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Irena KACZMARSKA [1], Wincenty KILARSKI [2]

THE STRUCTURE OF *MELOSIRA SULCATA* (EHR.) KÜTZ. VAR. SULCATA FRUSTULES FROM LOWER OLIGOCENE DIATOMITES FROM FUTOMA (CARPATHIANS, POLAND)

(Pl. I—III)

Budowa pancerzyków Melosira sulcata (Ehr.) Kütz. var. sulcata z dolnooligoceńskich diatomitów z Futomy (Karpaty, Polska)

(*Pl. I—III*)

Abstract. Under the light and scanning electron microscope the three known *Melosira sulcata* (Ehr.) Kütz. var. sulcata types of valve face ornamentation were observed; "f. radiata", "f. radiolata", "f. coronata". Fourth type unknown so far, was found and described. It is characterized by the presence of a distinct swelling in the centre of the valve face.

Significant differences were noted between frustule structure of *M. sulcata* and the type species for *Melosira genus* — M. *nummuloides* C. Ag. The *M. sulcata* frustule is composed of a single (not 3, as *M. nummuloides*) layers of silica, has the labiate processes on the mantle (not on the valve face); and has no girdle bands. It is more like to the *M. granulata* (Ehr.) Ralfs and *M. arenaria* Moore groups, and it is suggested that occupy an intermediate taxonomic position between them.

INTRODUCTION

M. sulcata (Ehr.) Kütz. var. sulcata, one of the most common littoral species of contemporary seas and oceans, is known from Upper Cretaceous and continuously represented in Tertiary and Quaternary marine deposits. The great variability of its valve structure was noted and examined by Grunow (1884), Hustedt (1930), and others, under the light microscope. Several photographs of the ultrastructure of contemporary specimen frustules, made by a scanning electron microscope (SEM), were discussed by Heimdal (1973).

[1] Irena Kaczmarska, Botanical Institute of the Polish Academy of Science, Phycological Department, ul. Lubicz 46, 31-512 Kraków.

[2] Wincenty Kilarski, Institute of Zoology, Laboratory of Scanning Microscopy, ul. Karasia 6, 30-060 Kraków.

The occurrence of the numerous colonies and single valvae or their fragments in Lower Oligocene diatomites (Krosno Beds) collected at Futoma near Błażowa (south-east Poland) [1], made it possible to examine comparative fossil materials using SEM.

METHOD

The investigated diatoms were prepared using Mandra's method (Mandra et al., 1973) and mounted in pleurax. The diatom frustules examined in a JSM-35 scanning electron microscope were prepared according to Miller's method (1969).

DESCRIPTION

Observations under the light microscope. The frustules are 8—20 μm in diameter and are composed of two domeshaped flattened valves, 5—9 μm in height. The details of the valva ornamentation do not differ either from the original description given by Ehrenberg (1838) or from later descriptions (Grunow, 1884; De Toni, 1894; Hustedt, 1930). Three types of valve face ornamentation (Grunow, 1884) were observed in the present material: radially arranged long ribs reaching almost to the centre of the valve ("f. radiata"); short ribs radially arranged (Fig. 1, 2, "f. radiolata"); and concentrically distributed ring of small spots near the valve face margin (Fig. 3, "f. coronata").

In the preparations were found single valves of *M. sulcata* as well as filamentous colonies and their fragments. In each slide from 50 to 70 colonies were observed, most frequently appearing as 2—3 complete frustules and two halves at the ends; a maximum of 10 complete frustules were observed. In the cuts of samples from which diatoms for light microscope and SEM observations were obtained, there occurred colonies of about 30 frustules.

