akad., Avh., Mat.-Naturv. Kl. (no. 1), pls. 1–27.

HALLDAL, P., MARKALI, J., and NAESS, T., 1954. A method for transferring objects from a light microscope to marked areas on electron microscope grids. Mikroskopie, vol. 9 (Heft 5/6), pp. 197–200.

HAY, W. W., and TOWE, K. M., 1962. Electron microscope examination of some coccoliths from Donzacq (France). Eclo. Geol. Helv., vol. 55 (no. 2), pp. 497–518, 10 pls.

—— 1962. Electron microscope studies of *Braarudosphaera bigelowi* and some related coccolithophorids. Science, vol. 137 (no. 3528), pp. 426–428.

JERLOV, N. G., 1955. Adriatic thalassographic cruise 1955. II. Distribution of suspended material in the Adriatic Sea. Arch. Ocean. Limnol., vol. 11 (fasc. 2), pp. 227–250.

JUKES-BROWNE, A. J., and HARRISON, J. B., 1892. The geology of Barbados. Part II. The Oceanic deposits. Geol. Soc. London, Quart. Journ., vol. 48, pp. 170–226.

KAMPTNER, E., 1927. Beitrag zur Kenntnis adriatischer Coccolithophoriden. Arch. Protistenk., vol. 58, pp. 173–184.

—— 1937. Neue und bemerkenswerte Coccolithineen aus dem Mittelmeer. Arch. Protistenk., vol. 89, pp. 279–316, pls. 14–17.

—— 1941. Die Coccolithineen der Südwestküste von Istrien. Ann. Naturhist. Mus. Wien, vol. 51, pp. 54–149, pls. 1–15.

—— 1943. Zur Revision der Coccolithineen-Spezies *Pontosphaera huxleyi* Lohm. Anz. Akad. Wiss. Wien, Math.-Naturw. Kl., vol. 80 (no. 11), pp. 43–49.

—— 1944. Coccolithineen-Studien im Golf von Neapel. Wiener Bot. Zeitschr. (= Österr. Bot. Zeitschr.), vol. 93, pp. 138–147.

—— 1946. Zur Kenntnis der Coccolithineen-Gattung *Thoracosphaera* Kpt. Anz. Akad. Wiss. Wien, Math.-Naturw. Kl., Nr. 11, pp. 100–103.

—— 1948. Coccolithen aus dem Torton des Inneralpinen Wiener Beckens. S.-B. Österr. Akad. Wiss., Math.-Naturw. Kl., Abt. 1, vol. 157, pp. 1–16.

—— 1950. Über den submikroskopischen Aufbau der Coccolithen. Anz. Akad. Wiss. Wien, Math.-Naturw. Kl., vol. 87, pp. 152–158.

—— 1952. Das mikroskopische Studium des Skelettes der Coccolithineen (Kalkflagellaten). Übersicht der Methoden und Ergebnisse. I. Die Gestalt des Gehäuses und seiner Bauelemente. Mikroskopie, vol. 7, pp. 232–244. Wien.

—— 1954. Untersuchungen über den Feinbau der Coccolithen. Arch. Protistenk., vol. 100 (Heft 1), pp. 1–90, text-figs. 1–50.

—— 1955. Fossile Coccolithineen-Skeletreste aus Insulinde. Eine mikropaläontologische Untersuchung. Kon. Ned. Akad. Wetensch., Verh., Ser. 2, vol. 50 (no. 2), pp. 1–87, pls. 1–9.

—— 1956a. Zur Systematik und Nomenklatur der Coccolithineen. Anz. Öst. Akad. Wiss. Wien, Math.-Naturw. Kl., vol. 93, pp. 4–11.

—— 1956b. Das Kalkskelett von *Coccolithus huxleyi* (Lohm.) Kpt. und *Gephyrocapsa oceanica* Kpt. Arch. Protistenk., vol. 101 (Heft 2), pp. 171–202.

—— 1963. Coccolithineen-Skeletreste aus Tiefseeablagerungen des Pazifischen Ozeans. Ann. Naturhist. Mus. Wien., vol. 66, pp. 139–204, pls. 1–9.

KLUMPP, B., 1953. Beitrag zur Kenntnis der Mikrofossilien des Mittleren und Oberen Eozän. Palaeontographica, vol. 103 (pt. A), pp. 377–406, pls. 16–20.

LOHMANN, H., 1902. Die Coccolithophoridae, eine Monographie der coccolithenbildenden Flagellaten. Arch. Protistenk., vol. 1, pp. 89–195, pls. 4–6.

—— 1920. Die Bevölkerung des Ozeans mit Plankton nach den Ergebnissen der Zentrifugenfänge während der Ausreise der "Deutschland" 1911. Arch. Boint., vol. 4. (Heft 3), pp. 1–617, pls. 1–16.

MANIVIT, H., 1958. Contribution à l'étude des Coccolithes de l'Éocene. Publ. Serv. Carte Géol. Algérie, N.S., Bull. 25, pp. 331–382, pls. 1–10.

MARKALI, J., and PAASCHE, E., 1955. On two species of Umbellospharea, a new Coccolithophorid genus. Nytt. Mag. Botan., vol. 4, pp. 95–100, 6 pls.

MARTINI, E., 1961. Ein Kalkflagellat in den Meeren der Gegenwart und Vorzeit. Natur und Volk, vol. 91, pp. 335–339.

MARTINI, E., and BRAMLETTE, M. N., 1963. Calcareous nannoplankton from the experimental Mohole drilling. Journ. Paleont., vol. 37 (no. 4), pp. 845–855, pls. 102–105.

METALLO, A., 1955. Il sistema meteo-oceanografico del Mediterraneo. In: Rivista Marittima, pp. 288–303, 1 map.

MURRAY, G., and BLACKMAN, V. H., 1898. On the nature of the coccospheres and rhabdospheres. Roy. Soc. London, Phil. Trans., vol. 190, ser. B, pp. 427–441.

MURRAY, G., and THOMPSON, C. W., 1874. "Challenger" soundings in the Southern Sea. Proc. Roy. Soc. London, vol. 23, pp. 32–49, 4 pls.

NOËL, D., 1956. Coccolithes des terrains Jurassiques de l'Algérie. Publ. Serv. Carte Géol. Algérie, N.S. Bull. 8, pp. 303–345.

—— 1958. Érude des Coccolithes du Jurassique et du Crétacé inférieur. Publ. Serv. Carte Géol. Algérie, N.S. Bull. 20, pp. 156–196, pls. 11.

OSTENFELD, C. H., 1899. Über Coccosphaera und einige neue Tintinniden im Plankton des nördlichen Atlantischen Oceans. pp. 433–436, 1 pl.

SCHILLER, J., 1913. Vorläufige Ergebnisse der Phytoplankton-Untersuchingen auf den Fahrten S.M.S. "Najade" in der Adria 1911/12. I. Die Coccolithophoriden. Sitz. ber. K. Akad. Wiss. Wien, Math.-Naturw. Kl., vol. 122 (Abt. 1), pp. 597–617, pls. 1–3.

—— 1925. Die planktonischen Vegetationen des Adriatischen Meeres. A. Die Coccolithoriden-Vegetation in den Jahren 1911–1914. Arch. Protistenk., vol. 51, pp, 1–130, pls. 1–9.

—— 1930. Coccolithineae. In: Rabenhorst, L., Kryptogamen-Flora, Leipzig, vol. 10 (pt. 2), pp. 89–273.

STRADNER, H., 1961. Vorkommen von Nannofossilien im Mesozoikum und Alttertiär. Erdoel Zeitschr., vol. 77 (no. 3), pp. 77–88, text-figs. 1–99.

—— 1962. Über neue und wenig bekannte Nannofossilien aus Kreide und Alttertiär. Verh. Geol. Bundesanst. Wien, Heft. 2, pp. 363–377, pls. 1–3.

—— 1963a. New contributions to Mesozoic stratigraphy by means of nannofossils. Sixth World Petrol. Congr., Frankfurt, Germany, 1963, Sect. 1, pp. 19–26.

—— 1963b. Die Nannoflora des "Badener Tegel" von Frättingsdorf, N. Österreich. Mikropaläontologische Studien. Mitt. Geol. Ges. Wien, vol. 56 (Heft 1), pp. 155–162, 2 pls.

—— 1964. Die Ergebnisse der Aufschluszarbeiten der ÖMV AG in der Molassezone Niederösterreichs in den Jahren 1957–1963. Teil III. Ergebnisse der Nannofossiluntersuchungen. Erdoel Zeitschr., (Heft 4), pp. 1–8.

STRADNER, H., and PAPP, A., 1961. Tertiäre Discoasteriden aus Österreich und deren stratigraphische Bedeutung. Geol. Bundesanst. Wien, Jahrb., Sonderband 7, pp. 1–159, pls. 1–42.

SULLIVAN, F. R., 1964. Lower Tertiary nannoplankton from the California coast ranges. I. Paleocene. Univ. Calif. Publ. Geol. Sci., vol. 44 (no. 3), pp. 163–228, 12 pls.

—— 1965. Lower Tertiary nannoplankton from the California coast ranges. II. Eocene. Univ. Calif. Publ. Geol. Sci., vol. 53, pp. 1–52, 11 pls.

TAN SIN HOK, 1927. Over de samenstelling en het onstaan van krijt- en mergelgesteenten van de Molukken. Mijnw. Ned. Oost Indië, Jaarb. (1926), pp. 1–165, 16 pls.

VEKSHINA, V. N., 1959. Kokkilithoforidy maastrikhtskikh otlozhenii Zapadno-Sibirkoi Nizmennosti. Trudy SNIIGGIMS, no. 2, pp. 56–77, pls. 1–2.

WALLICH, G. G., 1877. Observations on the coccosphere. Ann. Mag. Nat. Hist., vol. 19 (4th Ser.), pp. 342–350, 1 pl.

PLATES

PLATE 1

a—c *Coccolithus pelagicus* (Wallich)
a—c Plan view; a, plain light; b, polarized light; c, phase contrast.
Hypotypes: BF 81, BF 82.
d—i *Coccolithus* ? sp.
d—e Plan view; d, phase contrast; e, polarized light.
f—g Plan view; f, phase contrast; g, polarized light.
h—i Plan view; h, phase contrast; i, polarized light.
j—k ? *Coccolithus placomorphus* (Kamptner).
j—k Plan view; j, polarized light; k, phase contrast.

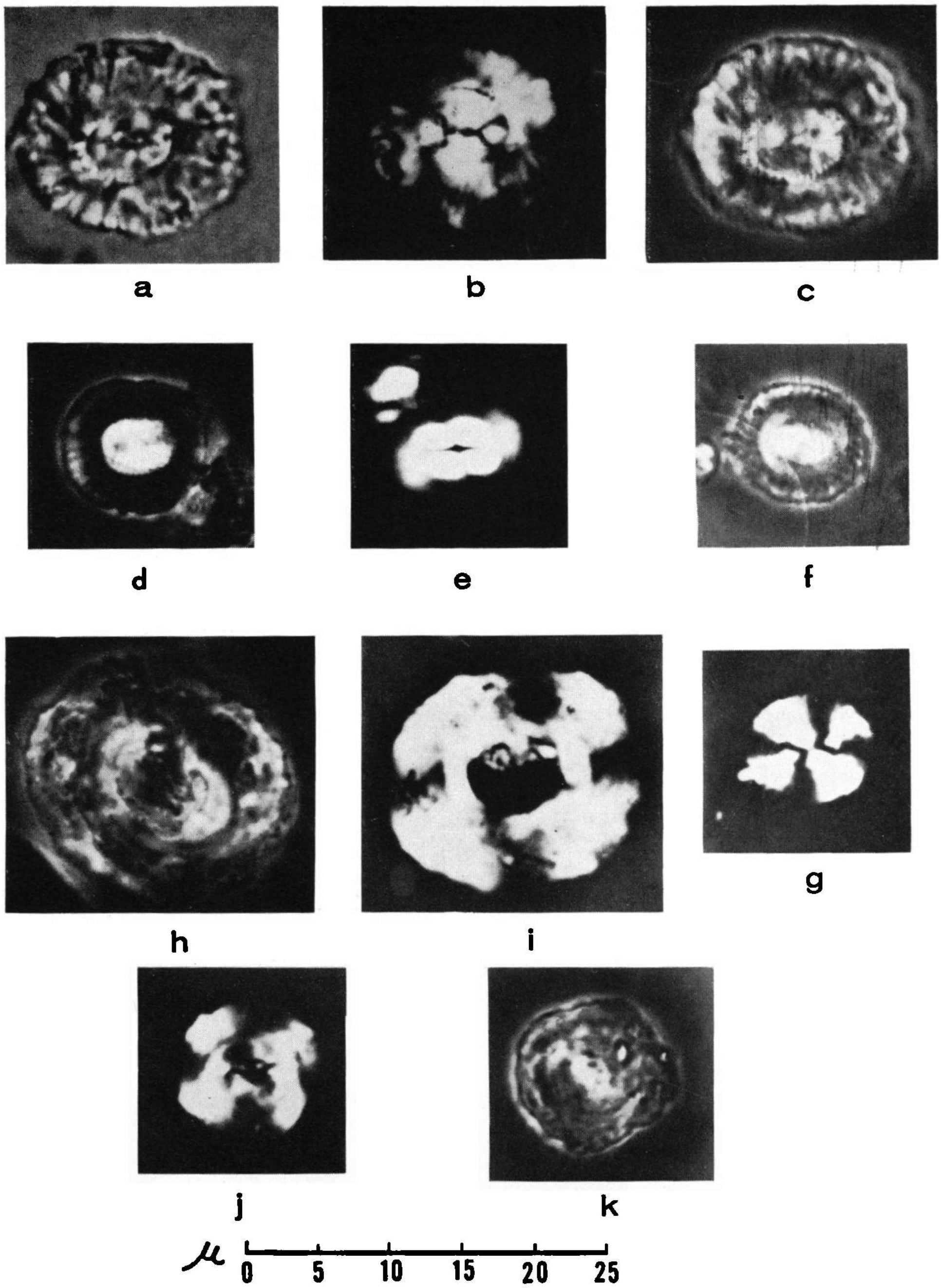

a
b
c
d
e
f
h
i
g
j
k
μ
0
5
10
15
20
25

PLATE 2

a—g	*Cyclococcolithus* cf. *formosus* Kamptner
a—c	Distal view; a, plain light; b, polarized light; c, phase contrast.
d—f	Proximal view; d, f, phase contrast; e, polarized light.
g	Side view, drawing.
	Hypotypes: BF 82, BF 83.
h—i	*Cyclococcolithus leptoporus* (Murray & Blackman) Kamptner.
h	Proximal side, phase contrast.
i	Side view, drawing.
	Hypotype: BF 80.
j—k	*Cricolithus jonesi* Cohen n. sp.
j—k	Plan view; j, phase contrast; k, polarized light.
	Holotype: BF 80.
	Paratype: BF 80.
l—o	*Coccolithus atlanticus* Cohen n. sp.
l—n	Plan view; l, polarized light, long axis 45° to x-nic.; m, polarized light, long axis // to x-nic.; n, phase contrast.
o	Side view, drawing.
	Holotype: BF 83.
	Paratype: BF 80.
p—s	*Discolithus planus* Bramlette & Sullivan.
p—r	Plan view; p, phase contrast; q, polarized light, long axis 45° to x-nic.; r, polarized light, long axis // to x-nic.
s	Side view, drawing.
	Hypotype: BF 80.

