SVERIGES GEOLOGISKA UNDERSÖKNING

SER C NR 647 AVHANDLINGAR OCH UPPSATSER ÅRSBOK 64 NR 4

SYLVIA FORCHHEIMER

SCANNING ELECTRON MICROSCOPE STUDIES OF SOME CENOMANIAN COCCOSPHERES AND COCCOLITHS FROM BORNHOLM (DENMARK) AND KÖPINGSBERG (SWEDEN)

WITH 44 FIGURES

STOCKHOLM 1970

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C DAVIDSONS BOKTRYCKERI AB, VÄXJÖ 1970

CONTENTS

ABSTRACT

New observations on coccospheres and coccoliths from Aarnager Greensand, Bornholm, Denmark and from the boring Köpingsberg I in SE Sweden, have been made by means of the scanning electron microscope (SEM).

The possibility of tilting and rotating the sample holder of the instrument has been used extensively. Certain comparisons are made with light microscope and transmission electron microscope investigations.

Under the scanning electron microscope certain calcareous nannofossils, formerly interpreted as being composed of two shields, are now found to be built up of at least three shields. Coccospheres of *Coccolithus* cf *barnesae* (BLACK) BRAMLETTE et MARTINI and of newly proposed species *Coccolithus bornholmensis* n. sp. are described. *Deflandrius cantabrigensis* BLACK investigated at different angles is treated and a new combination of *Discolithina theta* (BLACK) n. comb. is suggested.

ZUSAMMENFASSUNG

Coccosphaeren und Coccolithen aus dem Aarnager Grünsand, Bornholm in Dänemark und aus der Bohrung Köpingsberg I, SO Schweden, wurden untersucht, wobei die Möglichkeit, den Probenhalter des Instrumentes zu kippen und zu drehen, weitgehend ausgenützt wurde. Mit Hilfe dieser speziellen SEM – Technik zeigte es sich, dass gewisse Coccolithen, welche früher als aus zwei Platten bestehend beschrieben wurden, aus mindestens drei Platten aufgebaut sind. Coccosphaeren des *Coccolithus* cf *barnesae* (BLACK) BRAMLETTE et MARTINI und einer neu gebildeten Art des *Coccolithus bornholmensis* n. sp. sind beschrieben. *Deflandrius cantabrigensis* BLACK unter verschiedenen Winkeln studiert, und *Discolithina theta* (BLACK) n. comb. werden behandelt. Einige vergleichende Studien mit dem Lichtmikroskop und Elektronen-Mikroskop EM und JEM 1 000 KV wurden durchgeführt.

ACKNOWLEDGEMENTS

The author wishes to express her gratitude to Dr. R. Skoglund, Geological Survey of Sweden, Stockholm, and Docent V. Jaanusson, Swedish Museum of Natural History, Stockholm, for constructive criticism of the manuscript. Sincere thanks are also due to Drs. E. Norling and G. Kjellström, Geological Survey of Sweden, Stockholm, for valuable collaboration in collecting the material and stimulating discussions.

INTRODUCTION

The purpose of this paper is to present some new observations on coccospheres and coccoliths by means of the scanning electron microscope (SEM). Hitherto, the descriptions of nannofossils have mostly been based on studies using the light microscope.

The first SEM photograph of a coccolith was published by BLACK (1965), but the SEM did not being to play an important role in the micropalaeontology until 1967. The instrument permits the examination of surfaces bearing delicate structures which are extremely difficult to observe with a light microscope. The resolving power is about 200–500 Å with a depth of focus 300 times greater than that of light microscope. The SEM has a greater depth of focus than the conventional transmission electron microscope (see Figs. 32, 37, 39).

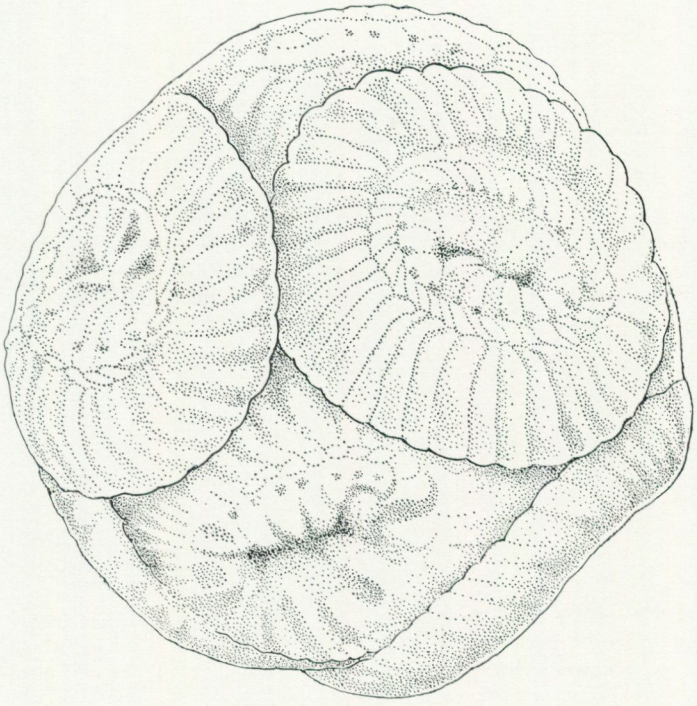

Fig. 1. *Coccolithus bornholmensis* n. sp.
Drawing, distal view of the coccosphere.
Aarnager Greensand, Bornholm, Denmark.
Middle Cenomanian. Magnification 7 200 x.

The preparation of specimens is simpler than for studies using the conventional transmission electron microscope since only vacuum coating with metal (e. g. gold, palladium) is required. The high resolution of SEM permits magnifications from 20 x to 100 000 x. The possibility of tilting and rotating the specimen allows observation from different angles.

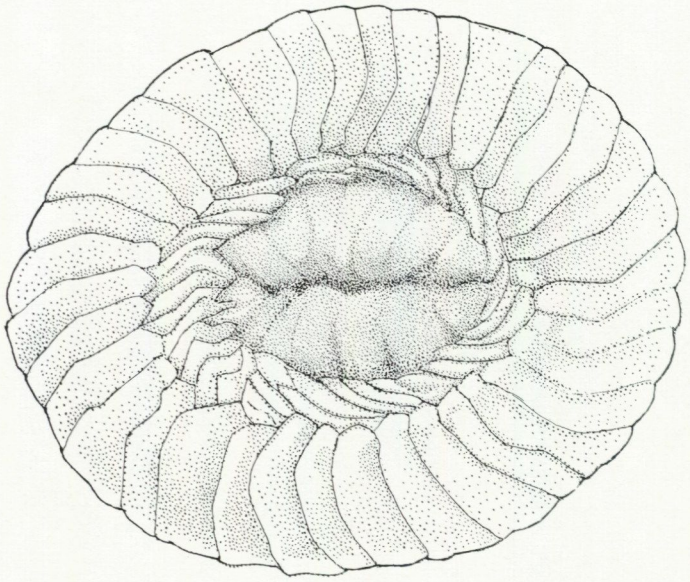

Fig. 2. *Coccolithus bornholmensis* n. sp.
Drawing, distal view of the coccolith
on the same coccosphere. Magnification 12 100 x.

Coccoliths (calcareous nannofossils) were discovered by EHRENBERG (1836), who studied and illustrated specimens found in samples of chalk. He suggested that they were of inorganic origin and called them "Morpholite der Kreide" (Cretaceous "morpholiths"). HUXLEY (1858) found a great number of oval and rounded bodies in the Atlantic deposits. After comparing the "morpholiths" with these minute objects he was doubtful about their inorganic origin. Due to the fact that they looked somewhat like cells of the green alga *Protococcus* he called them "coccoliths".

The inorganic origin of coccoliths was accepted until 1861, when SORBY (1860) and WALLICH (1860, 1861) found that the minute bodies are not separate individuals, but parts of cells with a diameter a few times greater than their own. SORBY found that they formed the walls of small spheres, and were not "flat discs" as described by EHRENBERG, but concave on one side and convex on the other one. He thought that they were derived from decomposed foraminifera.

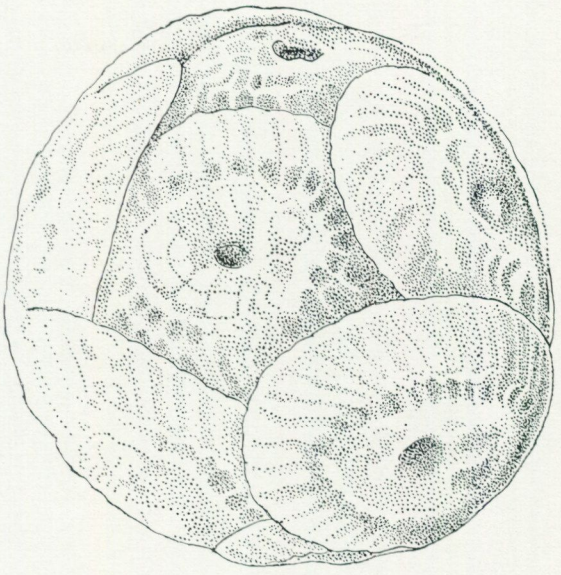

Fig. 3. *Coccolithus* cf *barnesae* (BLACK).
Drawing, distal view of the coccosphere.
Aarnager Greensand, Bornholm, Denmark.
Middle Cenomanian. Magnification 6 200 x.

The true origin of the coccoliths was recorded by WALLICH (1861), who some years later (1865) found the living organisms floating on the sea surface. He called them "coccospheres". Due to the fact that the designation "coccosphere" had earlier been used by PERTY (1852) for small fossils, LOHMAN (1902) suggested "*Coccolithophora*" instead of "*Coccosphaera*". However, the name "*Coccosphaera*" is still used to describe bodies covered with coccoliths.
HAECKEL (1870), SOLLA (1876), MURRAY et BLACKMAN (1897) and OSTENFELD (1899) described coccospheres from deposits in the Atlantic. Coccospheres have also been described by ARKHANGELSKY (1912), LEBOUR (1923), KAMPTNER (1927), SCHILLER (1930), and DEFLANDRE (1939). All the investigations mentioned were at that time naturally carried out by means of the light microscope. Investigations of coccospheres under the transmission electron microscope in the 1960's have been made by BLACK (1962), NOËL (1965), REINHARDT (1966), GARTNER (1968), PERCH-NIELSEN (1968) and BUKRY (1969).

