

Observations on Coccoliths of *Syracosphaera mediterranea* Lohm., *S. pulchra* Lohm., and *S. molischi* Schill. in the Electron Microscope.

By

Per Halldal and Joar Markali

Biological Laboratory B,
University of Oslo, Blindern. Central Institute for
Industrial Research, Blindern.

AN important part of the phytoplankton population in the warmer open ocean consists of coccolithophorids. Some of them, for instance *Coccolithus huxleyi* (Lohm.) Kampt., may also occur in vast numbers in the coastal waters of higher latitudes and cause discoloration of the sea. The coccolithophorids are minute flagellates (mostly 4–20 μ) and are not usually caught by plankton nets. Their cells are covered by calcified elements (coccoliths) of varied shape and structure.

The taxonomy of the group is to a great extent based upon the morphology of the coccoliths. Recently the electron microscope has been used for obtaining further information on their structure (Braarud and Nordli 1952, Braarud *et al.* 1952, Deflandre and Fert 1952 and 1953, Kamptner 1952, Halldal and Markali 1953).

The method now used for preparing specimens of coccoliths for electron microscope studies is by drying on the electron microscope grid.

As the coccoliths are more or less flat in shape, they are mostly observed normal to the base. When a part of the collodion or formvar films is exposed to violent electron radiation, the film often cracks and the coccoliths may then be studied at different angles.

By examining a great many samples in the electron microscope and combining these observations with those in light microscopes, Braarud *et al.* (l.c.) and Halldal and Markali (l.c.) succeeded in obtaining detailed information on the morphology of the coccoliths from four different genera: *Coccolithus*, *Syracosphaera*, *Anthosphaera*, and

Calyptosphaera. The present paper deals mainly with the structure of coccoliths belonging to the commonest type, the discolith, described on the basis of light microscope observations. Discoliths are cup- and saucer-shaped coccoliths with their concave side facing outwards (Figure 1). The outline is slightly elliptical or almost circular. A hump, a spine, or a rod usually protrudes from the base.

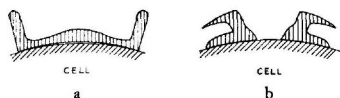
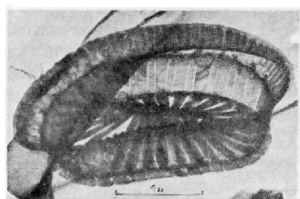


Figure 1. Cross-section of a discolith (a) and a placolith (b) as seen in a light microscope.

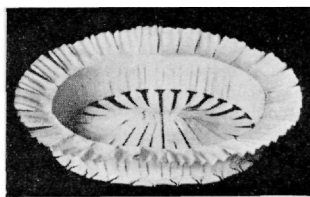
The coccolithophorids analysed in this paper (*Syracosphaera mediterranea*, *S. pulchra*, and *S. molischi*) have been isolated from preserved sea water samples collected at Weather Ship Station M (66°N., 2°E.) in the Norwegian Sea.

Syracosphaera mediterranea Lohm.

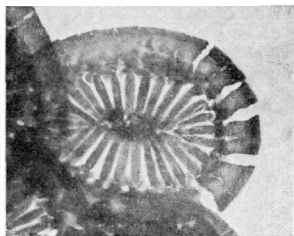
In Figure 2a a discolith from *Syracosphaera mediterranea* is seen in half side view. The coccolith is more or less covered by the cracked formvar film, but the outline of the film can be clearly distinguished from that of the coccolith. Schematically this coccolith may be divided



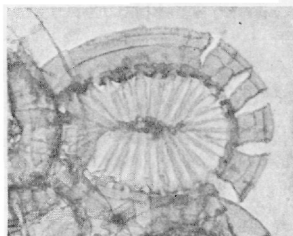
a) electron micrograph in half side view.



b) model in about the same angle of view.



c) seen from above.



d) the latter after treatment with hydrochloric acid.

Figure 2. Coccoliths of *Syracosphaera mediterranea* Lohm.

into four parts (see Figure 3):— (1) The bottom consists of 28 flat ribs (the numbers mentioned in this description may vary from one coccolith to the other), arranged at right angles to the elliptical outline. The bottom is concave, so it presumably fits the form of the cell. (2) The cylindrical wall is split up into alternately broad and narrow elements, 56 in all. The narrow elements end in an arch ca. $0.1\ \mu$ from the edge