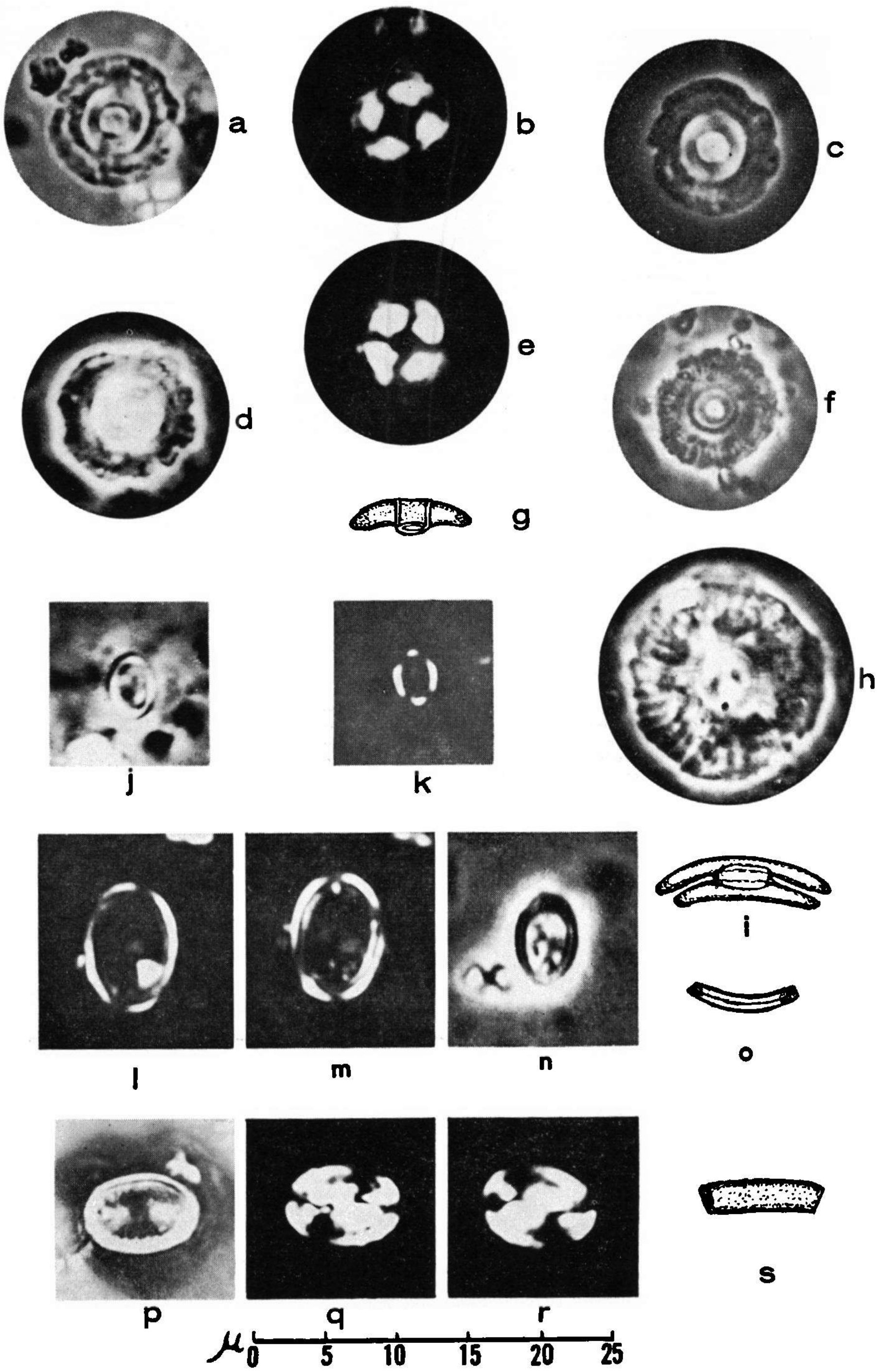

a
b
c
d
e
f
g
h
j
k
i
l
m
n
o
p
q
r
s
μ 0 5 10 15 20 25

PLATE 3

a—c *Rhabdosphaera claviger* Murray & Blackman.
a—c Side view; a, phase contrast; b, polarized light, stem // to x-nic.; c, polarized light, stem 45° to x-nic.
Hypotypes: BF 79, BF 80.
d—f *Rhabdosphaera stylifer* Lohmann.
d—e Side view; d, phase contrast; e, polarized light, stem 45° to x-nic.
f Top view, drawing.
Hypotype: BF 79.
g—i *Discophaera tubifer* Murray & Blackman.
g—h Side view; g, phase contrast; h, polarized light, stem 0° to x-nic.
i Top view, drawing.
Hypotype: BF 79.
j—l *Scapholithus* sp. Deflandre
j—k Plan view; j, polarized light, long axis 45° to x-nic.; k, phase contrast.
l Side view, drawing.
Hypotypes: BF 79, BF 80.
m—n *Ceratolithus cristatus* Kamptner.
m—n Plan view; m, phase contrast; n, polarized light, in 45° position.
Hypotype: BF 78.
o—q *Helicosphaera carteri* Kamptner.
o—q Plan view; o, phase contrast; p, polarized light, long axis 45° to- x-nic.; q, polarized light, long axis // to x-nic.
Hypotype: BF 83.
r—t *Discolithus* cf. *distinctus* Bramlette & Sullivan.
r—s Plan view; r, phase contrast; s, polarized light, long axis 5° to x-nic.
t Side view, drawing.
Hypotypes: BF 79, BF 82.
u *Discolithus macroporus* Deflandre.
Plan view, plain light.
Hypotype: BF 80.
v *Syracosphaera dalmatica* Kamptner.
Plan view, plain light.
Hypotype: BF 80.

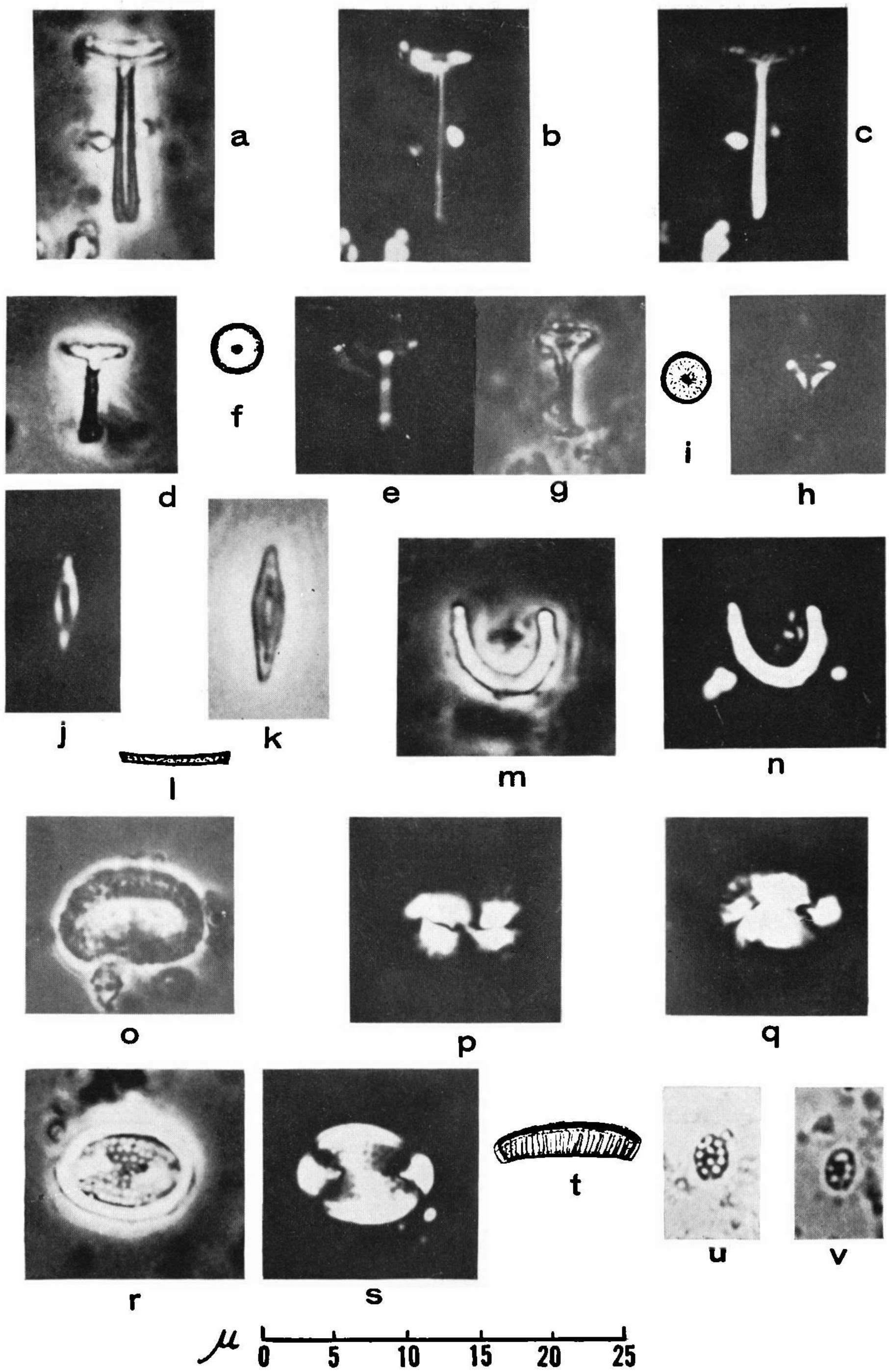

a
b
c
d
f
e
g
i
h
j
l
k
m
n
o
p
q
r
s
t
u
v
μ
0 5 10 15 20 25

PLATE 4

a—b *Cribrosphaerella ehrenbergi* (Arkhangelsky).
a—b Plan view; a, polarized light; b, phase contrast.
Hypotypes: BF 78, BF 81, BF 83.
c—e *Deflandrius intercisus* (Deflandre).
c—d Side view; c, polarized light, stem // to x-nic.; d, phase contrast.
e Top view, drawing.
Hypotypes: BF 78, BF 82, BF 83.
f *Zygolithus dubius* Deflandre.
Plan view, phase contrast.
g *Zygrhablithus ? turriseiffeli* (Deflandre).
Plan view, polarized light.
Hypotype: BF 78.
h—m *Zygrhablitus bijugatus* Deflandre.
h—m Plan view; h, m, plain light; i, l, polarized light; j, k, phase contrast.

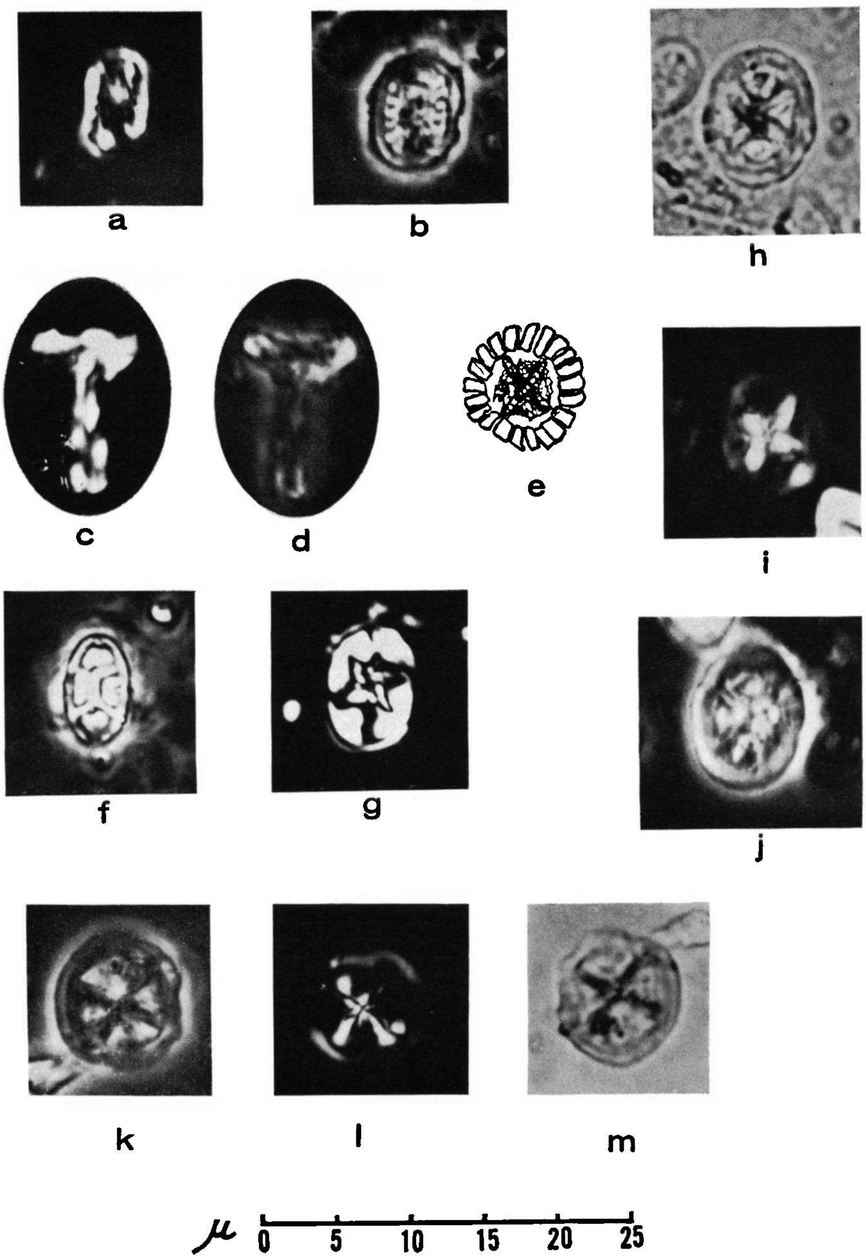

a
b
h
c
d
e
i
f
g
j
k
l
m
μ 0 5 10 15 20 25

PLATE 5

a—e *Lucianorhabdus cayeuxi* Deflandre.
a—d Side view; a, plain light; b, polarized light; c, phase contrast; d, drawing.
e Top view, drawing (broken specimen).
f *Thoracosphaera heimi* (Kamptner).
Polarized light.
g ? *Thoracosphaera imperforata* Kamptner
Polarized light.
h—m *Sphenolitus?* sp. Bramlette & Martini.
h—l Plan view; h, plain light; i, phase contrast; j, k, polarized light; l, drawing.
m Side view, drawing.
Hypotype: BF 82.
n—p *Sphenolithus radians* Deflandre.
n—p Side view; n, plain light; o, polarized light; p, phase contrast.
q—v *Fasciculithus involutus* Bramlette & Sullivan.
q—v Plan view; q, s, v, phase contrast; r, u, polarized light; t, plain light.