Observations in SEM. The three types of valve face ornamentation mentioned above were easy to distinguish in SEM, on the outer surface of the valve: the radially arranged ribs ("f. radiata", Fig. 7; and "f. radiolata", Fig. 4) are unequal, their height generally increasing at the margin of the valve face; the concentric swellings ("f. coronata", Fig. 6) are narrow, vary in length, and are unequal in height. Upon SEM examination an additional, fourth type of valve face ornamentation was found, characterized by the presence, markedly protruding over the

[1] Editor's note: Geological setting and detailed stratigraphy of the region will be discussed in a paper by J. Kotlarczyk „Catalogue of the Carpathian Diatomites", now in preparation.

external surface of the valve face and covering about 1/2 its diameter (Fig. 8). The margin of these swelling in uneven owing to hoofshaped separated grooves penetrating into the valve face.

The ornamentation of the external surface of the valve ridge and the mantle is the same in all four types of the valve face. The undulations of the valve face ridge (Fig. 1, 2, 3) is in fact formed by a ring of three-armed marginal structures (Fig. 4, 6, 7, 8). The two shorter arms of these structures lie on the surface of the valve face (Fig. 4) while the third and longer one is vertical to it and parallel to the valve mantle (Fig. 4). The arms of the three-armed marginal structures of the valve face are archwise joined with each other, the arcs being open to the centre of the valve face; only rarely are they grown together (Fig. 6). At the point where the arms of two neighbouring arcs meet (Fig. 10, 11), long teeth (2,7—3,6 μm) with nodulously broadened or bifurcate endings are observed (Fig. 10, 11). Both types of teeth could be found on the same valve (Fig. 12). On the neighbouring valves without such teetch, holes are found, their diameter corresponding with the size of the endings of the teeth (Fig. 10, 11, 12).

The external surface of the mantle is perforated with longitudinal parallel, pervalvar rows of puncta (Fig. 11); 25—30 rows in 10 μm, some of which are covered by the mantle arms of the three-armed structures of the valve face margin. The puncta of the mantle reach the ridge of the valve face. Two of them, at the point where neighbouring arcs meet, are larger than the remaining ones. Sometimes 1—5 puncta may also be observed here. The abvalvar margin of the mantle is thicker and flattened.

Only one type of internal surface of the valve ornamentation has been observed so far (Fig. 9). Almost the whole valve face area is plain, without ornamentation, only the margin of the valve face there appearing rows of radially distributed grooves with internal openings of puncta on the bottom (Fig. 5). These grooves are continuous and are pervalvar on the internal surface of the mantle. In two neighbouring grooves these openings are alternately distributed (in hexagonal system). The openings are similar in diameter.

On the internal abvalvar margin of the mantle there occur arch-like labiate processes (Fig. 13) without external tubes. The processes are found at intervals of 10—30 grooves.

The observed *M. sulcata* colonies (Fig. 12) are composed of three types of frustule: A-the teeth, nodulously broadened or bifurcate on the valve face margin are found on epi- and hypovalves; B- the teeth occur on one valve only; C — no teeth occur on epi- or hypovalves.

Within a colony the teeth (both nodulous and bifurcate) of one valva are meshed with the corresponding holes in valves of the neighbouring

frustules, thus connecting them with each other. Only once (Fig. 14) were valves without teeth, joined by direct coupling of the arms of the three-armed marginal structures of the valve face.

Aparat from the teeth on the ridge of the valve face, the frustules are additionally connected by radially arranged striae of the valve face (Fig. 13), and in "F. coronata" probably by concentrically arranged swellings. However how the valves presented in the figure eight were meshed was not observed.

The epi- and hypovalves of the frustule have the same diameter and do not overlap, simply lying close together.

DISCUSSION

Under the light microscope no significant differences were noted between Lower Oligocene frustules of *M. sulcata var. sulcata* from Futoma and those known so far both from contemporary and fossil materials (Grunow, 1884; Hustedt, 1930; Proskhina-Lavrenko, 1949—1950; Cleve-Euler, 1951). Nevertheless, it should be noted that only small frustules occurred in Futoma diatomites (8—20 μm in diameter) though a maximum diameter of 80 μm was described by Hustedt (1930). The pervalvar rows of puncta were also finer (25—30 rows in 10 μm) than Hustedt's monographs (1930).