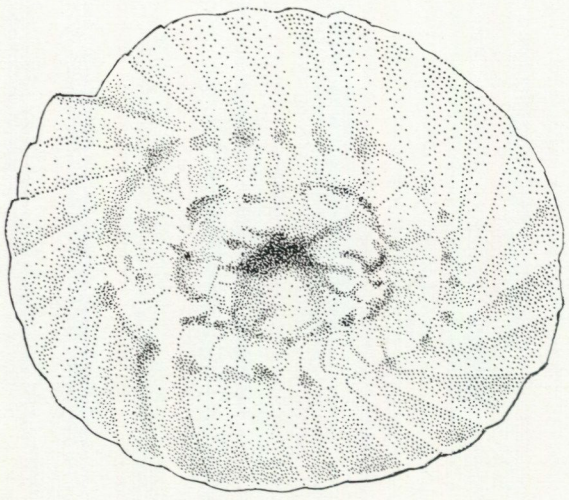

Fig. 4. *Coccolithus* cf *barnesae* (BLACK).
Drawing, distal view of the coccolith.
Aarnager Greensand, Bornholm, Denmark.
Middle Cenomanian. Magnification 10 900 x.

These new investigations with higher resolution gave important contributions to the knowledge of the coccoliths. The forms previously described as *Coccolithus pelagicus* (WALLICH) SCHILLER have been divided into several species such as *Coccolithus barnesae* (BLACK), *Elippsagelosphaera frequens* NOËL and *Watznaueria barnesae* (BLACK). Further studies of these species using SEM and JEM 1 000 KV may give the answer to the question of whether all these are the same species, known from the Jurassic.

MATERIAL

The coccospheres and coccoliths described in this paper are from Aarnager Greensand on the island of Bornholm, Denmark, and the boring Köpingsberg I, SE Sweden. The Cretaceous on the island of Bornholm begins with basal phosphoritic conglomerate covered by Aarnager Greensand rich in calcareous matter. According to RAWN (1916, 1930) these two layers belong to the Middle and Upper Cenomanian respectively. STOLLEY (1930), however, stated that these sediments represent the boundary between the Upper Cenomanian and Turonian or the Lowermost Turonian. Based on foraminiferal and lithological evidence in the boring Höllviken I, BROTZEN (1945) supported the opinion of STOLLEY.

The samples from the Köpingsberg I boring are preliminarily dated to the Cenomanian by NORLING (1968) in an unpublished report.

The samples from Bornholm which are very rich in coccoliths were collected in 1967 when the Köpingsberg I boring was carried out in SE Sweden.

Of the numerous species found in these sediments, two species are preserved as complete coccospheres (Figs. 5, 14, 15). Besides the coccosphere studies of *Coccolithus bornholmensis* n. sp. and *Coccolithus* cf *barnesae* (BLACK) also *Discolithina theta* (BLACK) n. comb. and *Deflandrius cantabrigensis* BLACK are treated in the present paper.

METHODS OF INVESTIGATION

The preparation and mounting methods have already been described in detail (FORCHHEIMER, 1968). In order to remove the excess of clay particles it has been necessary to add a few drops of concentrated hydrofluoric acid per 10 cc of the suspension and leave overnight before centrifugation.

The specimens were studied at the Geological Survey of Sweden, under the scanning electron microscope "STEREOSCAN II" (SEM), made by CAMBRIDGE INSTRUMENT CO LTD., CAMBRIDGE, ENGLAND.

As the instrument is equipped with two alternative camera attachements, "Polaroid" pictures were taken for quick investigations while closer studies were made by means of enlarged photographs from 35 mm KODAK Panatomix X film. Special pairs of pictures were prepared in order to show the stereoscopic effects (Figs. 41, 42, 43, 44). Figs. 32, 37, 39 are conventional transmission electron micrographs of a carbon replica, taken with an AKASHI TRONSCUPE 50 at Karolinska Institutet, Medicinsk Fysik and PHILIPS EM 200 at Institutet för Metallforskning, Stockholm. Comparison has been made

with micrographs from a light microscope ZEISS ULTRAPHOT II and electron microscope JEM 1 000 KV, JAPAN ELECTRON OPTICS LABORATORY CO. LTD.

Type specimens are deposited in the Museum of the Geological Survey of Sweden.

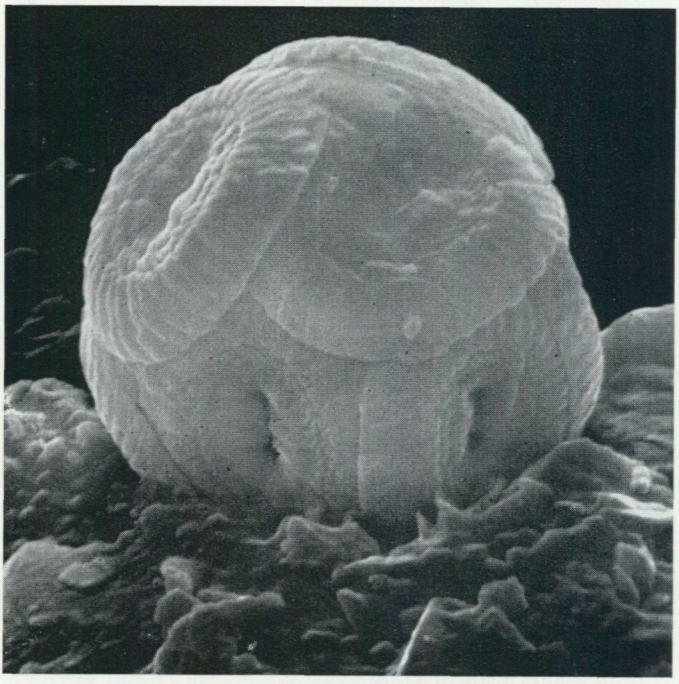

Fig. 5. *Coccolithus bornholmensis* n. sp.
Scanning electron micrograph, distal view of the coccosphere. 50 degrees/595 rotation. Aarnager Greensand, Bornholm, Denmark. Middle Cenomanian. Magnification 6 050 x. Collection number S B03 P1 99/10.

Fig. 6. The same coccosphere of *Coccolithus bornholmensis* n. sp.
Scanning electron micrograph, distal view.
57 degrees/535 rotation. Magnification 6 000 x.
Collection number S B03 P1 99/31.

Fig. 7. The same coccosphere of *Coccolithus bornholmensis* n. sp.
Scanning electron micrograph, distal view.
50 degrees/430 rotation. Magnification 6 200 x.
Collection number S B03 P1 100/3.

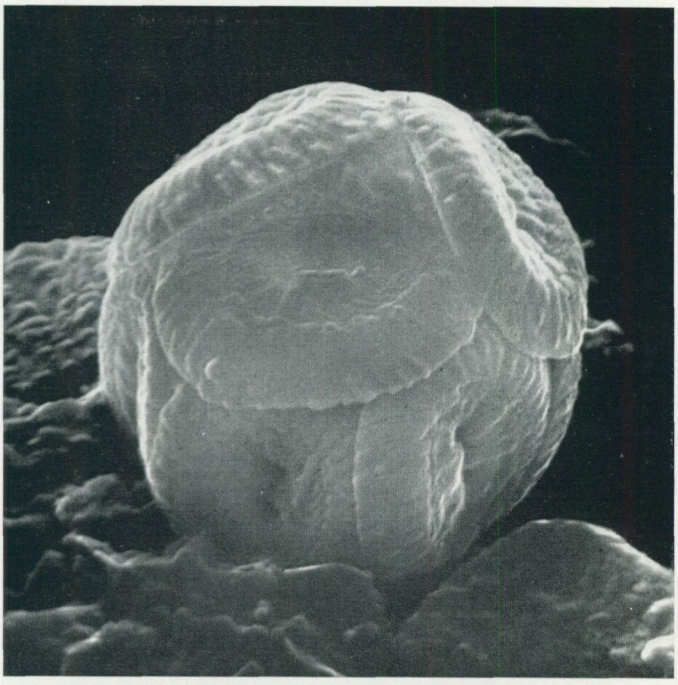

Fig. 6.

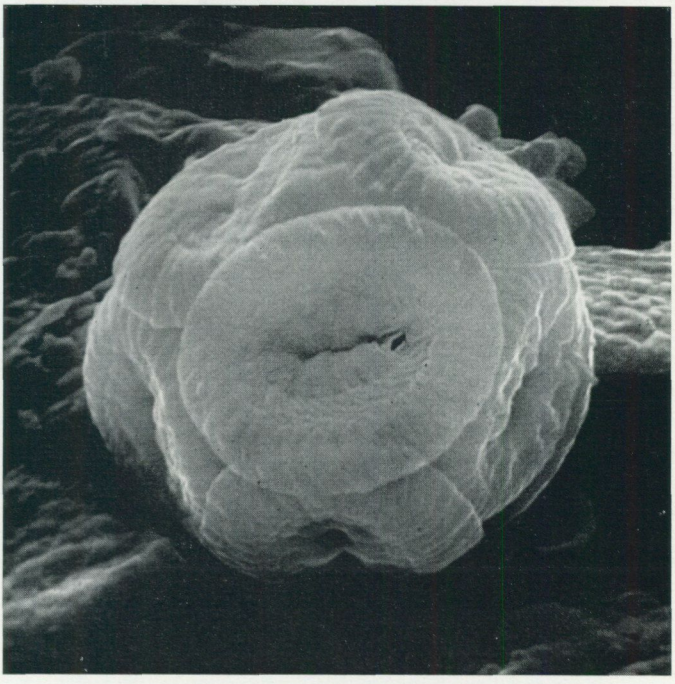

Fig. 7.

SYSTEMATIC DESCRIPTIONS

Family *COCCOLITHACEAE* KAMPTNER, 1928

Genus *Coccolithus* SCHWARZ, 1894

Coccolithus bornholmensis n. sp.

Figs. 1, 2, 5–13, 41

DERIVATION OF NAME. – Named after the island of Bornholm, Denmark.

HOLOTYPE. – S B03 P1 99/10.