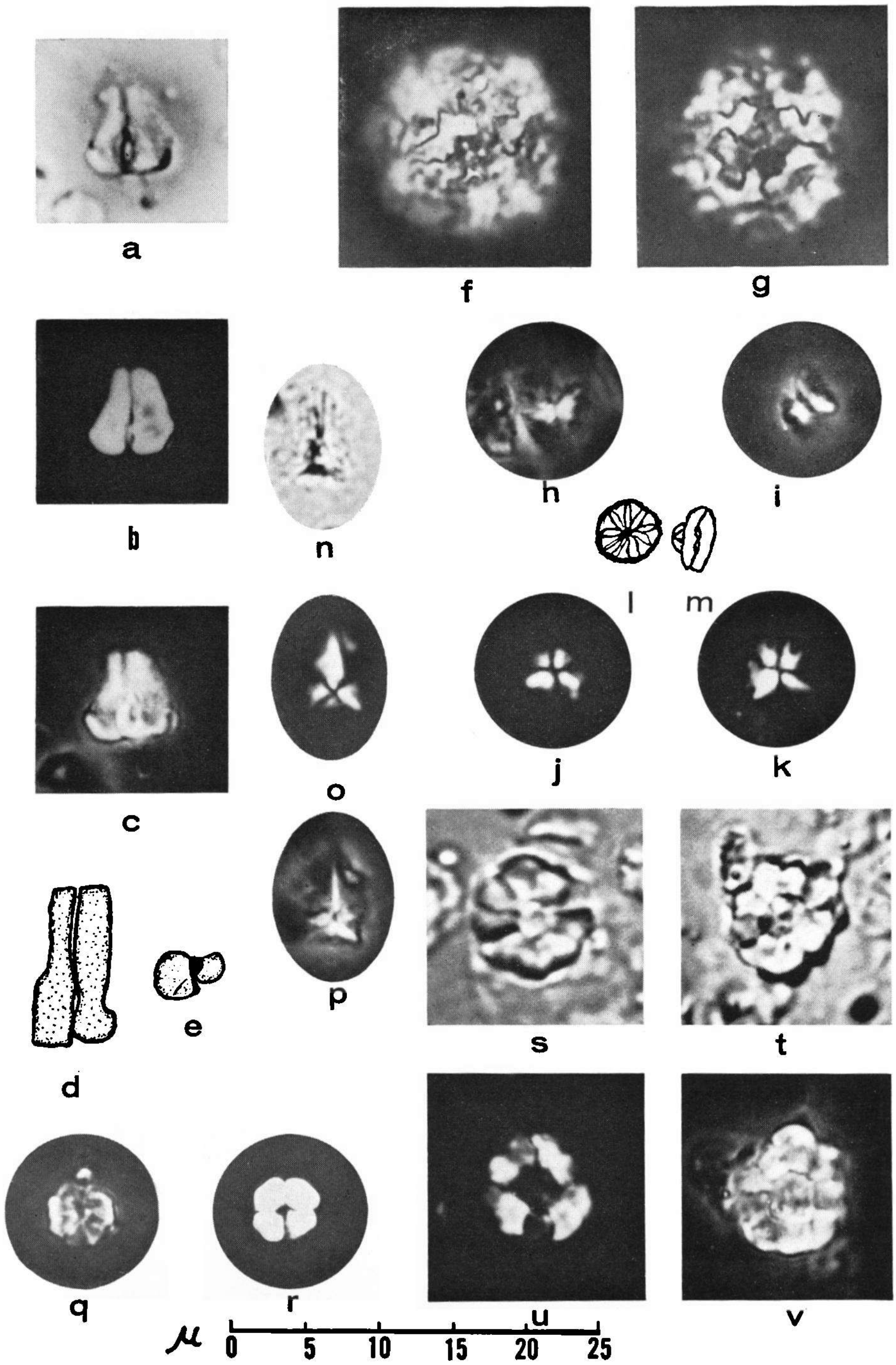

a
f
g
b
n
h
i
l
m
c
o
j
k
d
e
p
s
t
q
r
u
v
μ 0 5 10 15 20 25

PLATE 6

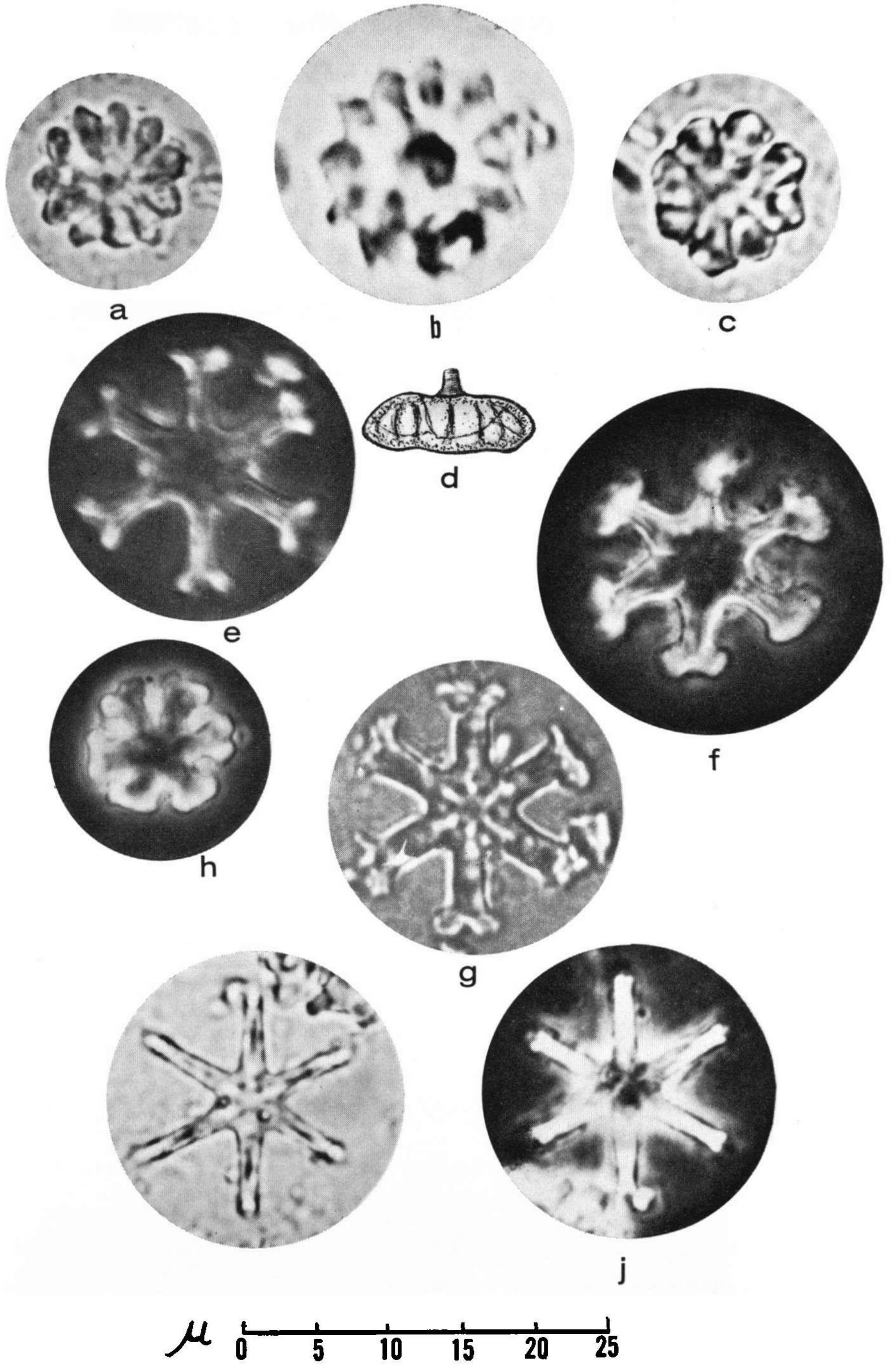
a—d *Braarudosphaera bigelowi* (Gran & Braarud).

a—d Plan view of pentalith; a, phase contrast; b, c, polarized light; d, plain light (corroded specimen).

e ? *Pemma rotundum* Klumpp.
Plan view of pentalith, plain light.

f—m *Micula decussata* Vekshina.
f, h, k, Phase contrast; g, i, l, polarized light; j, m, plain light.
Hypotype: BF 81.

n—p *Lithostromation perdurum* Deflandre.
n, Phase contrast; o, polarized light; p, plain light.



a
b
c
d
e
f
h
g
j
μ 0 5 10 15 20 25

PLATE 7

a—d *Discoaster barbadiensis* Tan Sin Hok.
a—c Plain light.
d Side view, drawing.
Hypotype: BF 82.
e—g *Discoaster challengeri* Bramlette & Riedel
e—f Phase contrast; g, plain light.
Hypotypes: BF 81, BF 83.
h *Discoaster deflandrei* Bramlette & Riedel.
Phase contrast.
i—j *Discoaster surculus* Bramlette & Martini.
i Plain light; j, phase contrast.

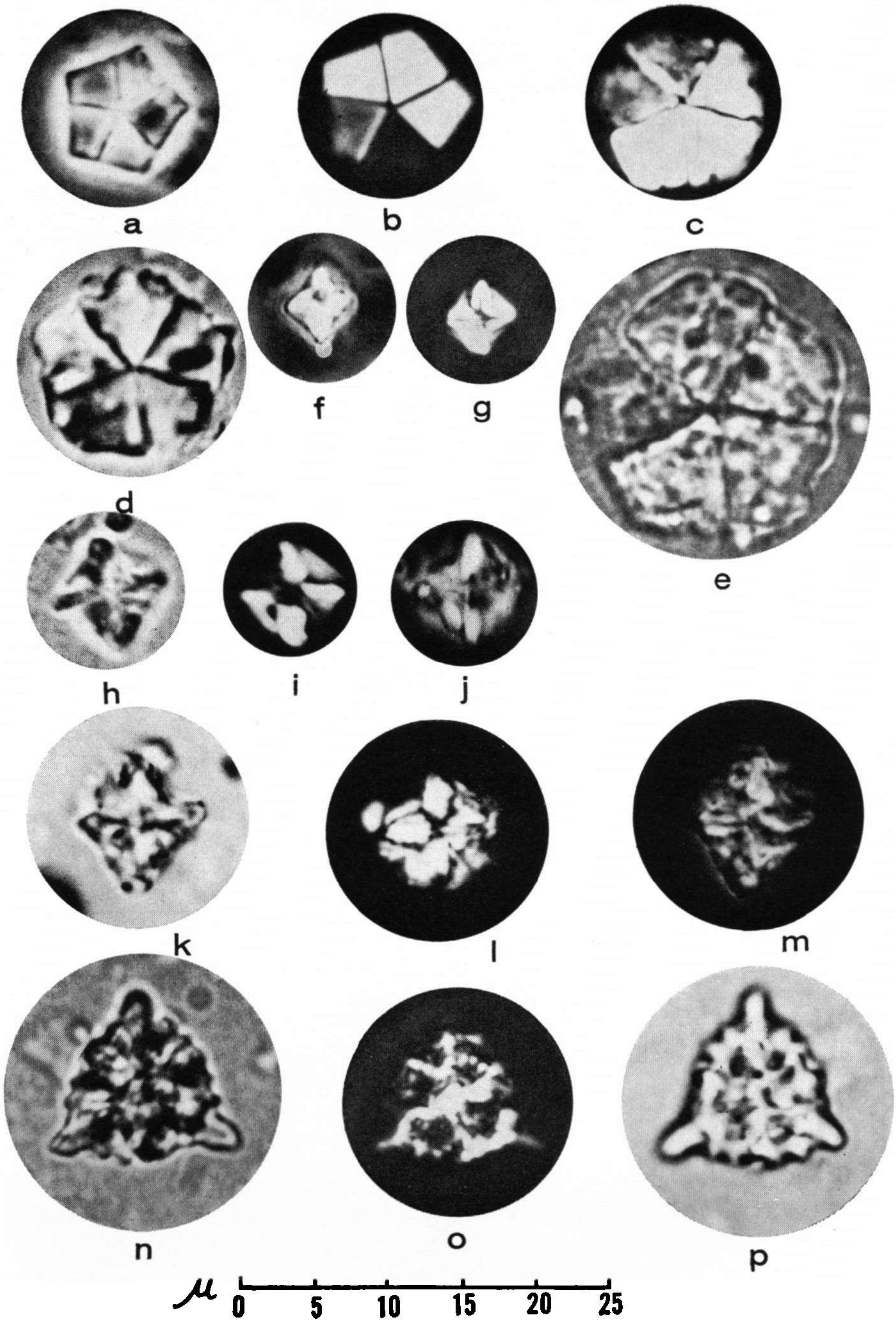
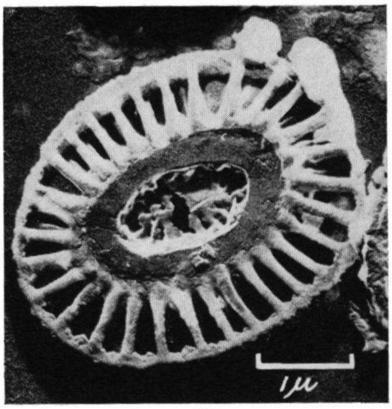
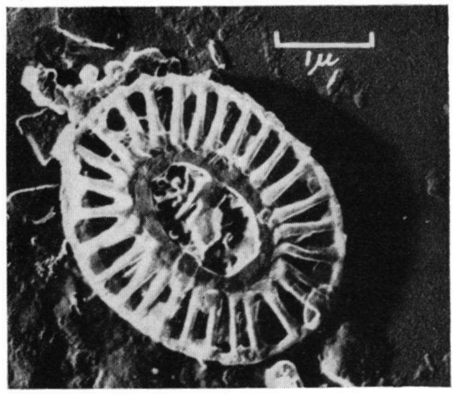

a
b
c
d
f
g
e
h
i
j
k
l
m
n
o
p
μ 0 5 10 15 20 25

PLATE 8

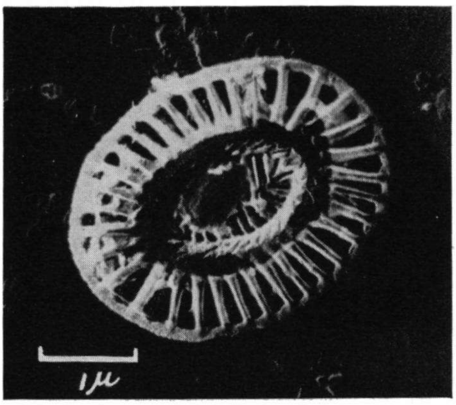
a—f *Coccolithus huxleyi* (Lohm.).
Plan views upper shield, electron micrographs:
Sample 291.
Hypotypes: T.N.O. X 473, IV 52272.