It was easy to distinguish in SEM three types of valve face ornamentation and an additional fourth type was found. This last one as seen under the light microscope was probably confused with "f. radiolata".

Other differences were found, as observed in SEM, between contemporary frustule originating from the White Sea (Heimdal, 1973) and those from Futoma. The diatoms from the White Sea have less distinctly shaped three-armed marginal structures of the valve face, their arms on the mantle being shorter and more delicately constructed. Moreover, on the external surface of these valves two types of tubular process occur, one on the valve face and the other on the mantle.

The processes on the valve are not high, lying the at meeting point of two neighbouring arcs of the three-armed marginal structures of the valve face (Heimdal, 1973, photos 15a and 15b). However, it seems that they are not processes but simply perforations through the valve, the same as those which occupy the same place on the valves from Futoma, since they are very similar to each other.

In the Futoma specimens no processes were found either on the external or internal surface of the valve face.

Another type of process, known also only from the external surface of the mantle abvalvar margin, is presented in (Heimdal, 1973) photo-

graphs 14a and 14b; no such external processes are found on Futoma valves. However, on the internal surface labiate processes (Fig. 13) occur in the same position. On the external surface of the abvalvar margin of the mantle of the Futoma specimens, the openings of these processes do not differ from the external openings of puncta, as if these processes were unilaterally developed. It may be that the external processes on the mantle abvalvar margin of valves from the White Sea are in fact the external openings of internal labiate processes, such as on the Futoma valve — in this case bilaterally developed. However, it is possible that they are visible on the valves from the White Sea because the three-armed marginal structures of the valve face are more delicately shaped and, in consequence, the margin of the mantle is more exposed.

Hustedt (1930) described the coupling of *M. sulcata* frustules into colonies, suggesting that these colonies are built up of frustules in which one valva has teeth while another one lacks them, having holes with which the teeth of the valves of the neighbouring frustules are meshed. These teeth may have a digital shape or they may be bi- or trifurcate at the end. Of these teeth described by Hustedt (l.c.) the first was the most common in the specimens from Futoma, the second was rare, and the third one was not observed. However, a further way of coupling was found in the present study, the arms of the three-armed marginal structure of the valve face being directly meshed. In fact, for the most part of the frustules from colonies by meshing the endings of the teeth with the corresponding holes of the valves of the neighbouring frustules, as was described by Hustedt (l.c), though the structure of the colonies from Futoma is much more complicated, the frustules within a colony occurring in a definite order (Fig. 12). Such a colony, like other filamentous diatom colonies can be formed by simultaneous divisions of all cells, while the initiating cell can be any of the three discussed types (A, B, C) of frustules.

In one frustule the valves do not overlap but simply lie close together. Owing to such coupling a colony usually disrupts between two valves of one frustule.

Recent detailed studies on numerous species of the genus *Melosira* C. Ag. revealed a very variable structure of their frustules (Crawford, 1971, 1975a, 1977; Miller, 1969; Florin, 1970; Gasse, 1975). *Melosira nummuloides* C. Ag., the type species for this genus, and *M. varians* C. Ag. and *M. moniliformis* (O. Müll.) C. Ag. have a frustule composed of 3 layers of silica, the labiate or tubular processes on its valve face, and girdle bands (Crawford, 1971; 1975a; 1977).

Melosira granulata (Ehr.) Ralfs group species (e.g. also *M. italica* (Ehr). Kütz., *M. islandica.* (O Müll.) and the *Melosira arenaria* Moore

group, have a frustule composed of one silica, layer, no processes on the valve face, and girdle bands (Crawford, 1975b).

The *M. sulcata* frustule is also composed of a single layer (not of two layers, as Hustedt claimed in 1930, can be seen in the light microscope), and has neither the processes on the valve face nor girdle bands. Therefore it is more like the *M. granulata* group than *M. nummuloides* group frustules. However, it differs from the *M. granulata* group in the absence of sulcus and of areole, and in the presence of puncta as elements of the mantle ornamentation.