TYPE LOCALITY. – Aarnager, Bornholm, Denmark.

DIAGNOSIS. – Coccospheres composed of elliptical coccoliths with more than two shields of different size (observed on free coccoliths). A central area with a central folded slit along the long axis is made up of longitudinal crystal elements surrounded by a ring of overlapping plates. Crystal columns on the proximal side of the distal shield support the proximal shields.

Fig. 8. *Coccolithus bornholmensis* n. sp.
Coccolith of the same coccosphere. Scanning electron micrograph, distal view.
57 degrees/430 rotation. Magnification 12 200 x.
Collection nummer S B03 P1 100/9.

Fig. 9. *Coccolithus bornholmensis* n. sp.
Transmission electron micrograph, JEM 1000 KV, proximal view.
Aarnager Greensand, Bornholm, Denmark.
Middle Cenomanian. Magnification 13 500 x.
Collection number JEM B08 1/8.

DESCRIPTION. – Some coccospheres and free coccoliths of this species have been found in the Aarnager Greensand. The spherical coccospheres are composed of about eight elliptical coccoliths, which slightly overlap each other. In certain positions the coccoliths slightly overlap three adjacent ones (Fig. 5). In other positions an overlap upon five adjacent coccoliths has been noticed (Fig. 7).

The coccoliths of the coccosphere could, of course, be observed only in the distal view. The coccolith shields consist of a border of about 36 crystal elements with a dextral imbrication. The border is inserted into a ring consisting of an equal number of overlapping crystals surrounding the central area. On the inner margin of each crystal there is a small perforation. Photographed at various angles, the central opening shows varying shape, such as a folded slit (Figs. 5, 7), two circular openings (Fig. 6) or sometimes a closed area (Fig. 5).

The proximal view shown on Figs. 10, 11 and 13 has been investigated on free coccoliths from the Aarnager Greensand as well as from the Köpingsberg I boring (Fig. 13). The dark colour gradation on the JEM picture (Fig. 9) shows that the coccoliths are built up of more than two shields.

DIMENSIONS. – HOLOTYPE: Coccosphere: 10 μ in diameter. Coccoliths: length 7 μ, width 6 μ.

REMARKS. – WALLICH (1877) distinguished between two coccosphere species: a spherical one (*Coccosphaera pelagica* WALLICH) and an oblong form (*Coccosphaera carterii* WALLICH). LOHMANN (1902) united the two species with *Coccosphaera atlantica* OSTENFELD, 1899 and proposed a new species *Coccolithophora pelagica* LOHMANN, 1902. Referring to the descriptions of MURRAY et BLACKMAN (1898) he stated that the difference recorded by WALLICH was not relevant. COHEN's (1965) opinion that the shape, size and position of the pores are not important systematic characters seems to be doubtful. I have observed that in the investigated samples coccoliths with a single perforation in the centre proved to be morphologically different from coccoliths with a folded slit. Plenty of possibly unnecessary synonyms have been created due to the observations having been made first under light microscope and later the transmission electron microscope. In the first case the species could have been observed at different levels of focus, but due to the lower resolution of the microscope no fine structure could be seen. In the second case the fine structure has been studied and due to new observations, new names have been proposed. By means of the JEM 1 000 KV and SEM it may be possible to get a truer picture of the coccoliths, their fine structure and their morphology.

"*Coccolithus*" sp. is published by BLACK (1965) without any description. HAQ (1968) has found "a few reworked specimens" in samples from Upper Eocene which he compared to the species described by BLACK. He described the Tertiary form as a narrow elliptical coccolith with a slot-like opening in the centre and with a ring of small elliptical perforations surrounding the central area.

Fig. 10. *Coccolithus bornholmensis* n. sp.
Scanning electron micrograph, proximal view. 0 degrees/000 rotation. Aarnager Greensand, Bornholm, Denmark. Middle Cenomanian. Magnification 10 800 x.
Collection number S B08 P2 89/2.

Fig. 11. The same specimen.
Scanning electron micrograph, proximal view. 51 degrees/000 rotation.
Collection number S B08 P2 89/5.

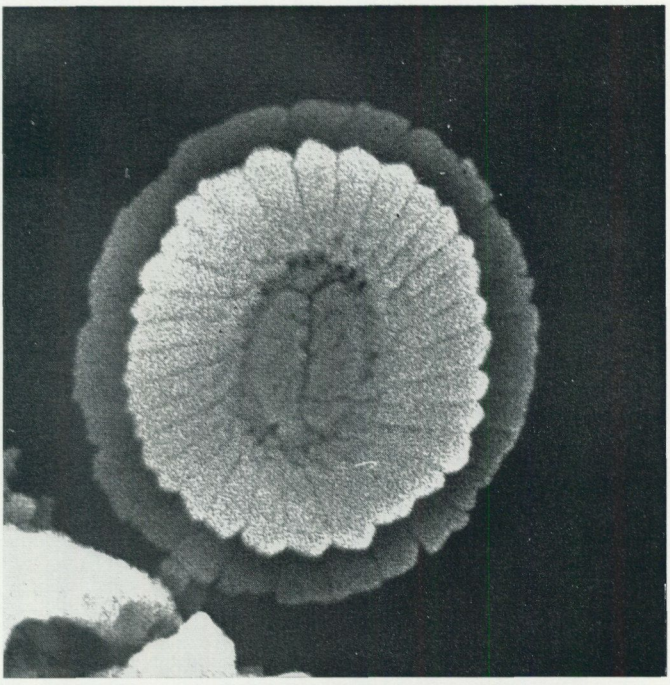

Fig. 10.

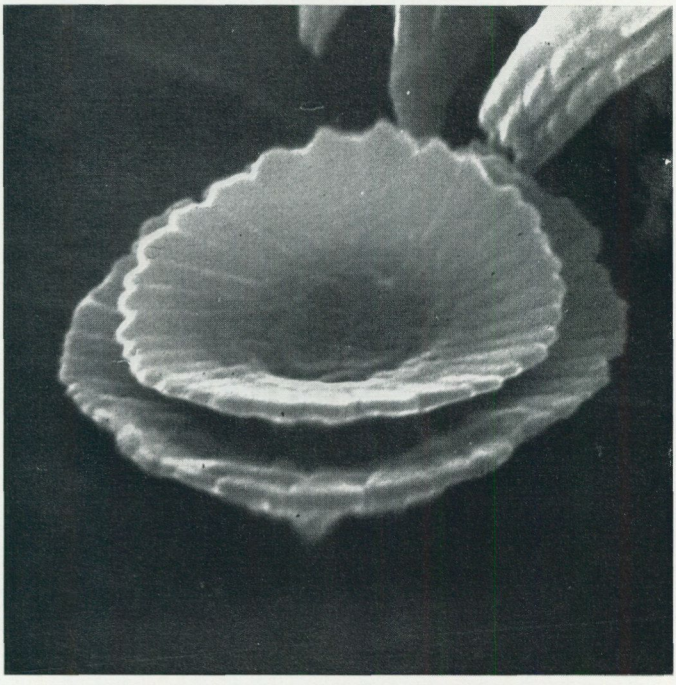

Fig. 11.

Fig. 12. *Coccolithus bornholmensis* n. sp.
Scanning electron micrograph, distal view. 25 degrees/000 rotation.
Aarnager Greensand, Bornholm, Denmark.
Middle Cenomanian. Magnification 6 250 x.
Collection number S B03 P1 104/8.

Coccolithus perforatus HAQ, 1968 differs from *Coccolithus bornholmensis* n. sp. in the smaller number of shields, the absence of the longitudinal crystal in the central area, the ring of the overlapping crystal elements surrounding this aera and the shape of the central opening. These differences are the reason for proposing the new species *Coccolithus bornholmensis* n. sp.

OCCURENCE. – Free coccoliths are abundant in the Aarnager Greensand on the island of Bornholm in Denmark (Middle Cenomanian) and in the Köpingsberg I boring, SE Sweden (Cenomanian). Coccospheres have been found only in the Aarnager Greensand.

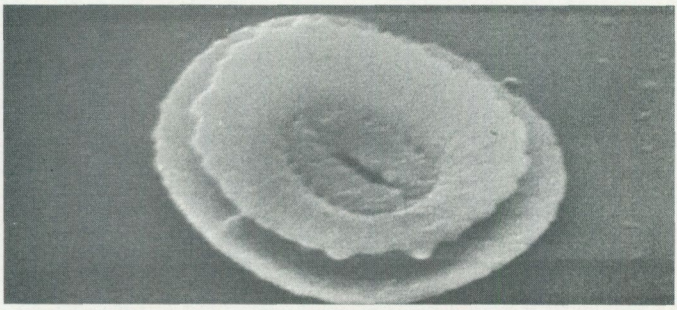

Fig. 13. *Coccolithus bornholmensis* n. sp.
Scanning electron micrograph, proximal view. 45 degrees/000 rotation.
Köpingsberg I boring, SE Sweden. Cenomanian. Magnification 10 000 x.
Collection number S Kp 6 68/19.

Coccolithus cf *barnesae* (Black) Bramlette et Martini, 1964

Figs. 3, 4, 14–22, 42, 43

cf 1959 *Tremalithus barnesae* Black, p. 324, Pl. 9, Figs. 1–2.
cf 1964 *Coccolithus* cf *barnesae* Bramlette et Martini, p. 298, Figs. 13, 14.
cf 1965 *Elipsagelosphaera frequens* Noël, p. 119, Pl. XI, Figs. 7–9, Pl. XII, Fig. 8, Text.Figs. 35, 36.
cf 1966 *Coccolithus paenepelagicus* Stover, p. 139, Pl. 1, Fig. 11; Pl. 8, Fig. 5.
cf 1968 *Coccolithus paenepelagicus* Stover, – Forchheimer, p. 89, Pl. I, Figs. 4a–4b, Text.-Fig. 2 (17).
cf 1968 *Coccolithus barnesae* (Black) Bramlette et Martini – Stradner, p. 24, Pl. 1–2, Text.Fig. 8.
cf 1968 *Coccolithus barnesae* (Black) – Gartner, p. 17, Pl. 1, Fig. 12; Pl. 8, Figs. 18, 19; Pl. 11, Figs. 4–5; Pl. 16, Figs. 15–16; Pl. 20, Figs. 12–13; Pl. 22, Figs. 16–17; Pl. 24, Fig. 8; Pl. 25, Figs 1–2.
cf 1968 *"Ellipsagelosphaera"* sp. – Black, p. 796, Pl. 143, Figs. 5–6.
cf 1968 *Watznaueria barnesae* (Black) Perch-Nielsen, p. 69, Fig. 32; Pl. 22, Figs. 1–7; Pl. 23, Figs. 1, 2, 3, 16.
cf 1969 *Watznaueria barnesae* (Black) Bukry, p. 31, Pl. 10, Figs. 1, 2, 4, 5.