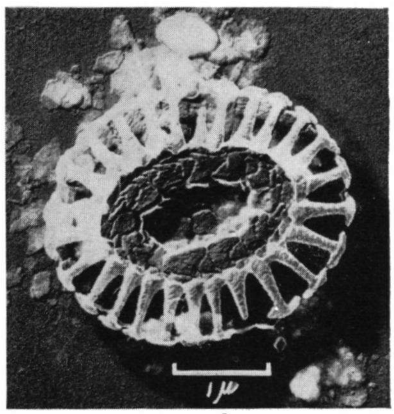
a



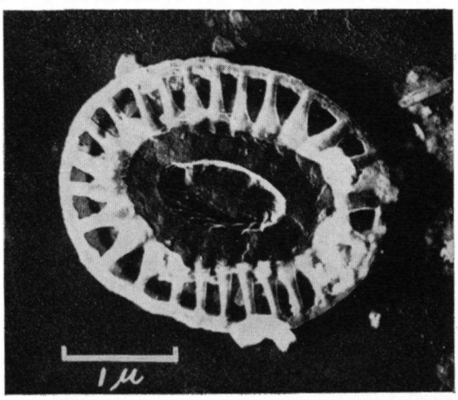
b



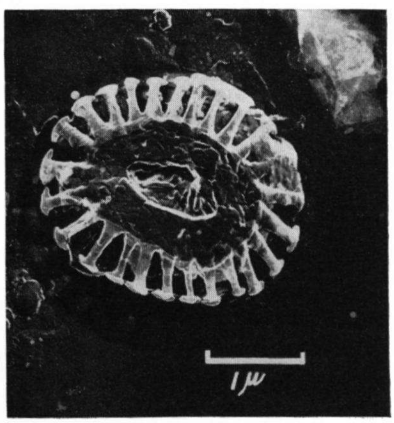
c



d



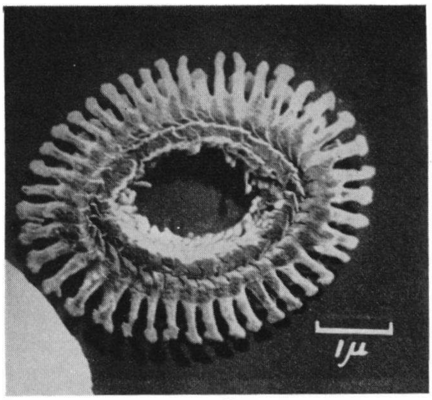
e



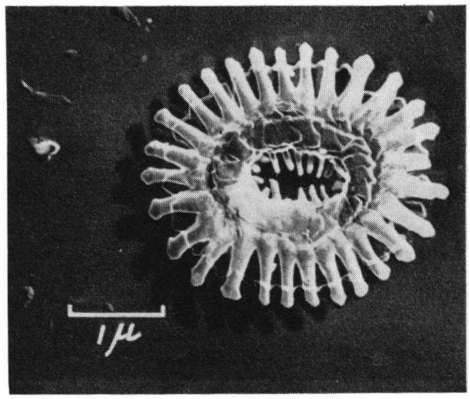
f

PLATE 9

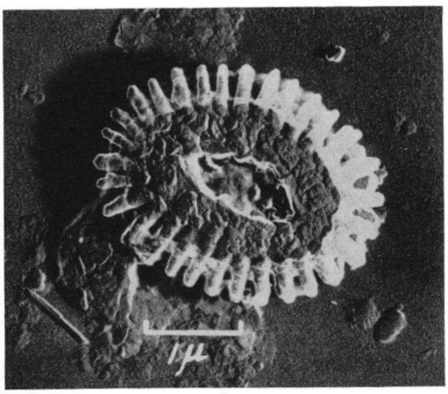
a—f *Coccolithus huxleyi* (Lohm.).
Plan views upper shield, electron micrographs; Sample 291.
Hypotypes: T.N.O. IV 52363, IV 52416, IV 52265.



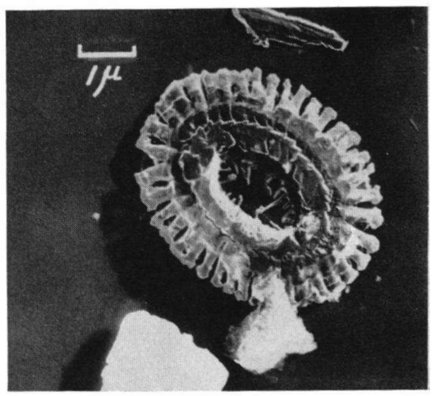
a



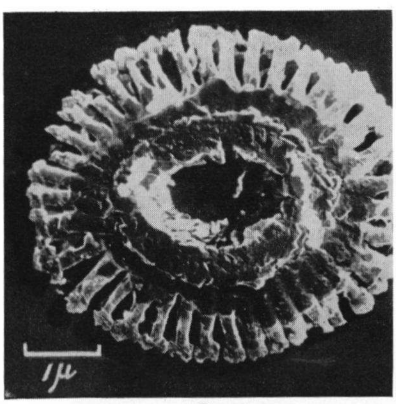
b



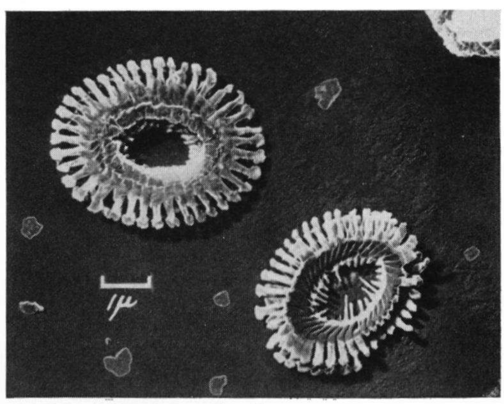
c



d



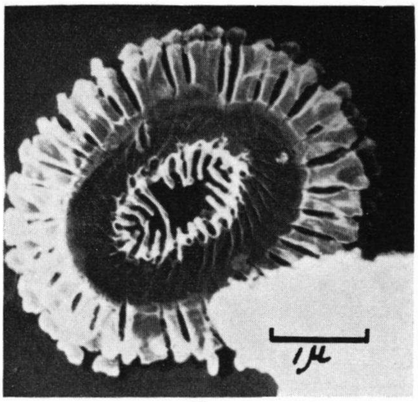
e



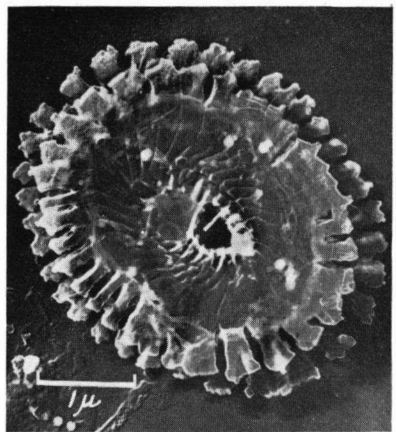
f

PLATE 10

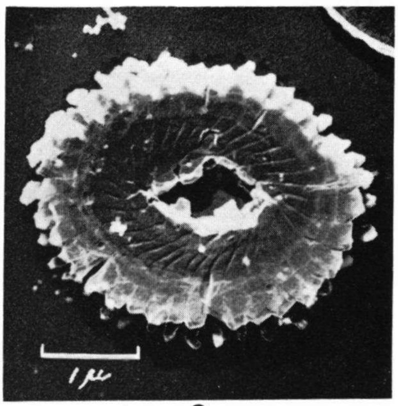
a—f *Coccolithus huxleyi* (Lohm.).
Plan views lower shield, electron micrographs; a, c, d, e, f, Sample 291; b, Sample 295.
Hypotypes: T.N.O. IV 52493, X 476.



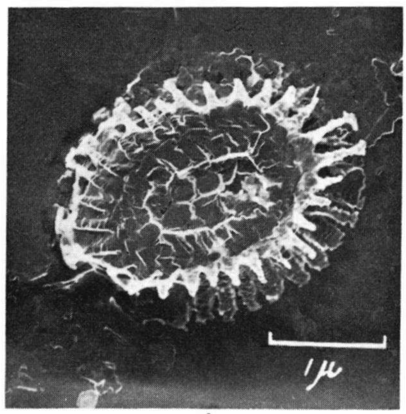
a



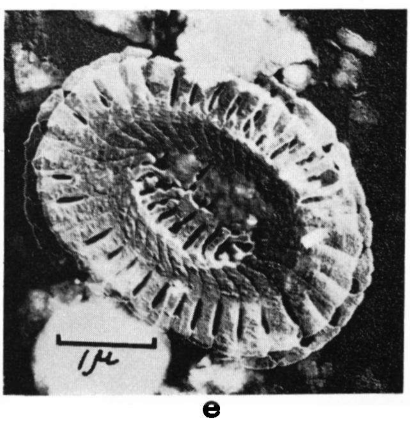
b



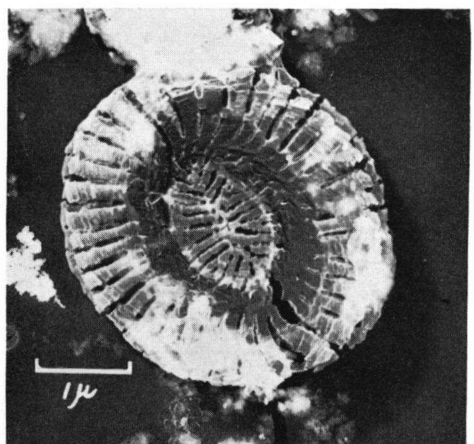
c



d



e



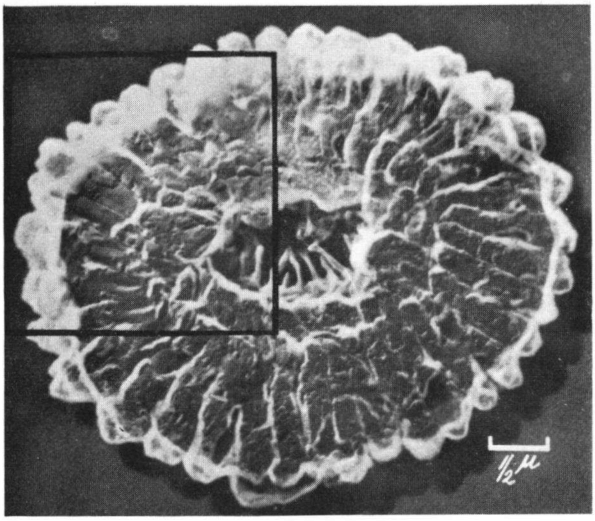
f

PLATE 11

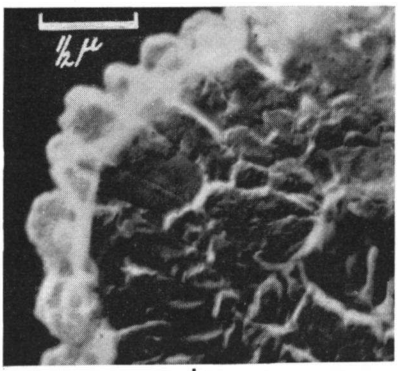
a—b *Coccolithus brambatii* Cohen n. sp.
Plan view upper shield, electron micrograph; a, b, Sample 291.
Holotype: T.N.O. IV 52384.

c—e *Coccolithus huxleyi* (Lohm.).
c, Strongly corroded remnant; d, top view lower shield; e, top view upper shield; c, Sample 295; d. e. Sample 291.
Hypotype: T.N.O. IV 52269.

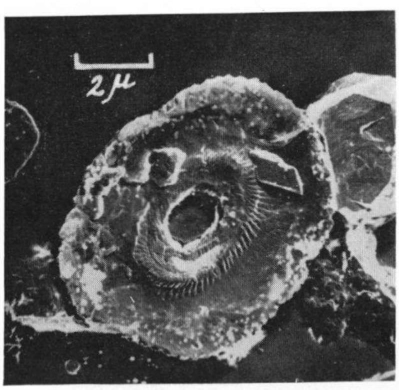
f *Coccolithus dissitus* Cohen n. sp.
Plan view upper shield, electron micrograph; Sample 298.
Holotype: T.N.O. IV 52484.