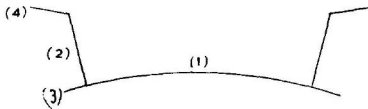
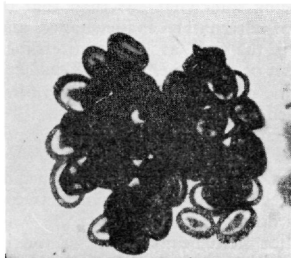
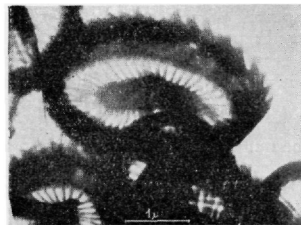


Figure 3. Cross-section of a *Syracosphaera mediterranea* discolith. 1) bottom, 2) wall, 3) lower rim, 4) upper rim.

of the wall. (3) The structure of the lower rim is closely connected with that of the wall, the narrow elements in the wall continuing as spade-shaped elements of the lower rim, the broad ones as tapering elements. (4) The upper rim is split up into 28 elements which are evenly corrugated.



a) surrounding a disintegrated cell.



b) seen slightly from the side.

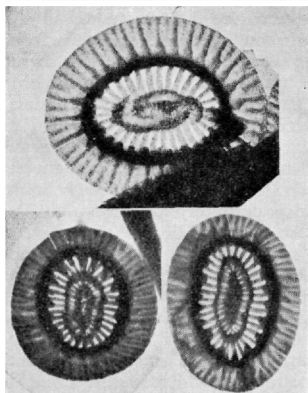


c) details of the bottom ribs.

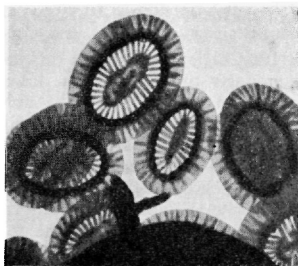


d) one of those bordering the flagellar field.

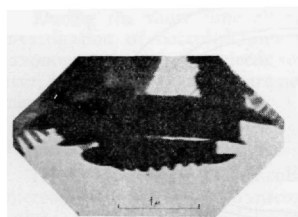
Figure 4. Coccoliths of *Syracosphaera pulchra* Lohm.



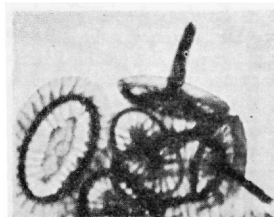
a) showing the different developments in the central part.



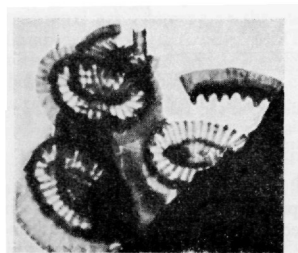
b) surrounding a disintegrated cell.



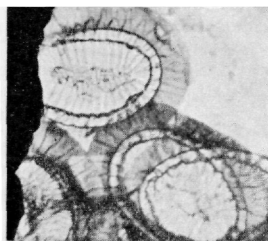
c) two different sizes seen from the side.



d) some of the coccoliths bordering the flagellar field.



e) a coccolith with its bottom torn away from the rest of it.



f) after treatment with hydrochloric acid.

Figure 5. Coccoliths of *Syracosphaera molischi* Schill.

0.2–0.3 μ high (Figure 5c). Its microstructure is best studied in the coccoliths treated with hydrochloric acid (Figure 5f). When seen from above, the wall appears as an area between the bottom and the broad upper rim. The lightest parts in these hydrochloric acid-treated coccoliths are those containing the greatest amount of CaCO_3 . A secondary system of CaCO_3 -rich elements may be developed and extend as spines from the wall towards the centre (Figures 5a and 5e). Each rib in the bottom corresponds to one of these elements. In the interval between the CaCO_3 -rich elements in the wall the organic matter is more abundantly present. (3) The lower rim is definitely narrower than the upper one (Figure 5c). The number of elements is the same as the number of ribs in the bottom and the number of elements in the upper rim. (4) The CaCO_3 -rich "shovels" appear to fortify a part of the elements in the upper rim. The rest of the upper rim is poorer in CaCO_3 .

The coccoliths bordering the flagellar field are smaller than the ordinary ones, and when seen from above, they are more circular in outline and the breadths of the upper and lower rims are about the same. The central part is shaped like a spine or rod, which is split along its long axis into two or three closely connected elements (Figure 5d).

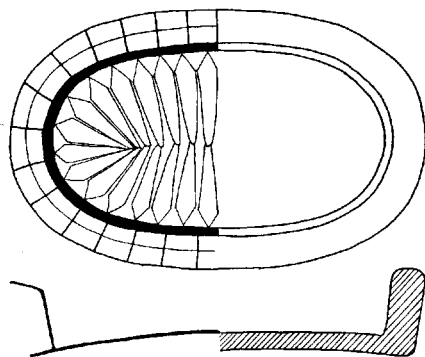


Figure 6. The discolith-type dealt with in this paper (simplified) as seen in former light microscope observations (right) and in the electron microscope (left).