DIAGNOSIS. – Spherical or oblong coccospheres composed of coccoliths, each coccolith consisting of at least three shields of different size (observed on free coccoliths). The central area of the coccolith is surrounded by a ring of small pores and shows a single perforation in the centre. Crystal columns on the distal shield support the proximal shields. A ring of crystals with a more rectangular outline in distal view separates the central area from the outer border.

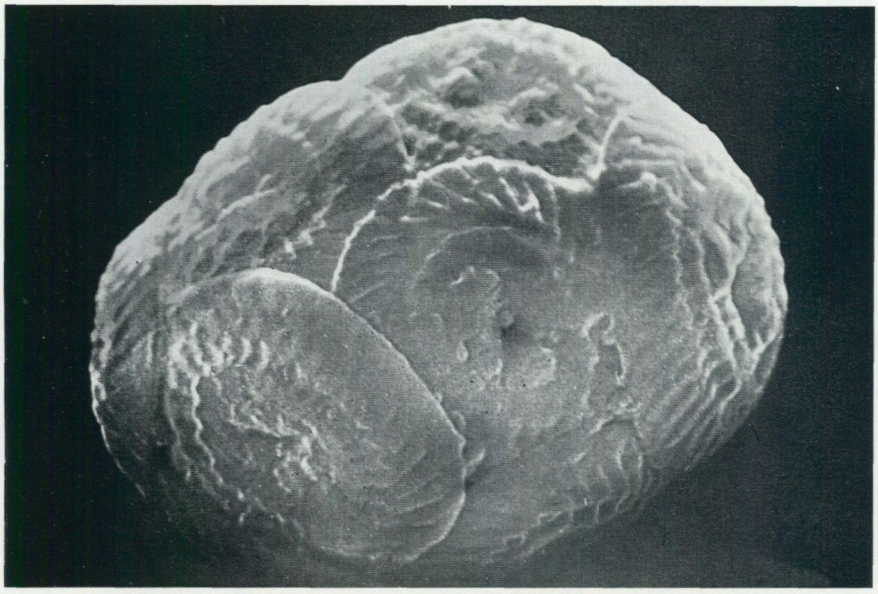

Fig. 14.

Fig. 15.

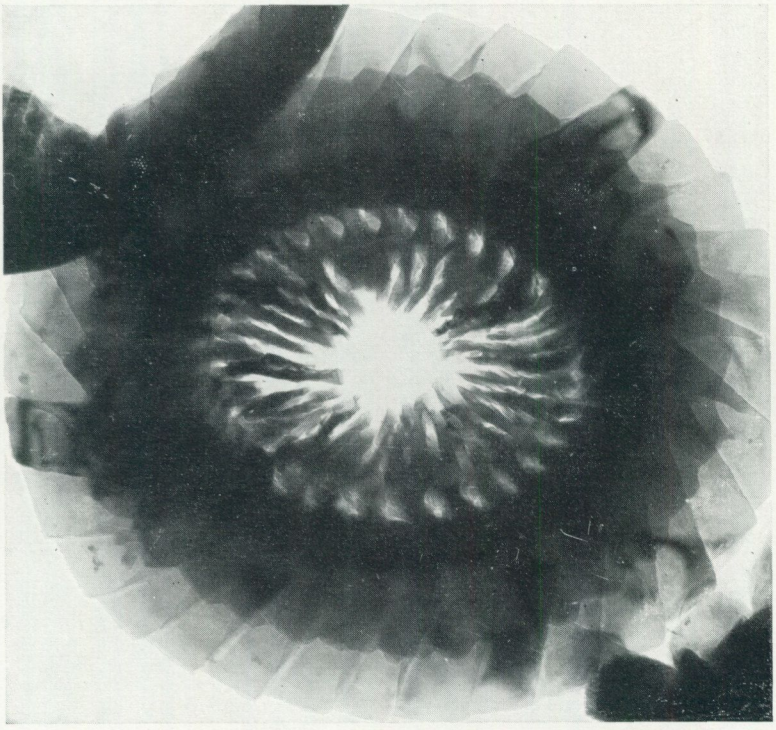

Fig. 16. *Coccolithus* cf *barnesae*.
Transmission electron micrograph, JEM 1000 KV, proximal view. Aarnager Greensand, Bornholm, Denmark. Middle Cenomanian. Magnification 20 000 x.
Collection number JEM 5 B0 P8.

Fig. 14. *Coccolithus* cf *barnesae*.
Scanning electron micrograph of the coccosphere, distal view. 45 degrees/000 rotation. Aarnager Greensand, Bornholm, Denmark. Middle Cenomanian. Magnification 9 000 x.
Collection number S B03 P1 95/6.

Fig. 15. *Coccolithus* cf *barnesae*.
Scanning electron micrograph, distal view of the coccosphere. 45 degrees/948 rotation. Aarnager Greensand, Bornholm, Denmark. Middle Cenomanian. Magnification 6 200 x.
Collection number S B03 P1 104/16.

DESCRIPTION. – The coccosphere of the *Coccolithus* cf *barnesae* BRAMLETTE et MARTINI, 1964 is composed of about ten elliptical coccoliths. The shields of the coccoliths consist of an outer ring with 28 to 33 crystal elements. They overlap each other and incline towards the centre, building up a furrow. The central area with a single opening in the middle is separated from the furrow by a ring of crystals with more rectangular outlines. In specimens photographed in distal (Fig. 21) and proximal (Figs. 19, 20) views the coccoliths are evidently composed of at least three discs of different size. On Fig. 20 the shields are not completely separated. By further cleaning of the samples it might be possible to remove adhering clay and thus reveal the number of shields. The proximal view of free coccoliths was previously studied by conventional transmission electron microscope, SEM and JEM 1 000 KV (FORCHHEIMER, 1968). With the aid of JEM it was possible to see that the coccoliths are built up of more than two shields. The inner shields rest on the proximal side of the distal shield on crystal columns. These crystal columns are placed on the distal rim at intervals of 8–10 crystal elements. The gradation of the dark colour shows the outlines of the different layers (Fig. 16).

Fig. 17. *Coccolithus* cf *barnesae*.
Scanning electron micrograph, distal view. 45 degrees/000 rotation.
Köpingsberg I boring, SE Sweden. Cenomanian. Magnification 10 500 x.
Collection number S Kp 22 84/17.

Fig. 18. The same specimen.
Scanning electron micrograph, distal view.
0 degrees/000 rotation. Magnification 10 800 x.
Collection number S Kp 22 84/29.

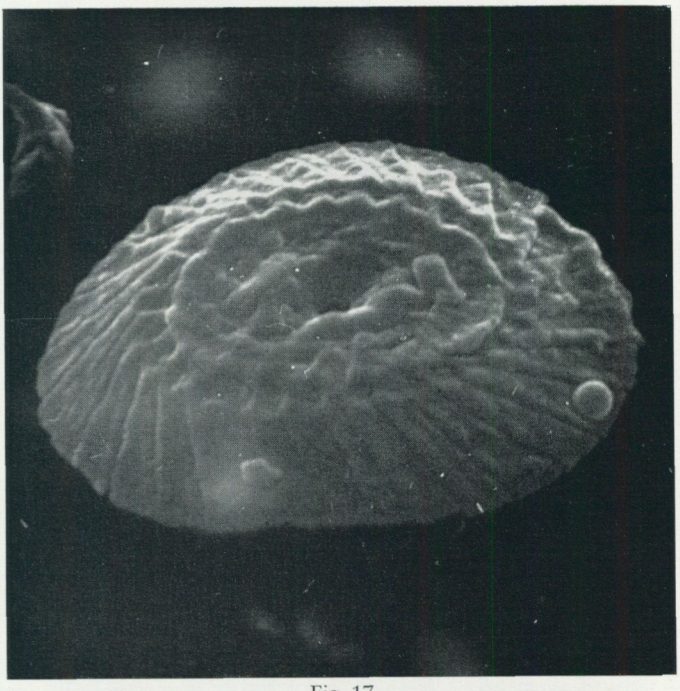

Fig. 17.

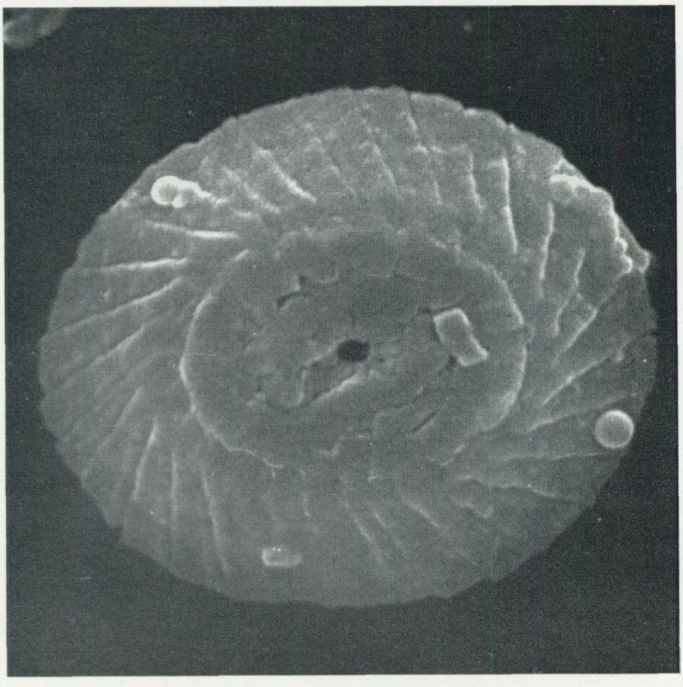

Fig. 18.