In the *M. arenaria* group, similarly as in *M. sulcata*, no sulcus occurs and the internal ornamentation of the mantle is also grooved, while in *M. arenaria* the processes are scattered on the whole mantle, in *M. sulcata* being found only on the abvalvar ridge of the mantle.

It therefore seems that *M. sulcata* frustule occupy an intermediate taxonomic place between the *Melosira granulata* and *Melosira arenaria* groups.

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STRESZCZENIE

W mikroskopach świetlnym i skaningowym obserwowano budowę pancerzyków i kolonii *Melosira sulcata* (Ehr.) Kütz. var. *sulcata*.

Znaleziono cztery typy zewnętrznej powierzchni centrum tarczki. Trzy z nich ("f. radiata", "f. radiolata", "f. coronata" Grunow 1884), znane są już z badań w mikroskopie świetlnym. Czwarty, nie znany dotychczas, charakteryzuje obecność wyraźnego, dyskowatego zgrubienia, którego brzeg, widziany w SEM, zawiera płytkie komory wnikające do jego wnętrza. W mikroskopie świetlnym, ten typ powierzchni, najprawdopodobniej łączony jest z "f. radiata". Każda obserwowana w SEM okrywa *M. sulcata* var. *sulcata*, na brzegu ma trójramienne struktury brzegowe tarczki, będące elementem ornamentacji zarówno tarczki, jak i płaszcza. Dwa ramiona tych struktur są prostopadłe do brzegu tarczki, a trzecie jest równoległe do powierzchni płaszcza i prostopadłe do dwóch poprzednich ramion. Ramiona te tworzą na brzegu tarczki łuki otwarte do jej centrum. U zbiegu dwóch sąsiednich łuków, w niektórych okrywach znajdują się ząbki, główkowato rozszerzone lub rozwidlone na końcu. Ząbki te mogą znajdować się równocześnie na jednej okrywie. Na okrywach, gdzie ich brak, znajdują się zagłębienia o średnicy odpowiadającej ich zakończeniu.

Ornamentację powierzchni płaszcza stanowią równoległe, perwalwarne rzędy poroidów. Niektóre z nich przykryte są ramionami trójramiennych struktur brzegowych tarczki, co może stwarzać mylne wrażenie w mikroskopie świetlnym, że pancerzyk tego gatunku okrzemki zbudowany jest z dwóch (Hustedt 1930) warstw krzemionki.

Ornamentacja wewnętrznej powierzchni okrywy jest taka sama we wszystkich czterech typach zewnętrznej powierzchni tarczki. Stanowią ją perwalwarne rzędy równoległych zagłębień, na których dnie znajdują się wewnętrzne ujścia poroidalnych areol. Rowki (zagłębienia) te

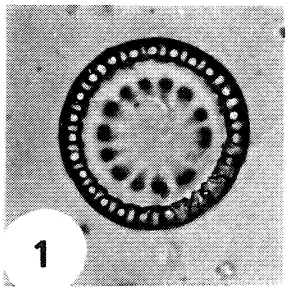
zachodzą nieco na brzeg tarczki. Pozostała powierzchnia tarczki jest gładka. Na wewnętrznej adwalwarnej krawędzi płaszcza znajdują się wyrostki wargowe, jednostronnie wykształcone.

Użycie mikroskopu skaningowego pozwoliło prześledzić budowę kolonii tego taksonu. Pancerzyki łączą się w kolonie przy pomocy systemu ząbków położonych u zbiegu trójramiennych struktur brzegowych tarczki oraz odpowiadających im zagłębień w okrywie sąsiedniego pancerzyka. Tak jak to opisywał Hustedt (1930). Jednak inny niż on przypuszczał jest układ pancerzyków w kolonii. Zaobserwowano trzy typy pancerzyków w kolonii, w zależności od tego, czy mają one ząbki na okrywach czy nie. Pierwszy (typ A.) ma ząbki zarówno na epi- jak i na hypowalwie. Drugi (typ B.) ząbki takie ma na jednej tylko okrywie. Typ trzeci (typ C.) odznacza się całkowitym ich brakiem. W obrębie kolonii wymienione typy pancerzyków występują w określonej kolejności; A, B, C, A, B, C. Nadzwyczaj rzadko spotykano pancerzyki połączone poprzez bezpośrednie zazębianie się trójramiennych struktur brzegowych tarczki.