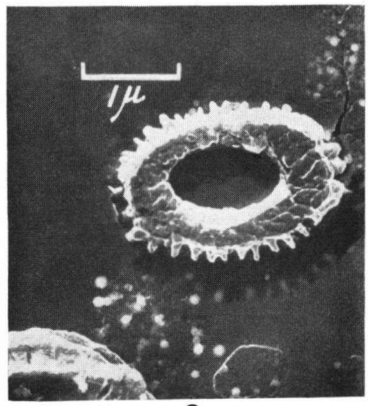
a



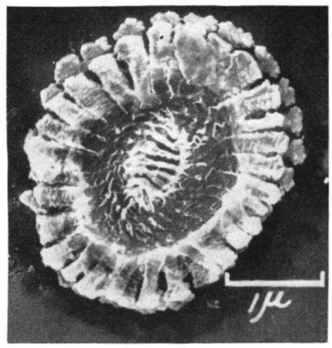
b



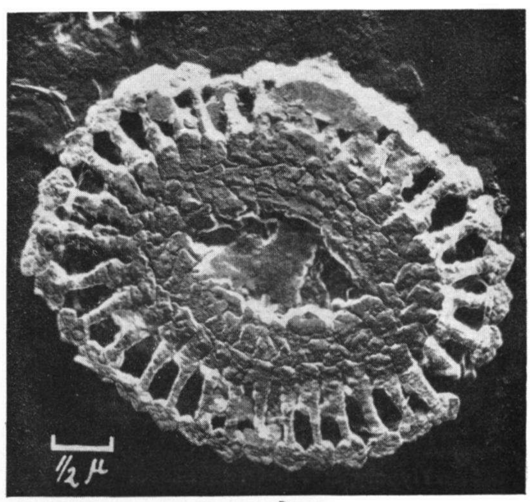
f



c



d



e

PLATE 12

a—b *Coccolithus huxleyi* (Lohm.).
a, Plan view upper shield; Sample 334; b, proximal view; Sample 334.

c ? *Coccolithus huxleyi* (Lohm.).
Distal view; Sample 334.

d *Syracosphaera pulchra* Lohmann.
Plan view.

e ? *Discosphaera thomsonii* Ostenfeld.
Side view; Sample 291.
Hypotype: T.N.O. IV 52353.

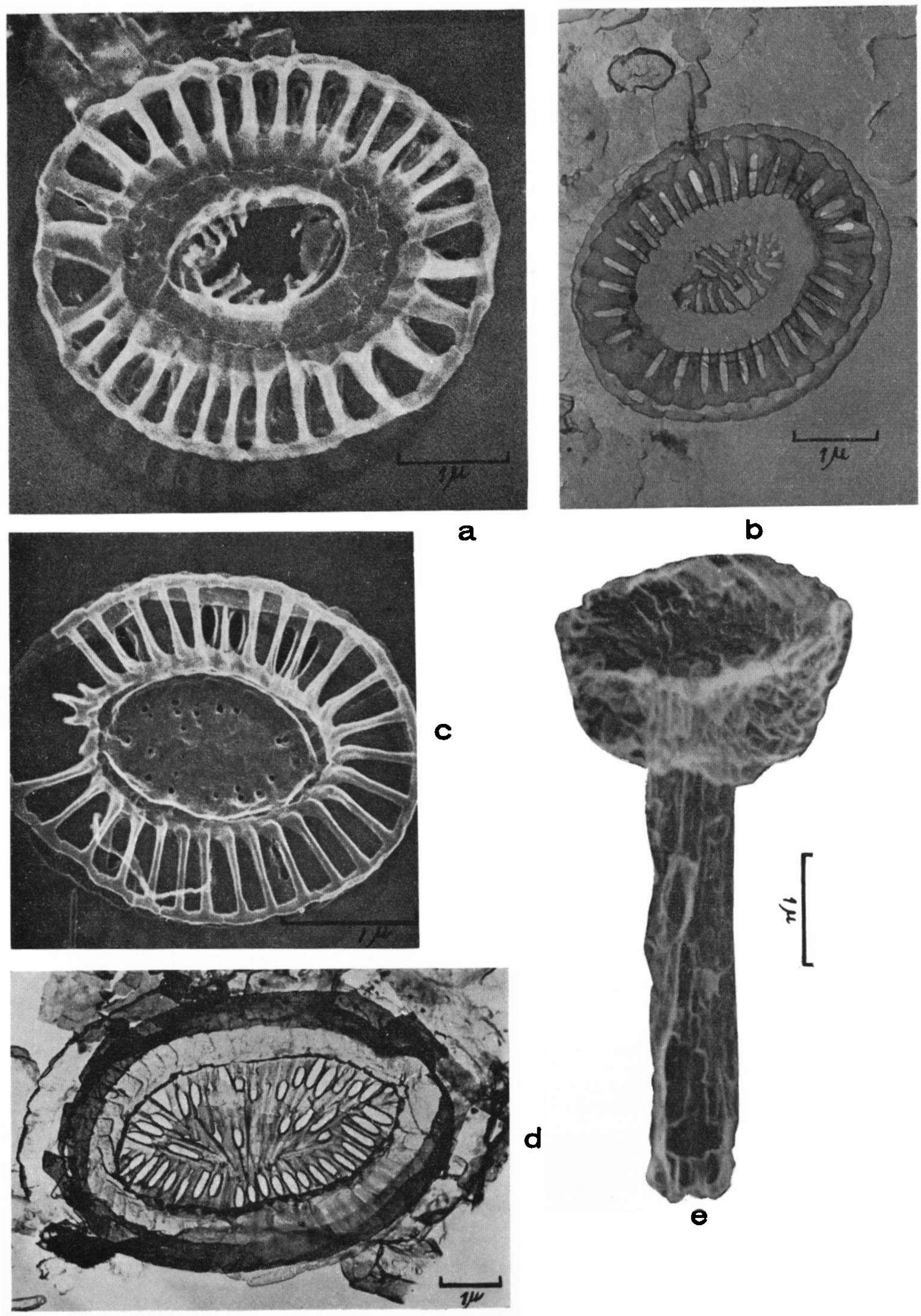

1μ
1μ
a
b
c
1μ
1μ
d
1μ
e

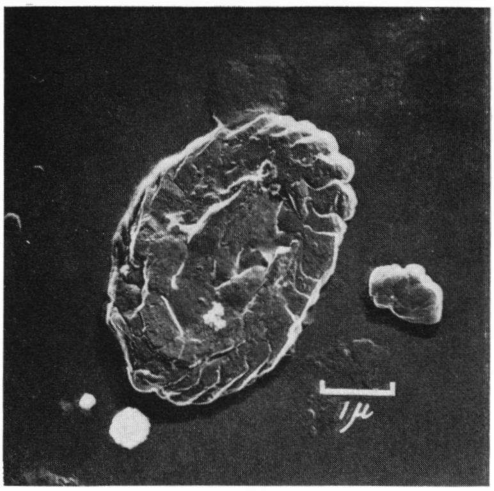
PLATE 13

a *Coccolithites repletus* Cohen n. sp.
Plan view; Sample 298.
Holotype: T.N.O. IV 52482.

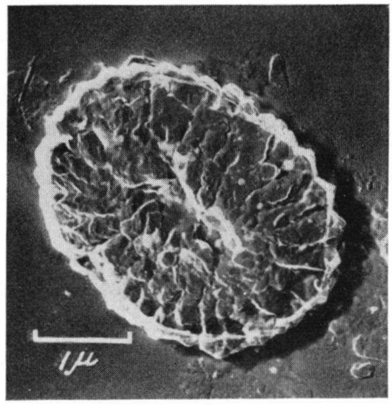
b *Coccolithites mendicus* Cohen n. sp.
Plan view; Sample 295.
Holotype: T.N.O. IV 52492.

c—d *Coccolithus* aff. *sarsiae* Black.
c, Distal view upper? shield; d, proximal view; Sample 298.
Hypotype: T.N.O. IV 52545.

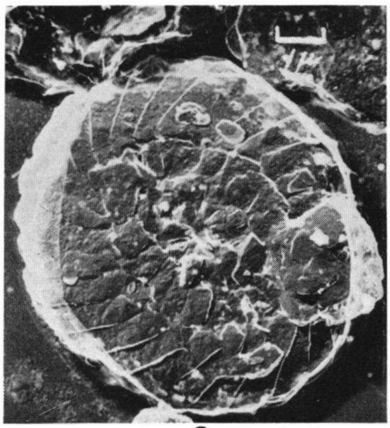
e—f *Umbellosphaera tenuis* (Kamptner) emend. Paasche.
e, Distal view, electron micrograph of carbon replica; f, distal view, electron micrograph; Sample 291.
Hypotype: T.N.O. IV 52264.



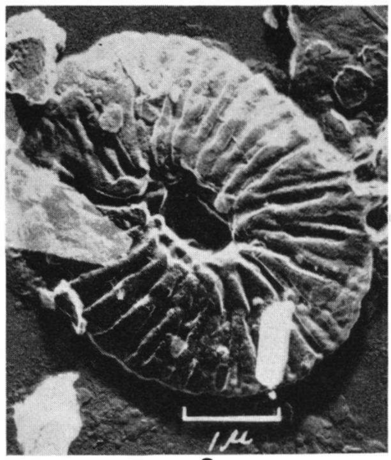
a



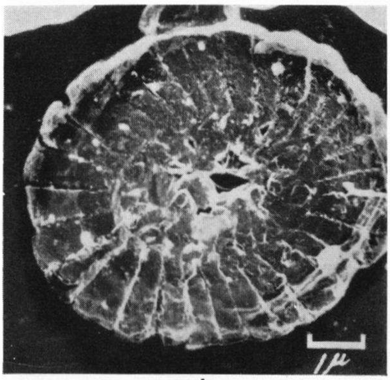
b



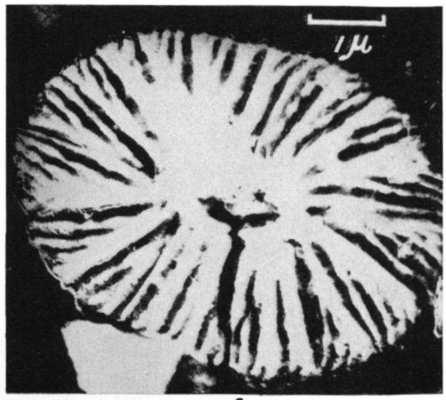
c



e



d



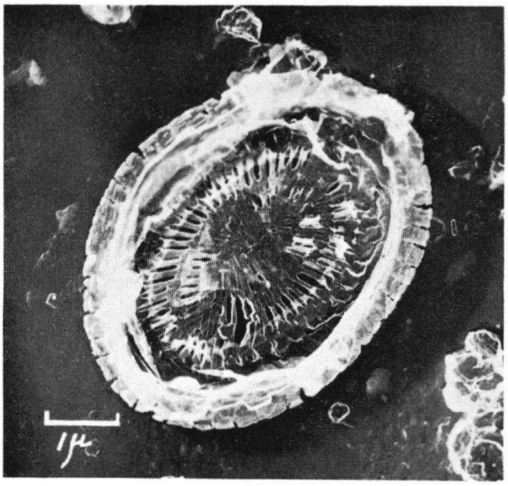
f

PLATE 14

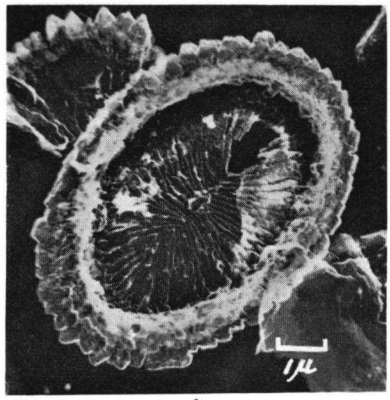
a—b *Syracosphaera pulchra* Lohmann.
Plan view; Sample 291.
Hypotypes: T.N.O. IV 52152, IV 52379.

c—e *Coccolithites viriosus* Cohen n. sp.
Plan views; Sample 291.
Holotype: T.N.O. IV 52408; paratypes: T.N.O. IV 52426, IV 52442.

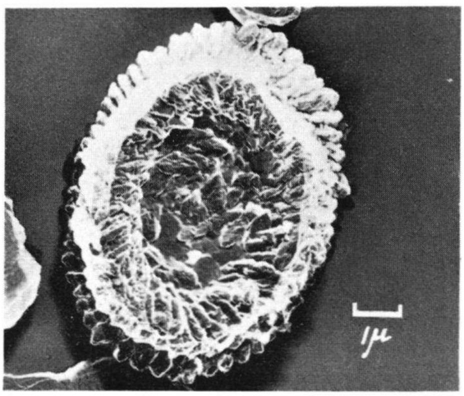
f *Coccolithites kueneni* Cohen n. sp.
Plan view; Sample 291.
Holotype: T.N.O. IV 52417.