REMARKS. – *Coccolithus* cf *barnesae* has been found in the same sample as *Coccolithus bornholmensis* n. sp. The main difference between the two species is confined to the composition of the central area, the furrow and the ring of rectangular crystals separating the central area from the furrow. The opening arrangement in the centre is also different.

Coccolithus cf *barnesae* differs from *Coccolithus barnesae* in STRADNER in having more than two shields and a central area surrounded by a ring of small perforations. The crystal columns supporting the proximal shields are absent in the latter species. *Coccolithus barnesae, Watznaueria barnesae, Ellipsagelosphaera frequens* and all the species of the *Coccolithus pelagicus* group with a single perforation in the centre were previously recorded as having coccoliths composed of two shields. They also lack the small perforations surrounding the central area and the crystal columns supporting the proximal shields. Further investigations of coccoliths of the *Coccolithus pelagicus* group using the SEM and JEM 1 000 KV may make it possible to follow the morphology of this genus from the Jurassic.

DIMENSIONS. – HOLOTYPE: Coccospheres: spherical forms 12 μ in diameter, the oblong one with length 16 μ and width 12 μ.

Coccoliths: length 7 μ, width 6,2 μ.

OCCURRENCE. – Free coccoliths are abundant in the Aarnager Greensand, Bornholm, Denmark (Middle Cenomanian) and in the Köpingsberg I boring, SE Sweden (Cenomanian). Coccospheres have been found in the Aarnager Greensand (Middle Cenomanian).

Fig. 19. *Coccolithus* cf *barnesae*.
Scanning electron micrograph, proximal view. 45 degrees/000 rotation.
Köpingsberg I boring, SE Sweden. Cenomanian. Magnification 10 500 x.
Collection number S Kp 22 83/32.

Fig. 20. The same specimen.
Scanning electron micrograph, proximal view.
51 degrees/000 rotation. Magnification 10 500 x.
Collection number S Kp 22 83/29.

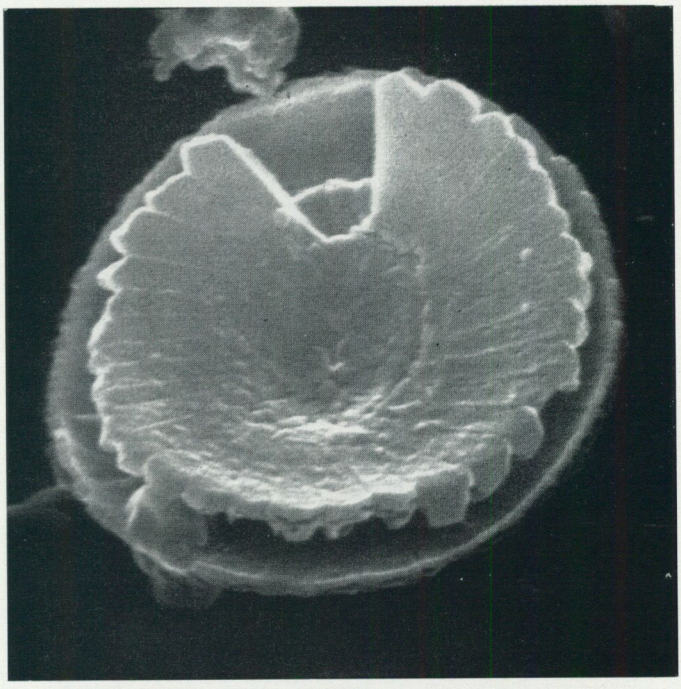

Fig. 19.

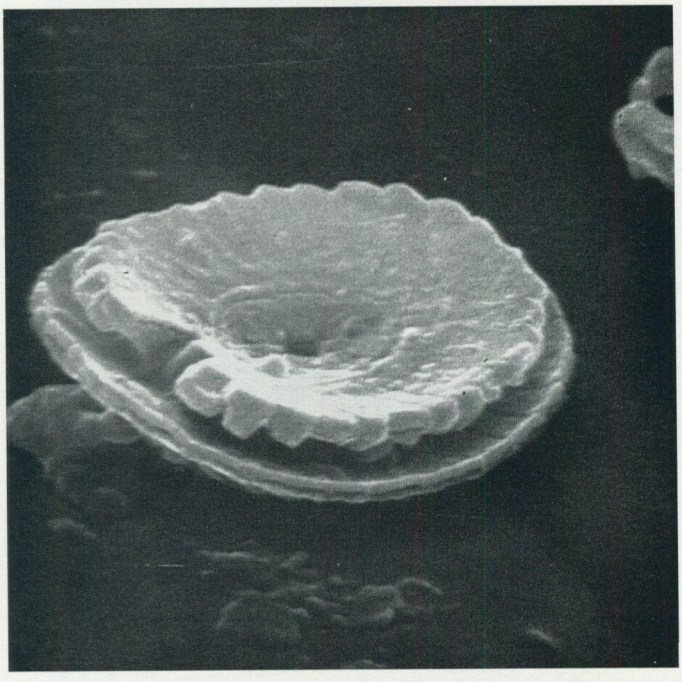

Fig. 20.

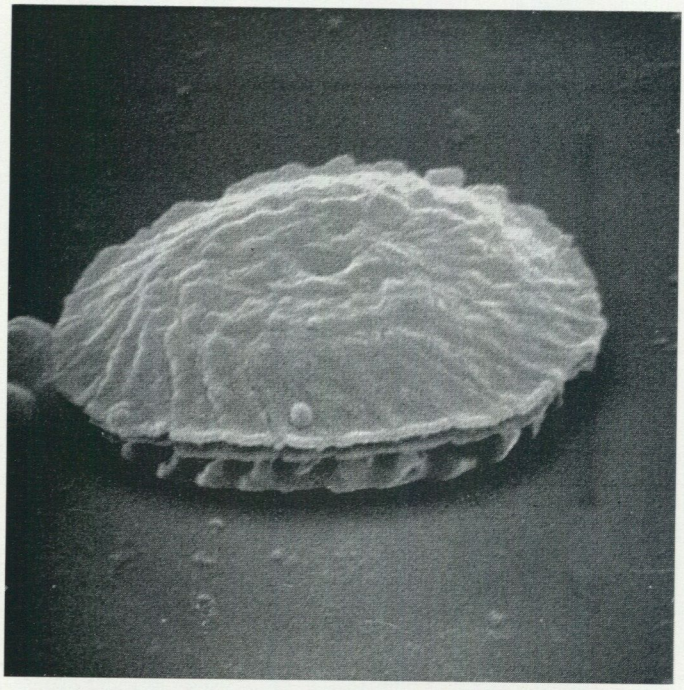

Fig. 21

Fig. 22.

Genus *Discolithina* Loeblich et Tappan, 1963

Discolithina theta (Black) n. comb.

Figs. 23–33, 44.

1959 *Discolithus theta*. Black, p. 327, Pl. XII, Fig. 1.
Non 1969 *Zygodiscus theta* (Black) Bukry, p. 62, Pl. 36, Figs. 7–8.

DESCRIPTION. – Discoliths with a broad rim and central disc with a large opening. The large central opening is divided by a cross-bar into two roughly triangular areas. The cross-bar is composed of two rows of numerous crystal elements orientated in the opposite direction in adjacent rows. The ratio between maximum and minimum diameter of the elliptical outline varies between 1.2 and 1.3. The convex outer rim in the proximal view consists of about 46 to 48 inclined crystal elements which terminate peripherally with deep indentations between. A furrow separates the central disc from the outer rim and supports a ring composed of about 48 roughly square crystals. The two openings are lined by a narrow rim consisting of an equal number of overlapping crystals, inclined in the opposite direction to the crystals of the outer rim. The elements of the internal rim extend into the cross-bar. On the distal side the outer rim is composed of 46 to 48 square crystal elements. The distal view of the bridge (Fig. 30) shows about ten overlapping crystal elements in each row. Figs. 23 and 24 show the same species photographed at different angles. In Fig. 24 the bridge is in shadow and cannot be seen. The shape of the discolith appears nearly circular. The angular difference between Fig. 23 and Fig. 24 is 15 degrees.

Fig. 21. *Coccolithus* cf *barnesae*.
Scanning electron micrograph, distal view. 45 degrees/000 rotation.
Köpingsberg I boring, SE Sweden. Cenomanian. Magnification 13 500 x.
Collection number S Kp 22 71/5.

Fig. 22. *Coccolithus* cf *barnesae*.
Scanning electron micrograph, distal view. 0 degrees/000 rotation. Aarnager Greensand, Bornholm, Denmark. Middle Cenomanian. Magnification 10 900 x.
Collection number S B08 P2 89/1.

DIMENSIONS. – HOLOTYPE: Length 10.7 μ; width 7.6 μ; height 1.1 μ.

REMARKS. – BLACK (in BLACK et BARNES, 1959) has described this species as "elliptical coccoliths with a stout rim of inclined plates, joined along the shorter diameter by a bridge of two rows of plates". He observed traces of crystals filling the openings and began to suspect that these openings were originally filled with a delicate reticle of crystals, easily destroyed later on. Among the numerous specimens from the Aarnager Greensand and Köpingsberg I boring, I only met a few specimens with reticulation and cross-bar as shown in Fig. 31. In the specimens studied there are square crystals on the proximal as well as the distal side and a furrow separating the central disc from the outer rim. These characters cannot be seen on the photograph published by BLACK, but would probably have been visible under SEM. The number of crystal elements is not given by BLACK.

BUKRY thought that *Discolithus theta* belonged to *Zygodiscus* and shows specimens with a rim, narrow cross-bar and two large openings. In distal view the rim is composed of 32 to 46 crystal elements, inclined radially. A stem rises from the centre of the cross-bar. *Discolithina theta* differs from these specimens in being without stem or any indication of it. The square crystals in the proximal as well as in the distal view have been seen in the material studied for this paper. The smaller number of crystals in the proximal side of BUKRY's specimens is a further difference between the two species. The specimens referred by BUKRY to *Zygodiscus theta* apparently belong to *Zygodiscus* and thus are not congeneric with BLACK's species.

OCCURRENCE. – Abundant in the Aarnager Greensand, Bornholm, Denmark (Middle Cenomanian) and in the Köpingsberg I boring, SE Sweden (Cenomanian).