Dwie okrywy jednego pancerzyka łączą się bez pomocy dodatkowych struktur, przylegając jedynie ściśle do siebie, dzięki czemu kolonie rozrywają się pomiędzy okrywami jednego pancerzyka.

Porównując pancerzyki *M. sulcata* z pancerzykami *M. nummuloides* C. Ag., gatunku typowego dla rodzaju *Melosira*, zaobserwowano zasadnicze różnice w ich budowie. *Melosira sulcata* ma jednowarstwowy (a nie trójwarstwowy pancerzyk), wyrostki wargowe rozmieszczone po adwalwarnej wewnętrznej krawędzi płaszcza (a nie na tarczce), nie ma pasów obwodowych, a w kolonie pancerzyki tego gatunku łączą się za pomocą ząbków znajdujących się na brzegu tarczki (a nie w jej centrum). Pancerzyki *M. sulcata* wykazują natomiast wiele podobieństw do pancerzyków dwóch grup gatunków; grupy *M. granulata* (Ehr.) Ralfs. i grupy *M. arenaria* Moore. Mają one, tak jak *M. sulcata*, jednowarstwowe pancerzyki, z wyrostkami znajdującymi się wyłącznie na płaszczu, nie mają pasów obwodowych i tworzą kolonie za pomocą specjalnych ząbków znajdujących się na brzegu tarczki. Jednak od grupy *M. granulata* (Ehr.) Ralfs, *M. sulcata* odróżnia się brakiem sulcus i areol, a obecnością poroidów jako elementów ornamentacji płaszcza. Od grupy *M. arenaria* Moore *M. sulcata* odróżnia się typem wyrostków (u *M. arenaria* są one tubularne) oraz ich rozmieszczeniem. Wyrostki są u *M. arenaria* Moore rozrzucone na całej powierzchni płaszcza, podczas gdy u *M. sulcata* znajdują się wyłącznie na jego adwalwarnej krawędzi.

Zasadnicze różnice budowy pancerzyków *M. sulcata* i *M. nummuloides* sugerują potrzebę rozważenia wydzielenia *M. sulcata* z rodzaju *Melosira*. Podobnie jak i grupy gatunków *M. granulata* i *M. arenaria*, do których badany takson bardzo jest podobny, zajmując jednak pośrednią pomiędzy nimi pozycję taksonomiczną.



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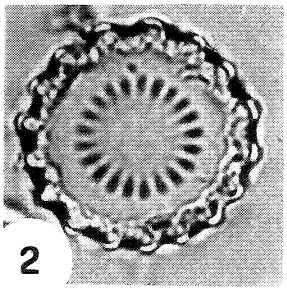

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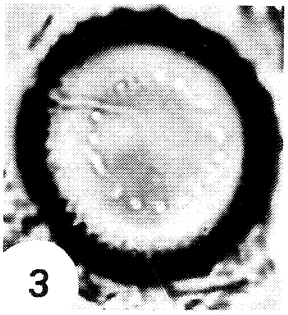