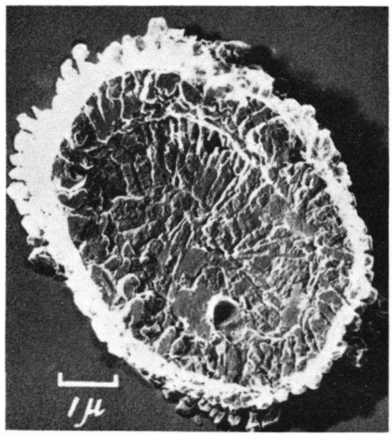
a



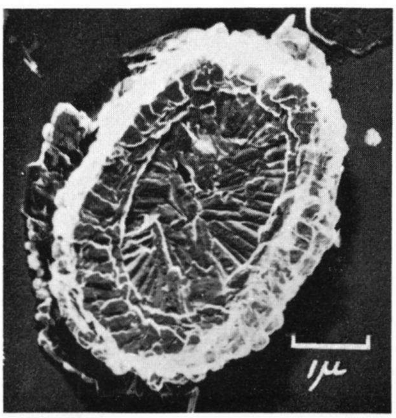
b



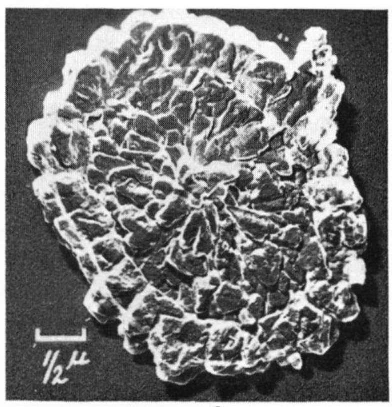
c



d



e



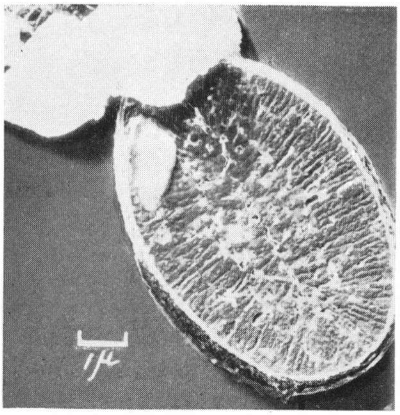
f

PLATE 15

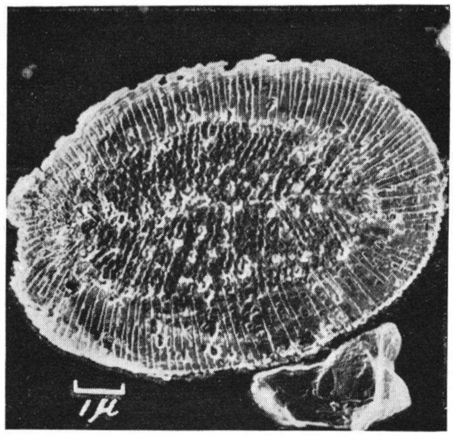
a—b *Pontosphaera scutellum* Kamptner
Plan views; a, Sample 295; b, Sample 291.
Hypotypes: T.N.O. IV 52559, IV 52393.

c—e *Coccolithus atlanticus* Cohen n. sp.
c, d, Stereoscopic pair; proximal view; e, distal view; Sample 291.
Hypotypes: T.N.O. IV 52275/6, IV 52414.

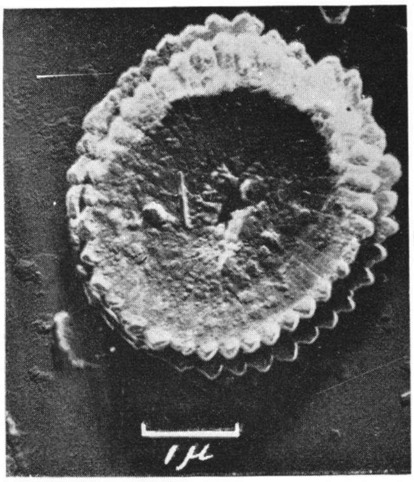
f Unnamed specimen of doubtful generic affiliation.
Plan view; Sample 298.



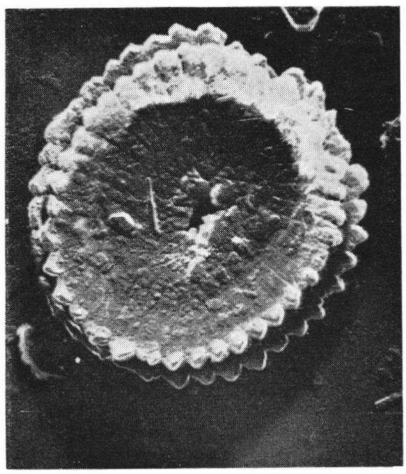
a



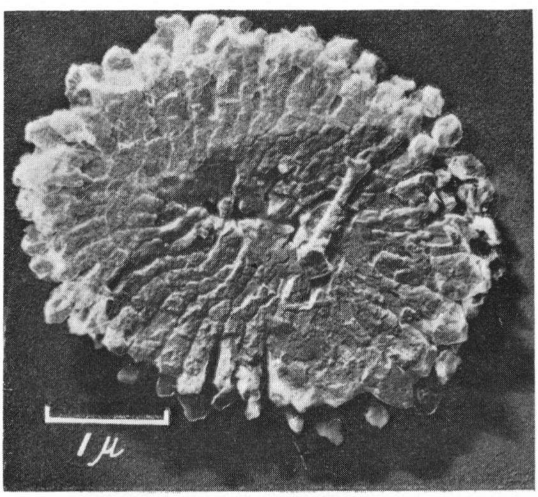
b



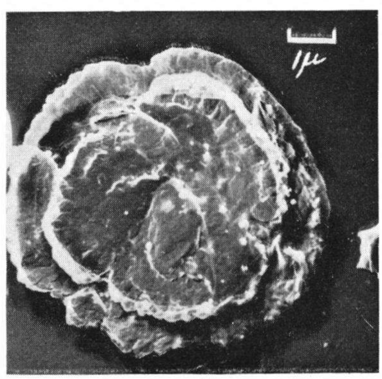
c



d



e



f

PLATE 16

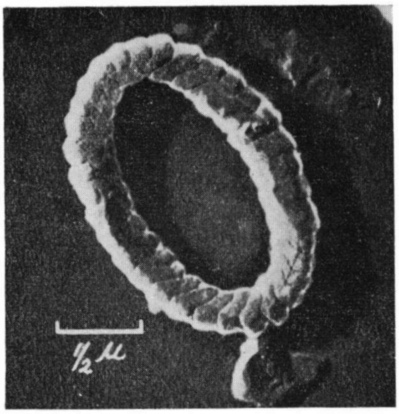
a—b ? *Cricolithus jonesi* Cohen, n. sp.
Stereoscopic pair; plan view; Sample 291.

c ? *Cricolithus jonesi* Cohen, n. sp.
Plan view; Sample 291.

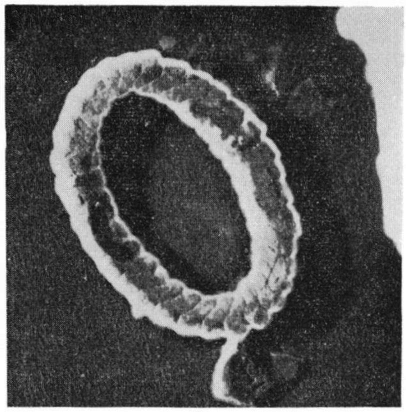
d *Cricolithus scabrosus* Cohen n. sp.
Plan view; Sample 291.
Holotype: T.N.O. IV 52377.

e *Cricolithus adriaticus* Cohen n. sp.
Plan view; Sample 291.
Holotype: T.N.O. IV 52420.

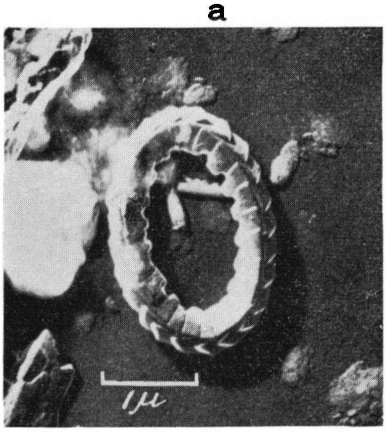
f ? *Cyclolithus rotundus* Kamptner.
Plan view; Sample 298.



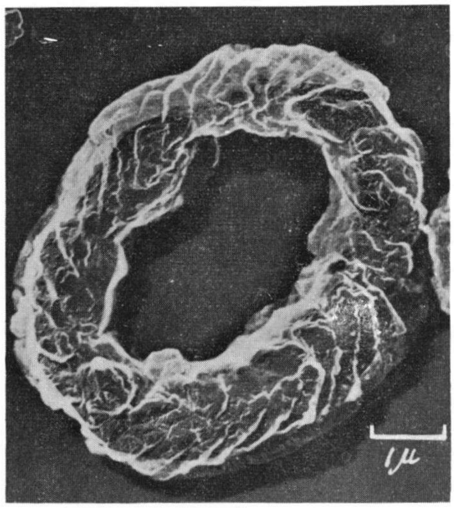
a



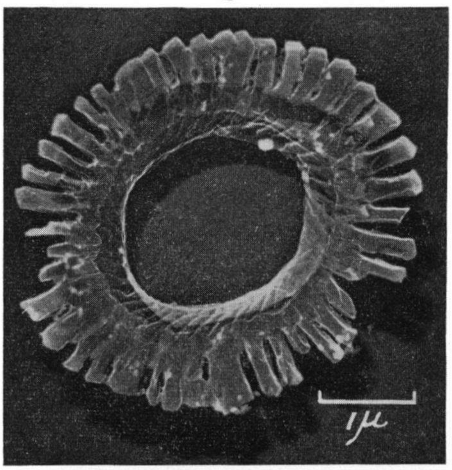
b



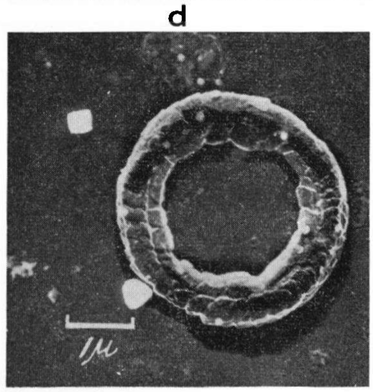
c



d



e



f

PLATE 17

a—d *Helicosphaera carteri* (Wallich).
a, b, d, Upper surface; c, lower surface; a, b, c, Sample 291; d, Sample 295.
Hypotypes: T.N.O. IV 52439, IV 52564.

e *Kamptnerius magnificus* Deflandre.
Plan view; Sample 291.
Hypotype: T.N.O. IV 52364.

f *Coccolithus atlanticus* Cohen n. sp.
Proximal view; Sample 291.
Hypotype: T.N.O. IV 52365.

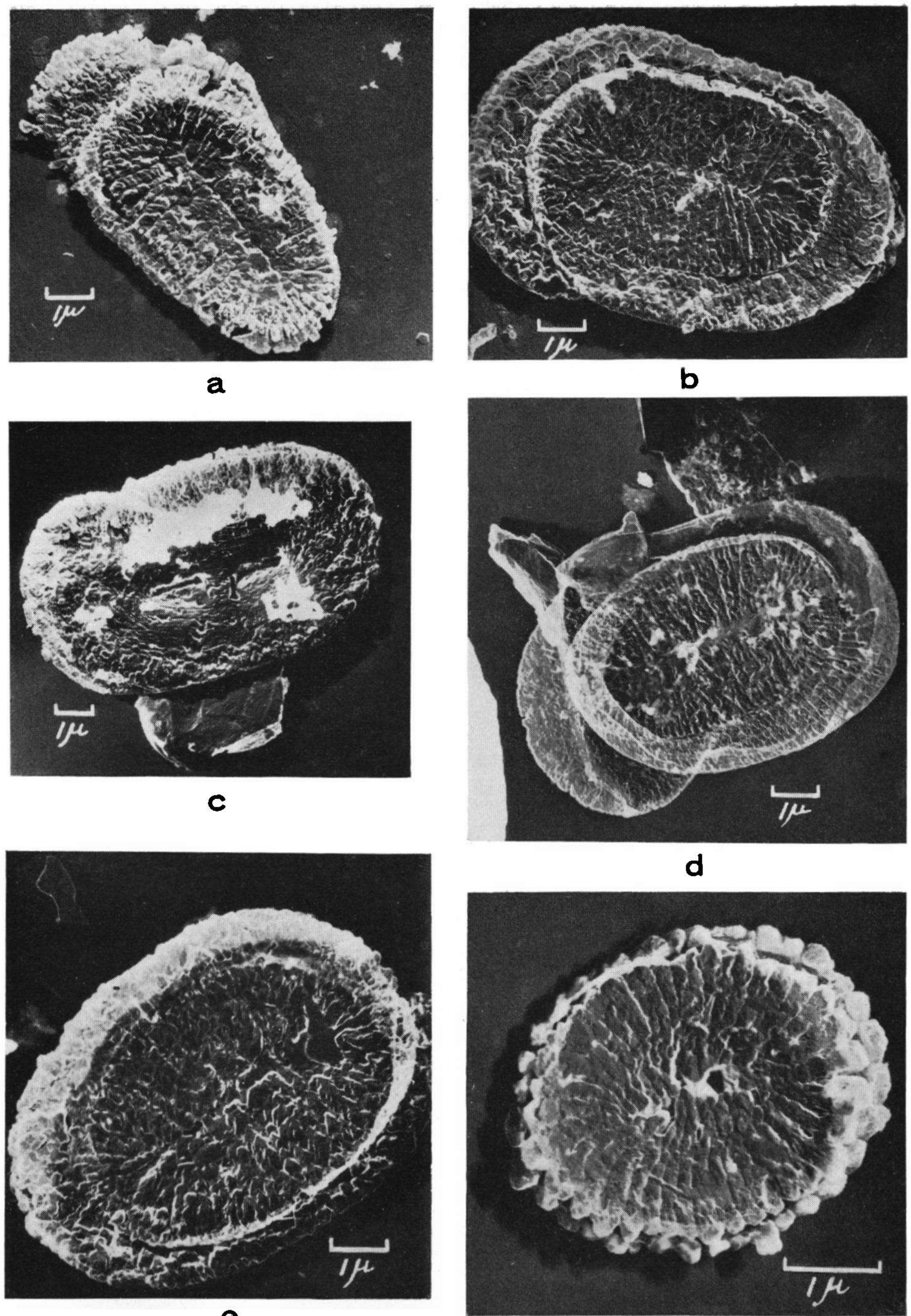
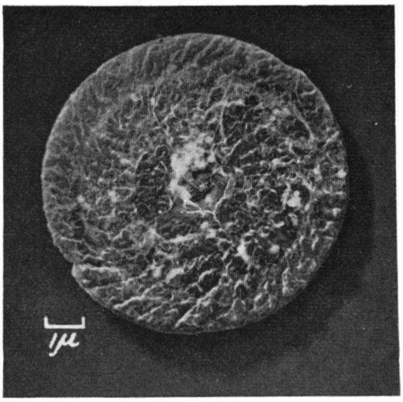
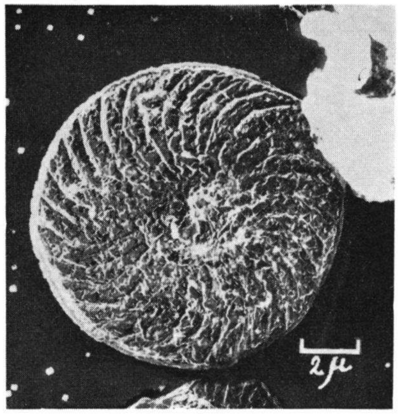

1μ
a
1μ
b
1μ
c
1μ
d
1μ
e
1μ
f

PLATE 18

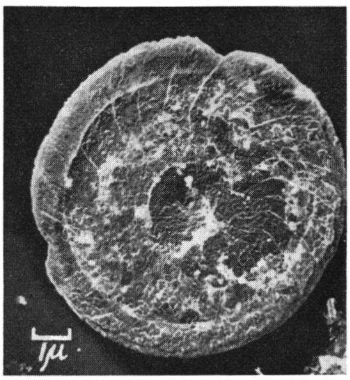
a—e *Cyclococcolithus leptoporus* (Murray & Blackman).
a—d Distal view; e, proximal view; a, b, c, Sample 295; d, e, Sample 291.
Hypotypes: T.N.O. IV 52565, IV 52373, IV 52428.