Comparison of electron microscopy with light microscopy.

It is of particular interest to compare the electron micrographs in this paper with the pictures obtained in a light microscope. The resolving power of a light microscope is limited to about 0.2 μ . This means that neither the upper nor the lower rim, when seen directly from the side, can be resolved in a light microscope, as the thickness scarcely exceeds 0.1 μ . On the other hand, the upper rim, being about 0.4 μ

broad, can easily be resolved when seen from above. Consequently we are of the opinion that the breadth of the rim when seen from above in a light microscope has been interpreted as the thickness of the discolith wall (see Figure 6).

The coccoliths which have hitherto been studied in electron microscopes have displayed a great variety of designs. Those described above seem to have many similarities with unidentified coccoliths depicted by Deflandre and Fert (l. c.) and with some which we have observed in water samples from the Norwegian Sea and the Faroe—Shetland Channel (unpublished).

On the other hand, they differ completely from the coccoliths in *Syracosphaera carterae* (Braarud et al. 1952), which, when examined in a light microscope were recorded as discoliths (Braarud and Fagerland 1946). Finally we may mention the many features common to the coccoliths of both *Syracosphaera mediterranea* and *Coccolithus huxleyi*, as the latter also has a bottom, a wall, and lower and upper rims (Braarud et al. 1953). This last comparison is of special interest, since *Coccolithus huxleyi*, on the evidence from light microscope observations, by Kamptner (1943), was transferred some years ago from the genus *Pontosphaera* (a genus with discoliths; see Figure 1a) to its present place (a genus with placoliths; see Figure 1b).

During the short time electron microscopy has been used in the investigation of coccolithophorids, it has become apparent that the taxonomy of this group needs to be reviewed on several points. However, far more observations are needed to obtain a satisfactory rearrangement of the species.

Summary.

(1) Coccoliths of the discolith type were studied in the electron microscope, single cells of *Syracosphaera mediterranea* Lohm., *S. pulchra* Lohm., and *S. molischi* Schill. being isolated from preserved sea water samples. (2) According to the electron micrographs these coccoliths consist of four parts, viz., bottom, wall, lower and upper rim. (3) The reciprocal arrangement of the elements in these different parts showed a high degree of regularity. (4) The electron micrographs were compared with the picture in an ordinary light microscope. (5) These species of the genus *Syracosphaera* show a coccolith morphology which is different in principle from that of *S. carterae* Braarud and Fagerland.

Literature.

- Braarud, T., and E. Fagerland, 1946. "A coccolithophoride in laboratory culture. *Syracosphaera carterae* n. sp." Norsk. Vidensk.-Akad. Oslo, Avh. I, 1946, No. 2.
- Braarud, T., and E. Nordli, 1952. "Coccoliths of *Coccolithus huxleyi* seen in an electron microscope." Nature, 170, p. 361.
- Braarud, T., K. Ringdal Gaarder, J. Markali, and E. Nordli, 1952. "Coccolithophorids studied in the electron microscope. Observations on *Coccolithus huxleyi* and *Syracosphaera carterae*." Nytt Magasin for Botanikk, 1, Oslo.

- Deflandre, G., and Ch. Fert, 1952. "Microscopie électronique et Micro-paléontologie." C. R. Acad. Sci., **234**, pp. 2100—2. Paris.
- 1953. "Microscopie électronique et Protistologie." Ibidem, **236**, pp. 328—330.
- Halldal, P., and J. Markali, 1953. "Morphology and microstructure of coccoliths studied in the electron microscope. Observations on *Anthosphaera robusta* (Lohm.) Kampt. and *Calyptrorphaera papillifera* Halldal." Nytt Magasin for Botanikk, **2**, Oslo.
- Kamptner, E., 1941. "Die Coccolithineen der Südwestküste von Istrien." Ann. Naturhist. Mus. Wien, **51**, Wien.
- 1943. "Zur Revision der Coccolithineen-Spezies *Pontosphaera huxleyi* Lohm." Akad. Wissensch. Wien, **11**, Wien.
- 1952. "Das mikroskopische Studium des Skelettes der Coccolithineen (Kalkflagellaten)." Mikroskopie, **7**, 7/8, 11/12, pp. 232—244, 375—386. Wien.
- Schiller, J. O., 1930. "Coccolithineae". Rabenhorst's Kryptogamen-Flora, **10**, **2**, Leipzig.