Fig. 23. *Discolithina theta* (BLACK) n. comb.
Scanning electron micrograph, proximal view. 45 degrees/000 rotation.
Aarnager Greensand, Bornholm, Denmark. Middle Cenomanian. Magnification 6 500 x.
Collection number S B08 P2 58/1.

Fig. 24. The same specimen.
Scanning electron micrograph, proximal view.
60 degrees/410 rotation. Magnification 12 000 x.
Collection number S B08 P2 58/4.

Fig. 23.

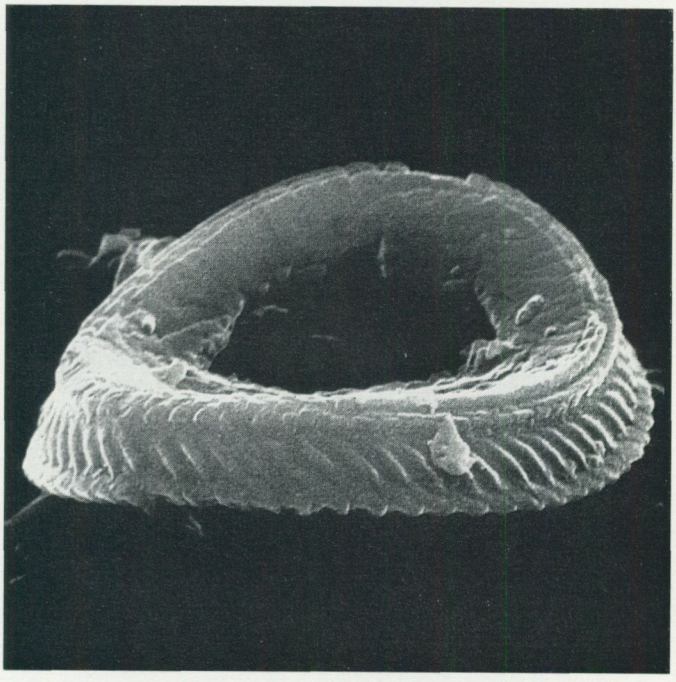

Fig. 24.

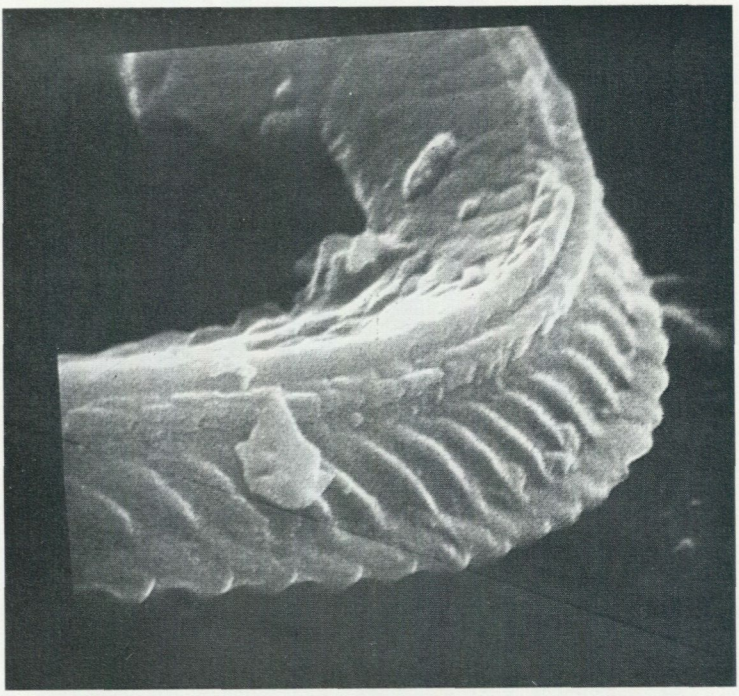

Fig. 25.

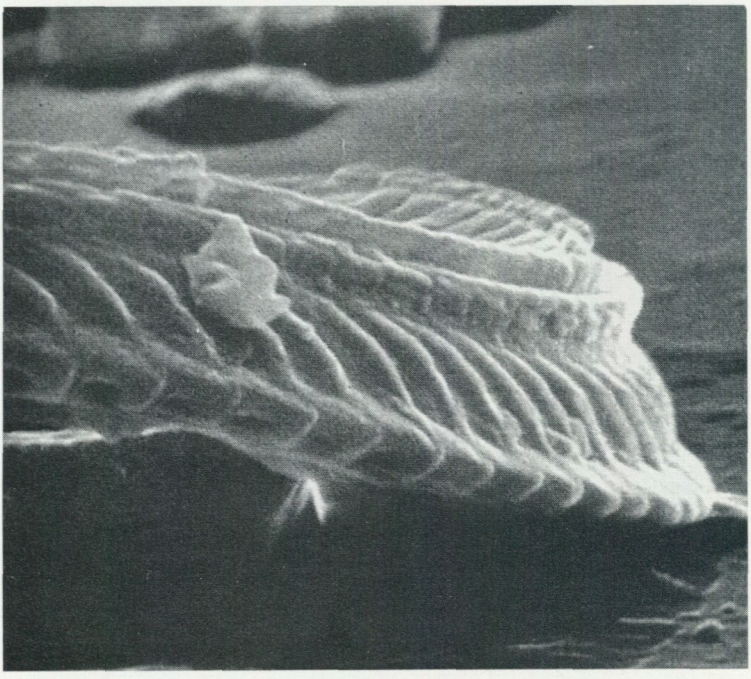

Fig. 26.

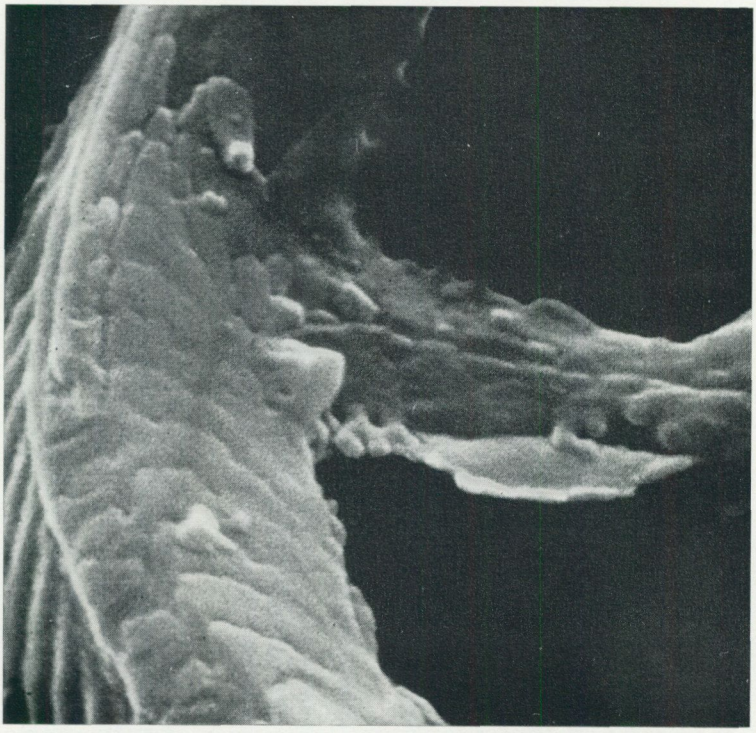

Fig. 27. The cross-bar and a part of the rim of the same specimen
Discolithina theta (BLACK) n. comb.
76 degrees/410 rotation. Magnification 24 200 x.
Collection number S B08 P2 58/6.

Fig. 25. The same specimen as on Fig. 23.
Scanning electron micrograph, a part of the rim.
60 degrees/410 rotation. Magnification 24 000 x.
Collection number S B08 P2 58/3.

Fig. 26. The same specimen as on Fig. 25.
80 degrees/410 rotation. Magnification 24 000 x.
Collection number S B08 P2 58/5.

Fig. 28. The same specimen of *Discolithina theta* (BLACK) n. comb.
Scanning electron micrograph of a part of the rim from above.
45 degrees/000 rotation. Magnification 24 300 x.
Collection number S B08 P2 58/5.

Fig. 29. *Discolithina theta* (BLACK) n. comb.
Scanning electron micrograph, proximal view. 27 degrees/000 rotation.
Aarnager Greensand, Bornholm, Denmark.
Middle Cenomanian. Magnification 10 500 x.
Collection number S B08 P2 60/10.

Fig. 30. *Discolithina theta* (BLACK) n. comb.
Scanning electron micrograph, distal view. 45 degrees/000 rotation.
Aarnager Greensand, Bornholm, Denmark.
Middle Cenomanian. Magnification 12 800 x.
Collection number S B03 P1 60/12.

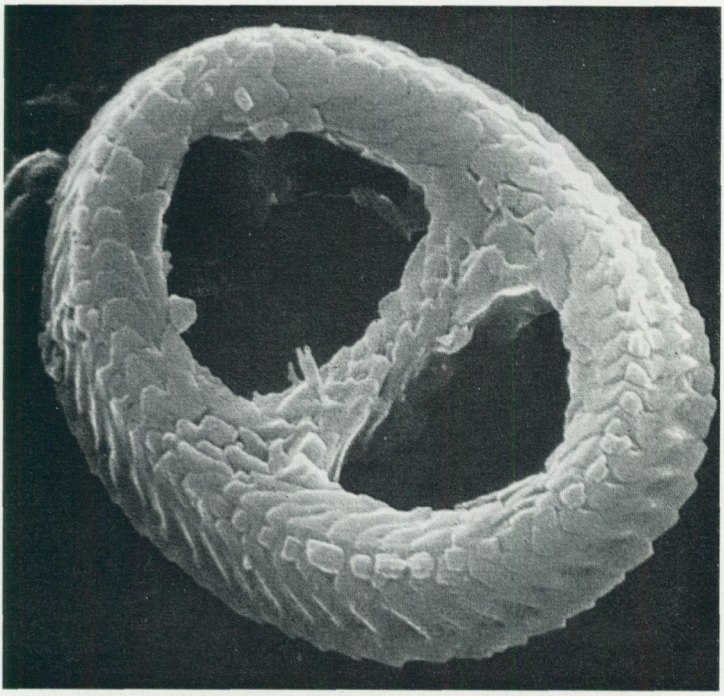

Fig. 29.