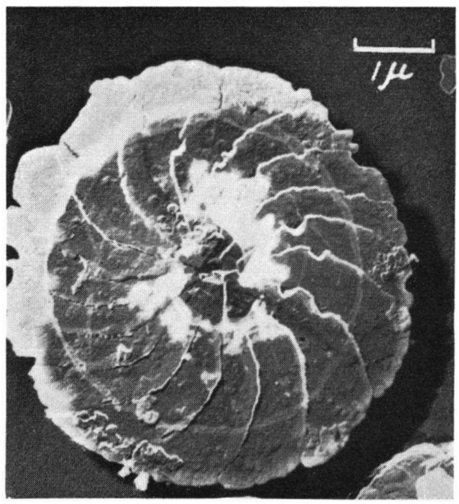
a



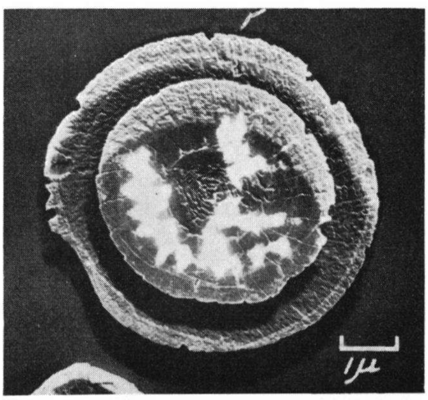
b



c



d

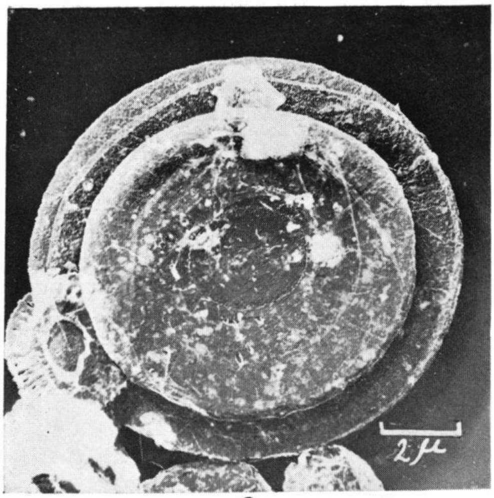


e

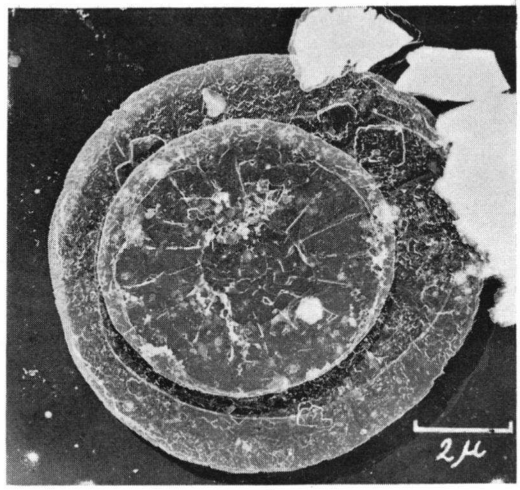
PLATE 19

a—b *Cyclococcolithus leptoporus* (Murray & Blackman).
Proximal view; Sample 295.
Hypotype: T.N.O. IV 52561.

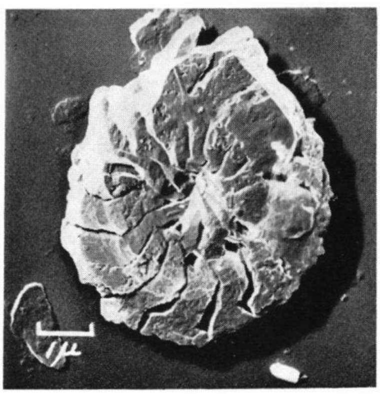
c—e *Cyclococcolithus* cf. *formosus* Kamptner.
Plan view; c, Sample 298; d, Sample 291; e, Sample 295.
Hypotypes: T.N.O. IV 52386, IV 52554.



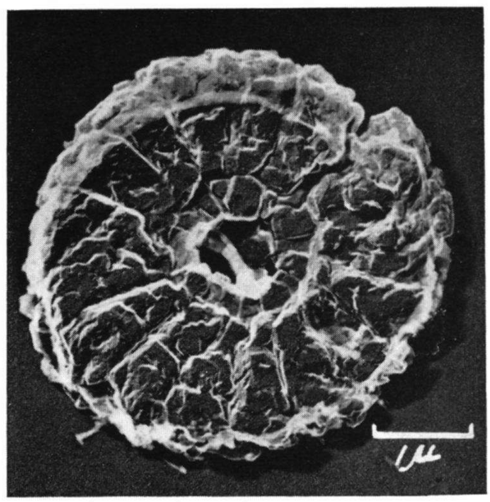
a



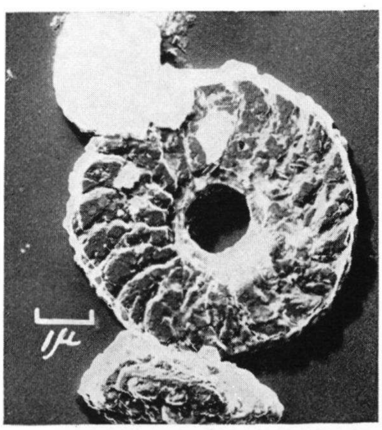
b



c



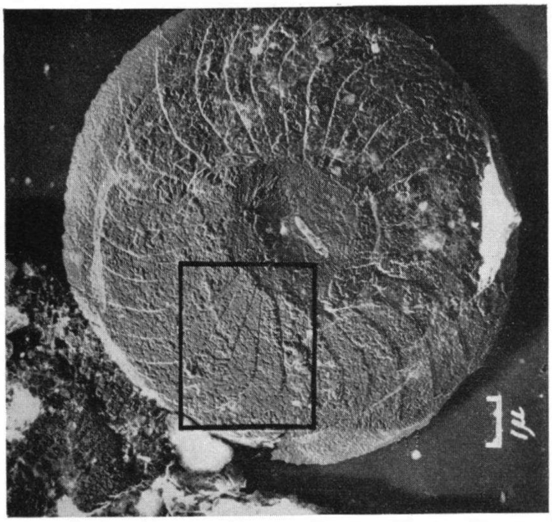
d



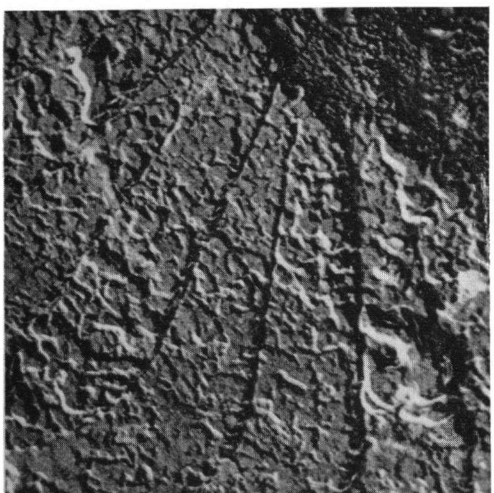
e

PLATE 20

a—b *Cyclococcolithus leptoporus* (Wallich).
a, Distal view; b, detail a, enlarged; Sample 295.
Hypotype: T.N.O. IV 52560.



a



b

PLATE 21

a—b *Rhabdosphaera vatricosa* Cohen n. sp.
Stereoscopic pair, side view; Sample 291.
Hypotypes: T.N.O. IV 52402/3.

c—f *Rhabdosphaera stylifer* Lohmann.

c—d Stereoscopic pair, side view; Sample 295.

e—f Ditto; Sample 291.
Hypotypes: T.N.O. IV 52562/3; IV 52406/7.

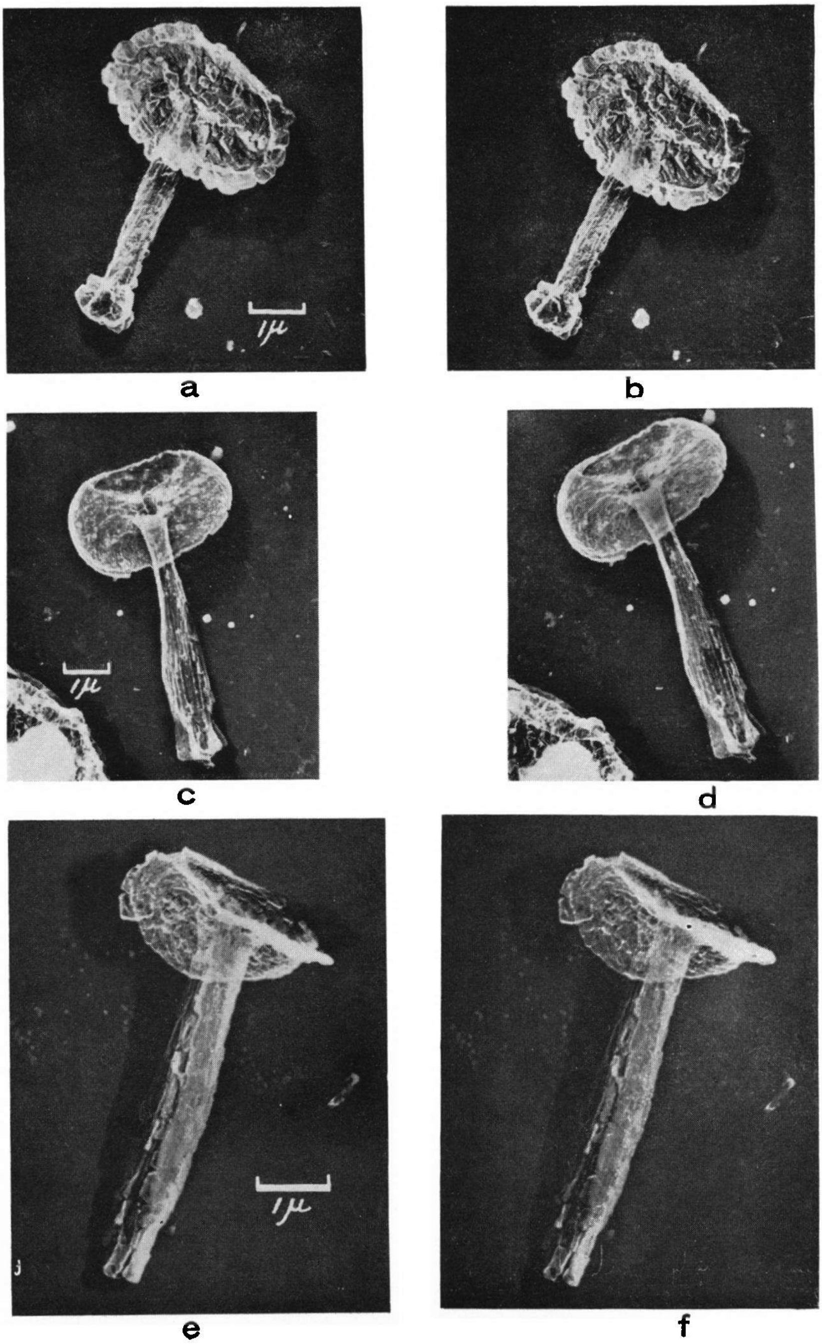
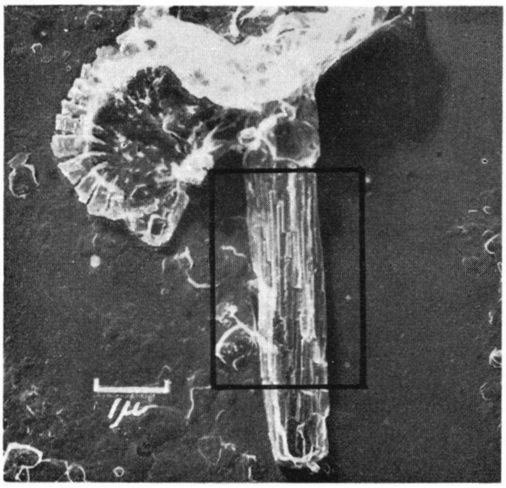

1μ
a
b
1μ
c
d
1μ
e
f

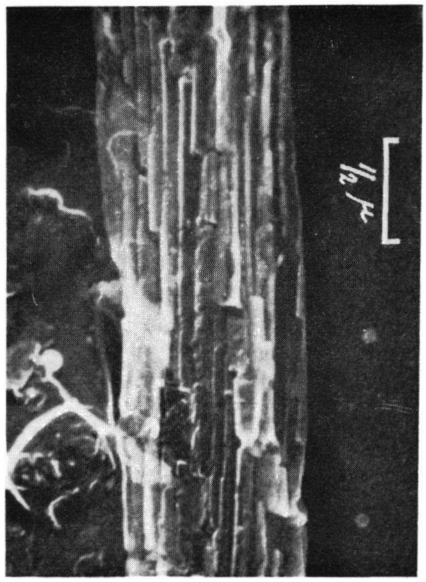
PLATE 22

a—b *Rhabdosphaera claviger* Murray & Blackman.
a, Side view; b, detail a, enlarged; Sample 291.

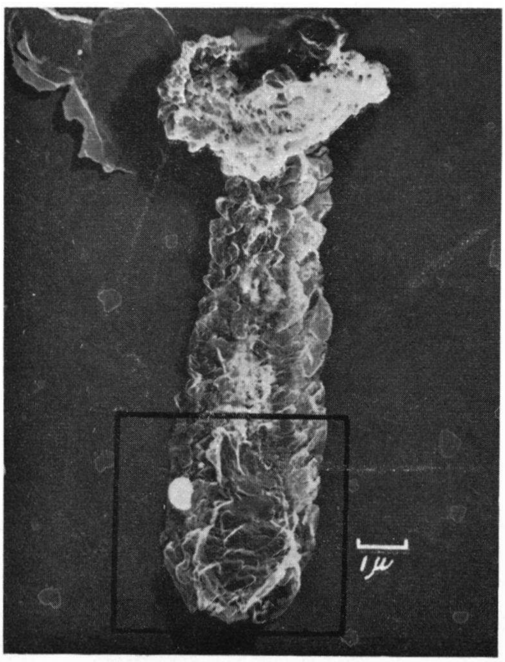
c—d ? *Rhabdosphaera* sp.
c, Side view, b, detail c, enlarged; Sample 291.