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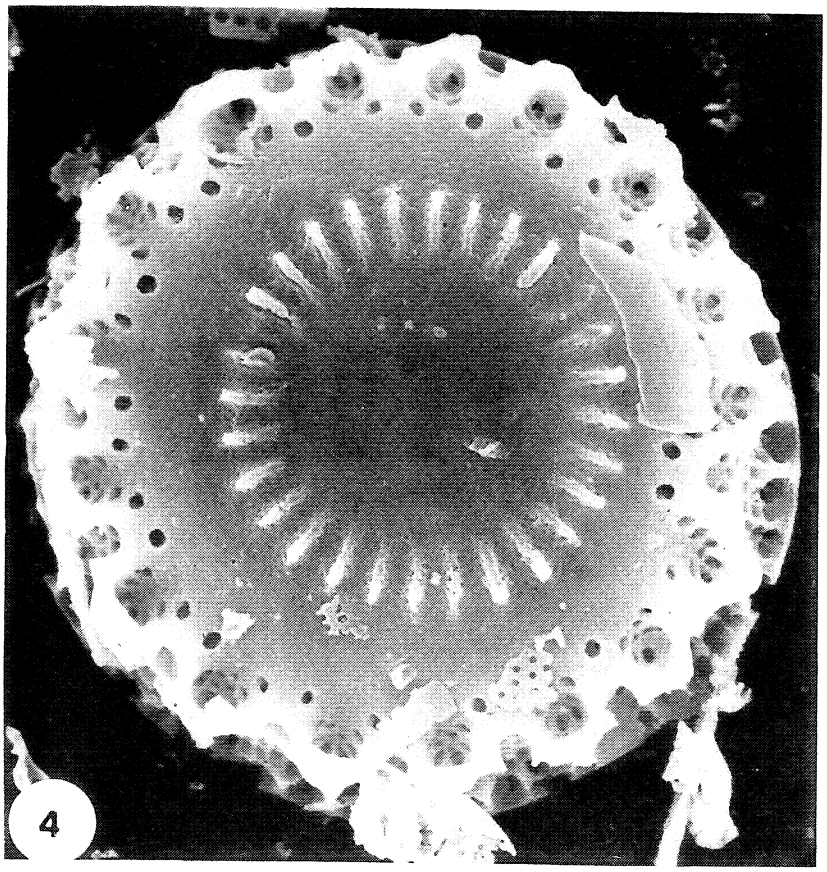

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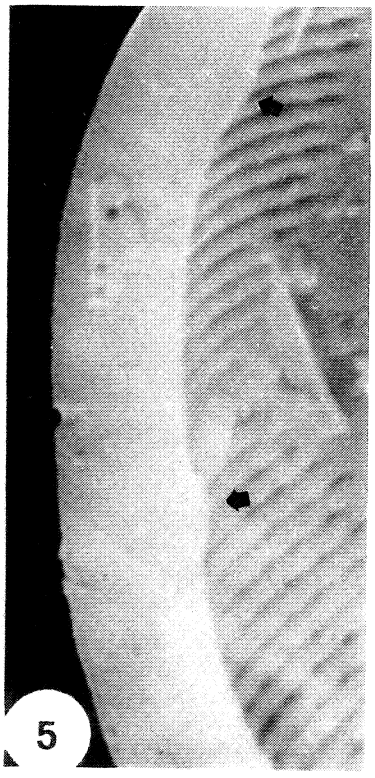

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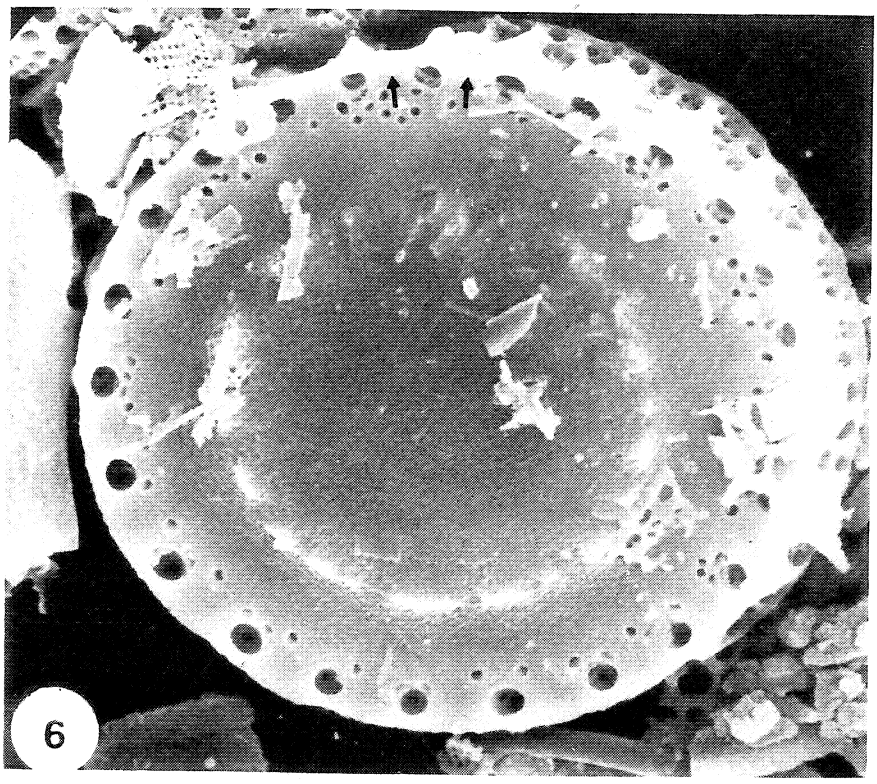