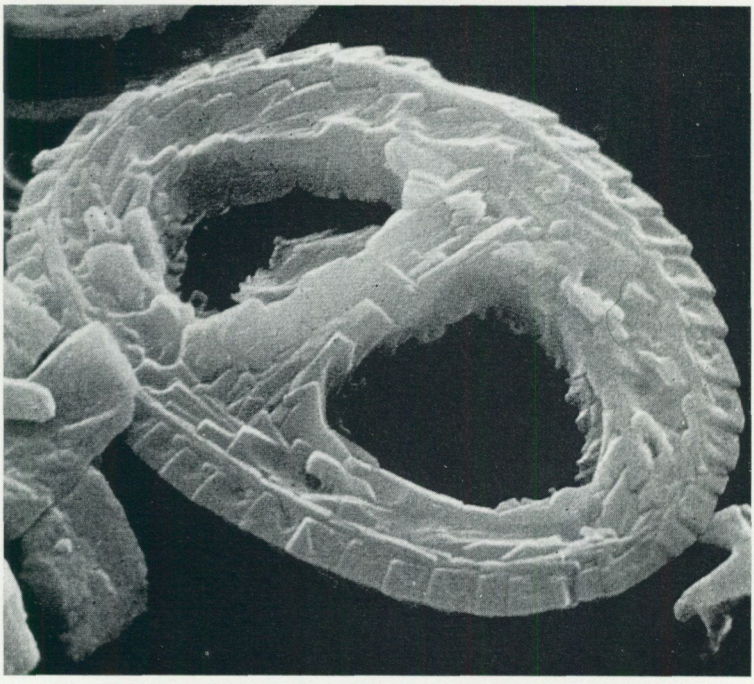

Fig. 30.

Fig. 31.

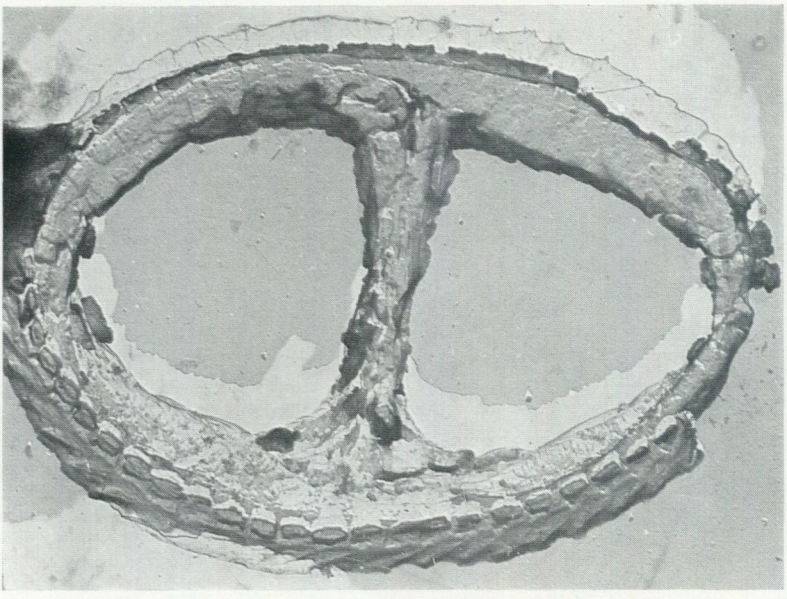

Fig. 32.

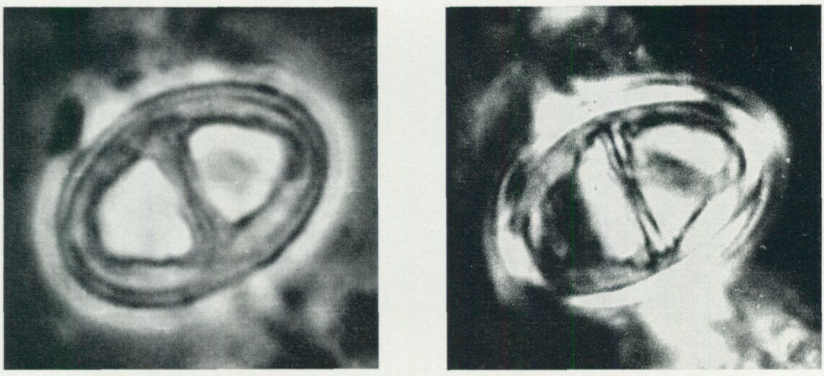

Fig. 33 a–b: a) *Discolithina theta* (Black) n. comb.
Light micrograph, phase contrast, proximal view.
Aarnager Greensand, Bornholm, Denmark.
Middle Cenomanian. Magnification 3 000 x.
Collection number L B08 P49 45/22.

b) X-Nicols.
Collection number L B08 P49 45/23.

Fig. 31. ? *Discolithina theta* (Black) n. comb.
Scanning electron micrograph, distal view of a broken coccolith.
Aarnager Greensand, Bornholm, Denmark.
Middle Cenomanian. Magnification 14 800 x. 45 degrees/000 rotation.
Collection number S B03 P1 97/8.

Fig. 32. *Discolithina theta* (Black) n. comb.
Transmission electron micrograph, proximal view.
Aarnager Greensand, Bornholm, Denmark.
Middle Cenomanian. Magnification 16 000 x.
Collection number P B08 51.

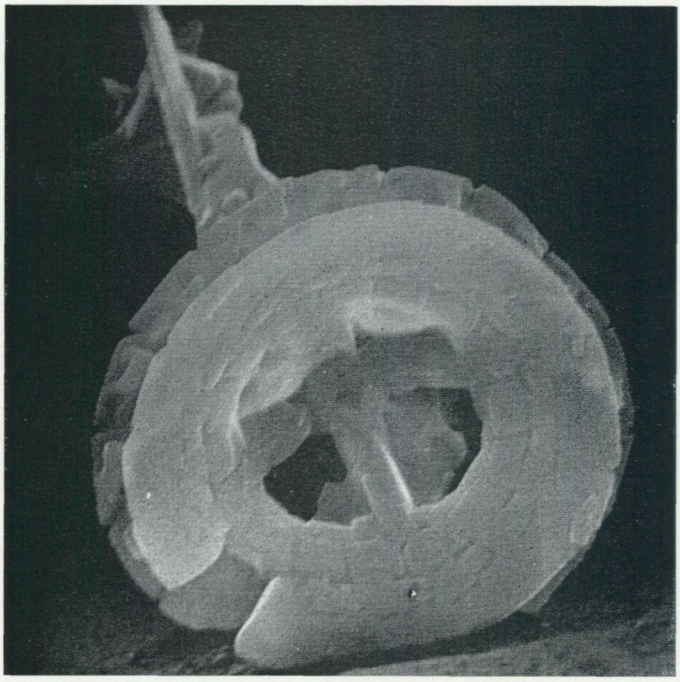

Fig. 34.

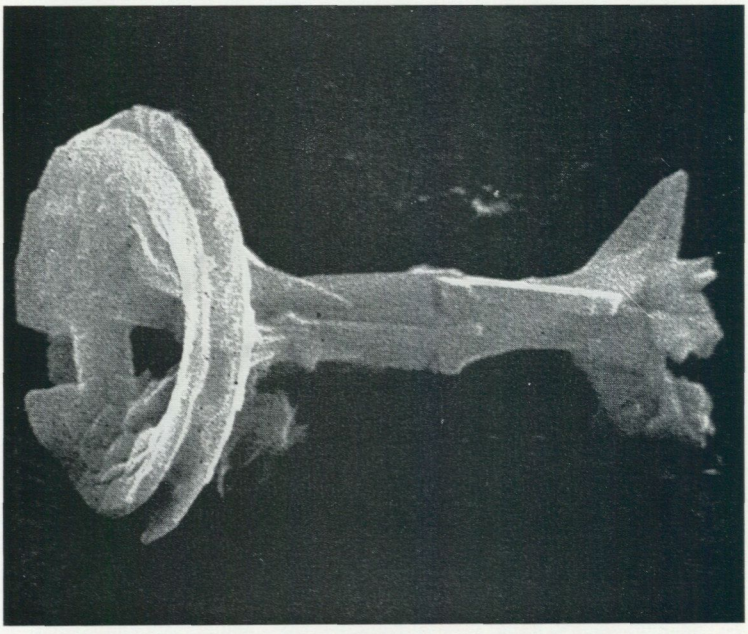

Fig. 35.

Fig. 36. The same specimen of *Deflandrius cantabrigensis* BLACK.
Scanning electron micrograph, side view of the basal shield.
60 degrees/1 098 rotation. Magnification 20 000 x.
Collection number S B08 P2 60/3.

Fig. 34. *Deflandrius cantabrigensis* BLACK.
Scanning electron micrograph, the basal shield and a part of the stem.
Aarnager Greensand, Bornholm, Denmark. Middle Cenomanian.
Magnification 11 800 x. 60 degrees/000 rotation.
Collection number S B08 P2 60/1.

Fig. 35. The same specimen.
Scanning electron micrograph, side view.
60 degrees/1 098 rotation. Magnification 8 400 x.
Collection number S B08 P2 60/2.

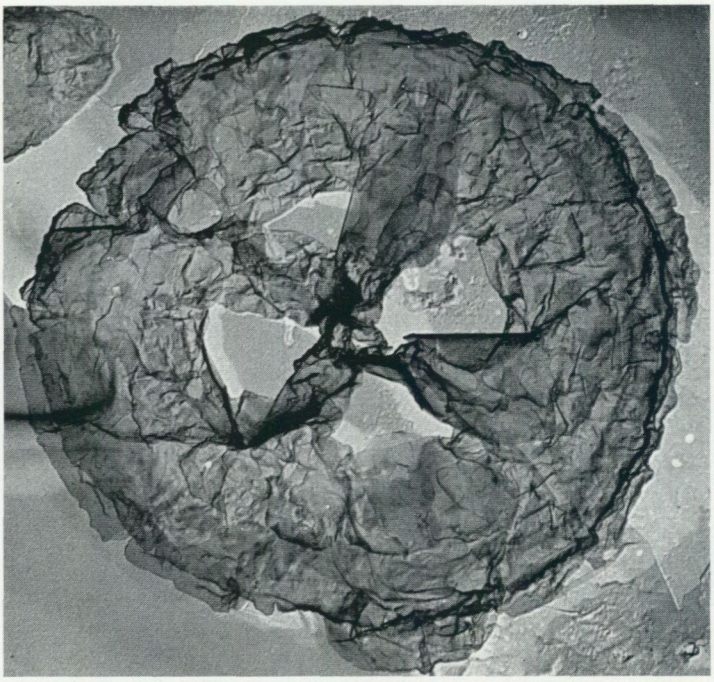

Fig. 37. *Deflandrius cantabrigensis.* BLACK.
Transmission electron micrograph, distal view of the basal plate.
Aarnager Greensand, Bornholm, Denmark.
Middle Cenomanian. Magnification 16 000 x.
Collection number A B08 4.