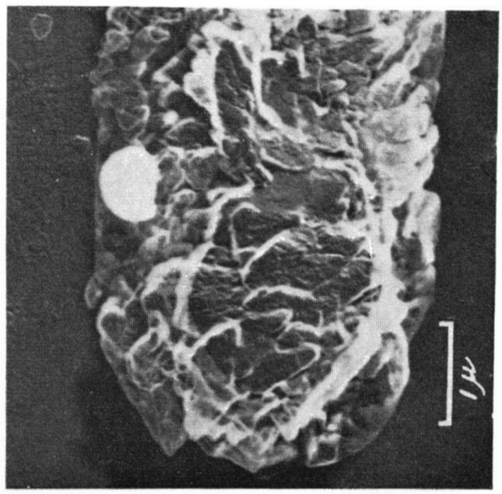
a



b



c



d

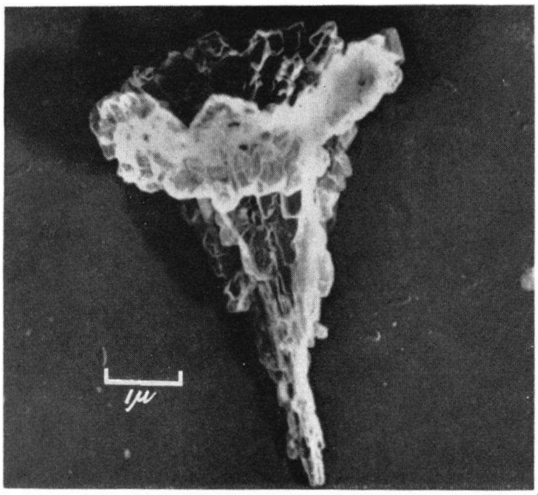
PLATE 23

a *Discosphaera tubifer* Murray & Blackman.
side view; Sample 291.
Hypotype: T.N.O. IV 52404.

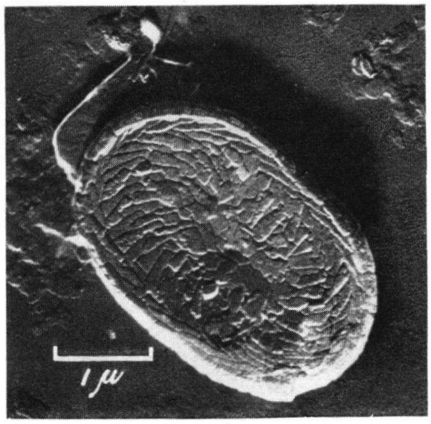
b—d *Rhabdosphaera stylifer* Lohmann.
b? Plan view basal plate; c, d, side view;
Sample 291.
b? Plan view basal plate; c, d, side view; Sample 291.
Hypotype: T.N.O. IV 52257.

e *Rhabdosphaera claiiger* Murray & Blackman.
Side view; Sample 291.
Hypotype: T.N.O. IV 52382.

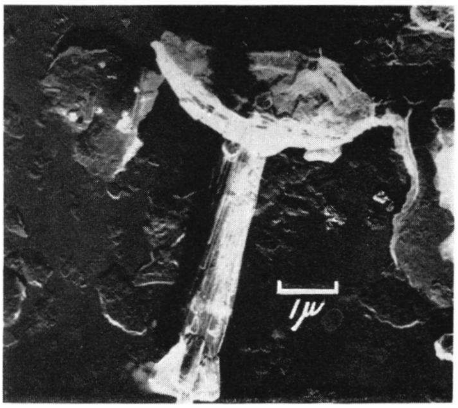
f ? *Pontosphaera* sp.
Complete sphere; X-ray projection; × ± 1,000.



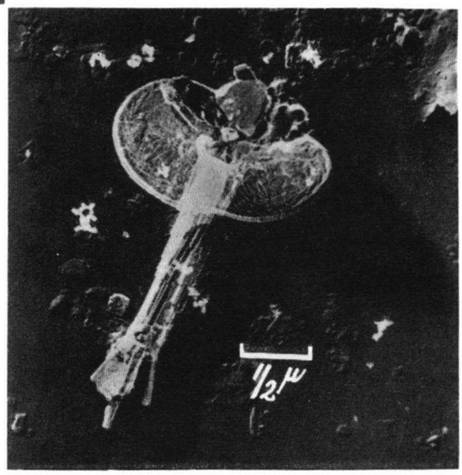
a



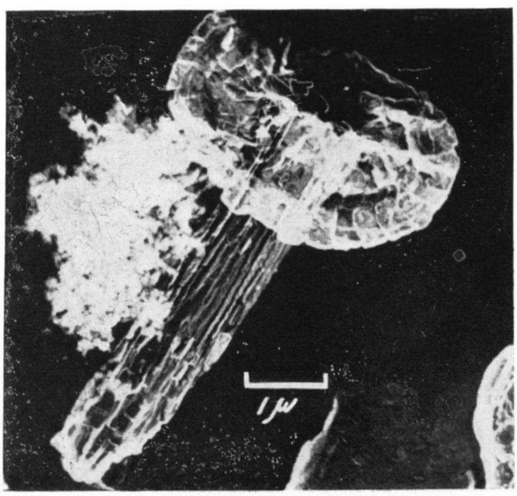
b



c



d



e

f

PLATE 24

a *Discolithus* aff. *histricus* Cohen.
Plan view; Sample 291.
Hypotype: T.N.O. IV 52278.

b—d *Syracosphaera dalmatica* Kamptner.
Plan view; b, c, Sample 298; d, Sample 291.
Hypotypes: T.N.O. IV 52480, IV 52544.

e—f *Discolithus* aff. *ponticulus* Deflandre.
Stereoscopic pair, plan view; Sample 291.
Hypotypes: T.N.O. IV 52566/7.

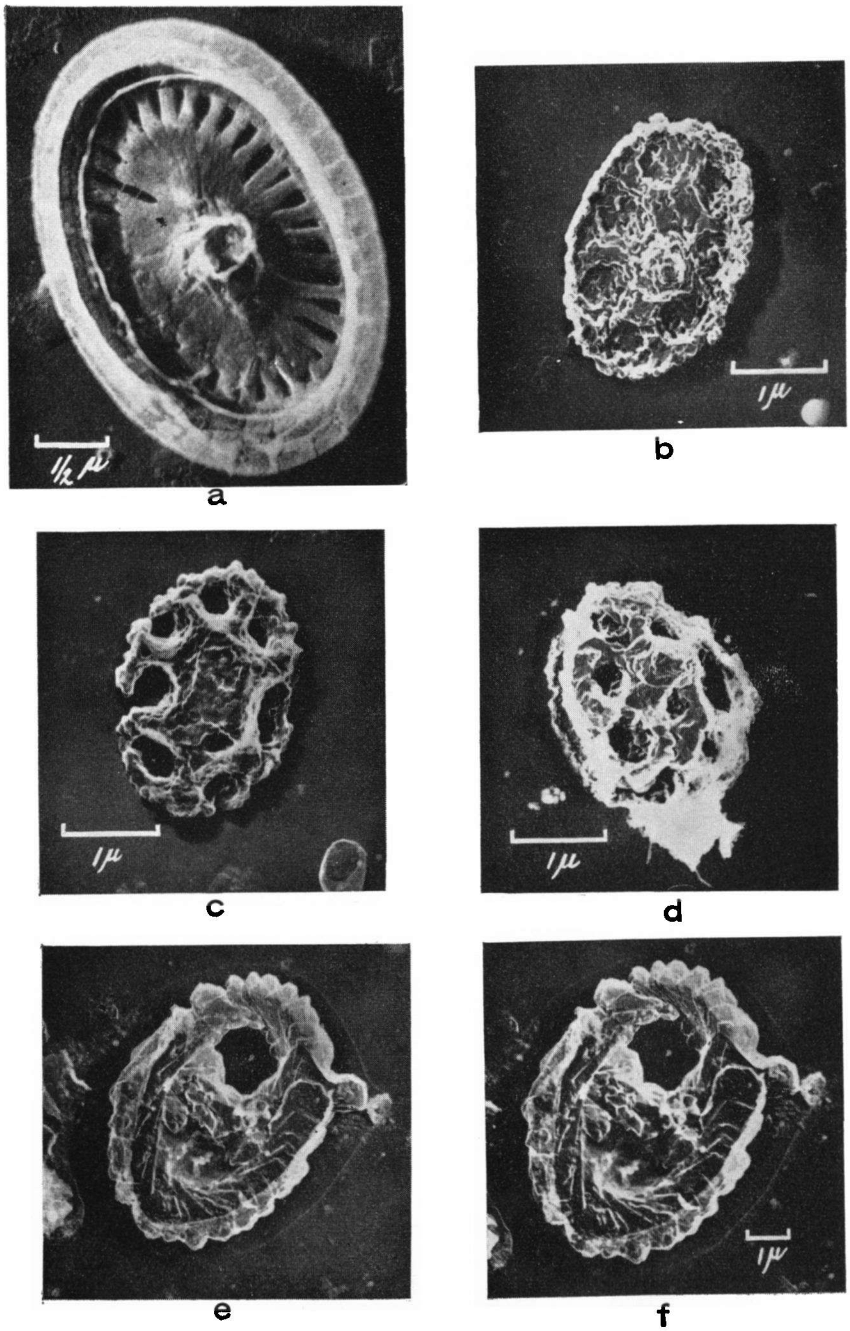

1/2 μ
a
1μ
b
1μ
c
1μ
d
e
1μ
f

PLATE 25

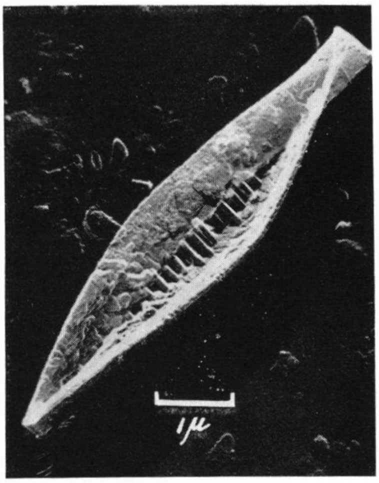
a—d *Scapholithus* sp. Deflandre

a—b Stereoscopic pair, plan view; Sample 291; c, plan view; Sample 291.
Hypotypes: T.N.O. IV 52286/7.

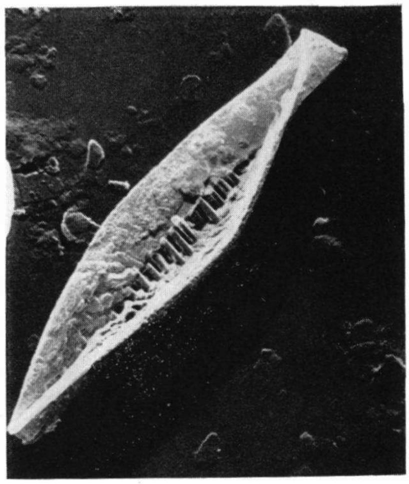
d Plan view; Sample 334.

e *Discoaster? lodoensis* Bramlette & Riedel
Plan view of strongly corroded specimen; Sample 298.

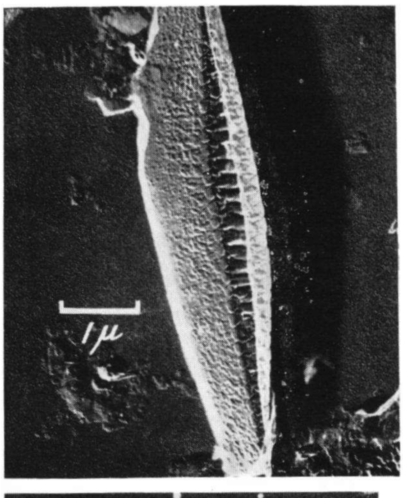
f *Syracosphaera* sp.
Plan view; Sample 291.



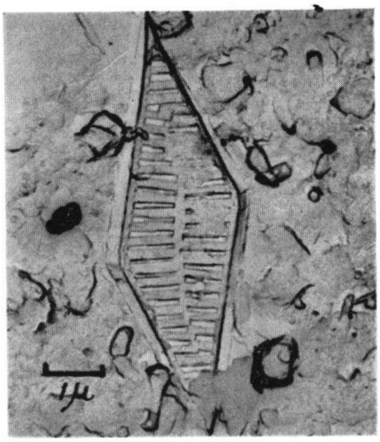
a



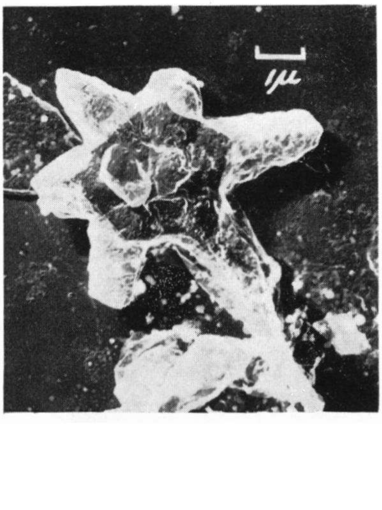
b



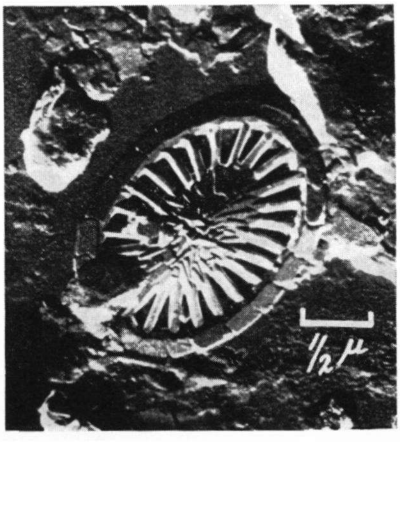
c



d



e



f