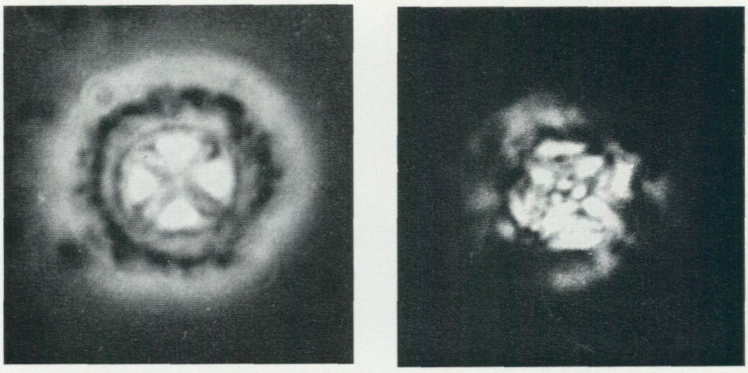

Fig. 38 a–b: a) *Deflandrius cantabrigensis* BLACK.
Light micrograph, phase contrast, distal view of the basal shield.
Middle Cenomanian. Magnification 3 200 x.
Collection number L B08 P49 45/1.

b) X-Nicols.
Collection number L B08 P49 45/3.

Family *DEFLANDRIACEAE* Black, 1967

Genus *Deflandrius* Bramlette et Martini, 1964

Deflandrius cantabrigensis Black, 1967

Figs. 34–40.

1861 Sorby H. C., p. 199, Figs. 3–4, p. 197.
1965 *"Deflandrius"* sp. Black, p. 134, Figs. 14–15.
1967 *Deflandrius cantabrigensis* Black, p. 140, Fig. 1.
1968 *Deflandrius cantabrigensis* Black, p. 807, Pl. 151, Fig. 1.

REMARKS. – Fig. 34 shows the basal shield of *Deflandrius* cf *cantabrigensis* Black and only the upper part of the stem. By rotation of the sample holder through 90 degrees it was possible to study the specimen from the side (Fig. 35). The discs of the basal shield appear now as one shield with a deep peripheral furrow (Fig 36). The whole stem with the protuberances and the "wings" is now visible, as well as three rims on the basal shield (Fig. 35). The JEM 1 000 KV picture (Fig. 40) also shows that the basal shield is built up of three rims consisting of 16 crystal elements each.

DIMENSIONS. – HOLOTYPE: The basal shield 6 μ in diameter. The length of the stem 6.7 μ.

OCCURRENCE. – Abundant in the Aarnager Greensand, Bornholm, Denmark (Middle Cenomanian) and in the Köpingsberg I boring, SE Sweden (Cenomanian).

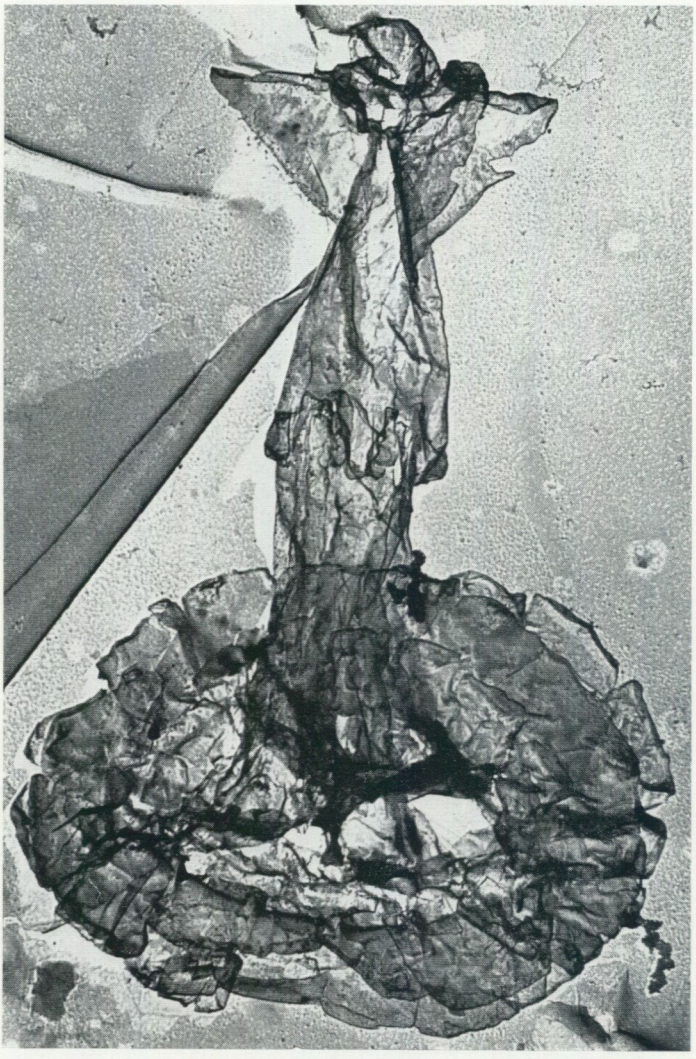

Fig. 39. *Deflandrius cantabrigensis* BLACK.
Transmission electron micrograph, side view.
Aarnager Greensand, Bornholm, Denmark.
Middle Cenomanian. Magnification 16 000 x.
Collection number A B08 16.

Fig. 40. *Deflandrius cantabrigensis* BLACK.
Transmission electron micrograph, JEM 1 000 KV, basal shield.
Aarnager Greensand, Bornholm, Denmark.
Middle Cenomanian. Magnification 10 500 x.
Collection number JEM B08 21.

Fig. 41–44.
Pairs of stereoscopic pictures for the ZEISS Stereoscop TS 4.
41. *Coccolithus bornholmensis* n. sp.
42. *Coccolithus* cf *barnesa*e (BLACK).
43. *Coccolithus* cf *barnesae* (BLACK).
44. *Discolithina theta* (BLACK) n. comb.

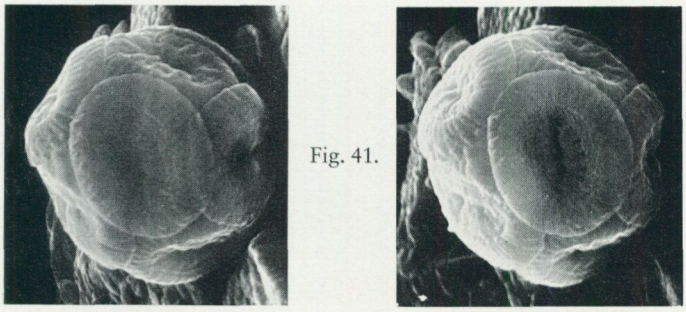

Fig. 41.

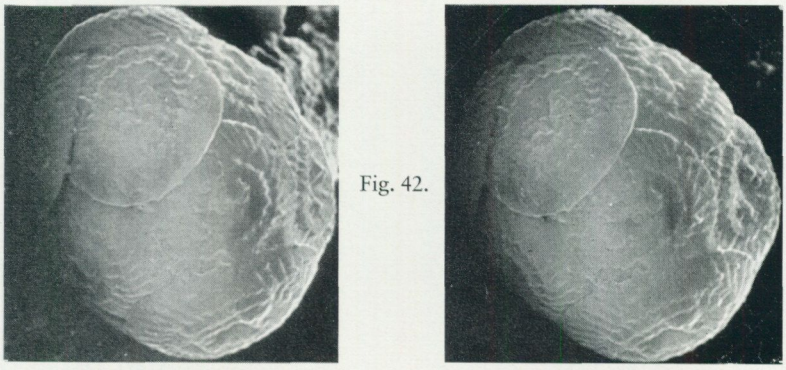

Fig. 42.

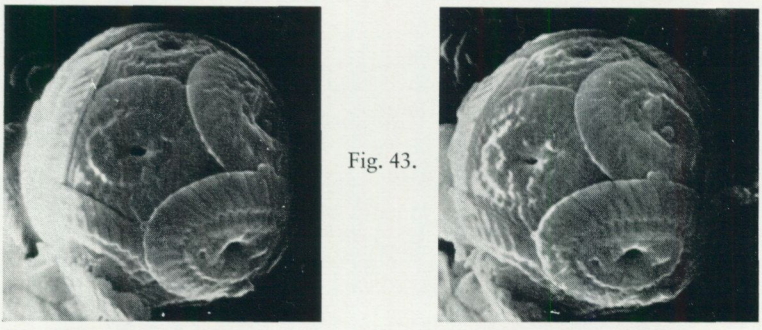

Fig. 43.

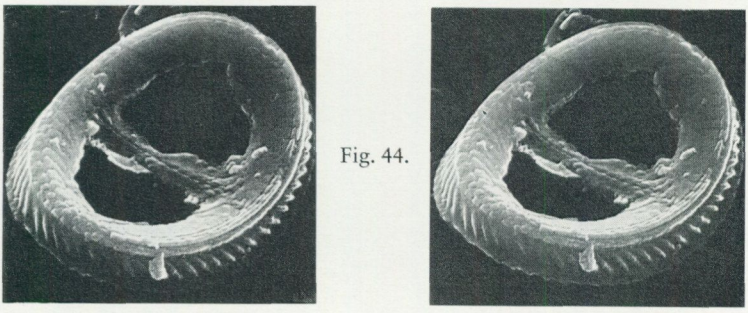

Fig. 44.

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