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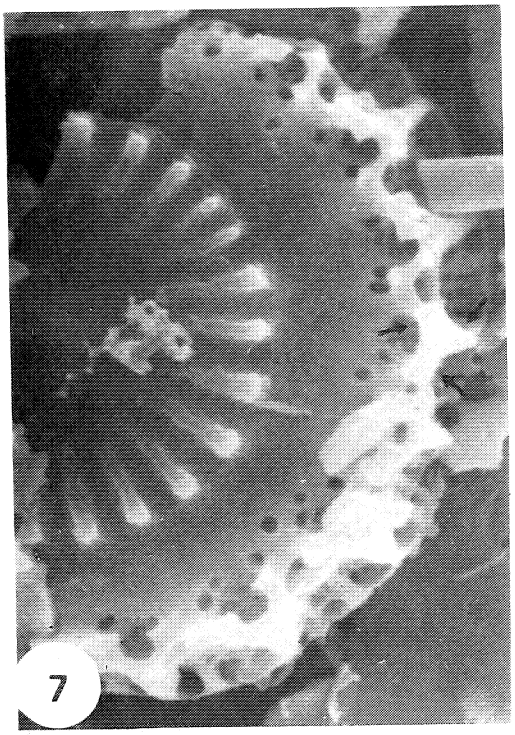

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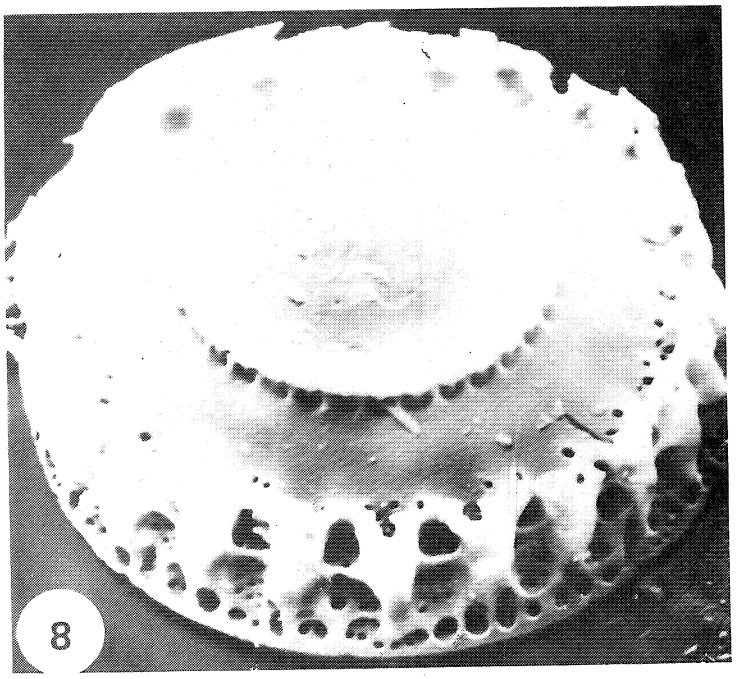

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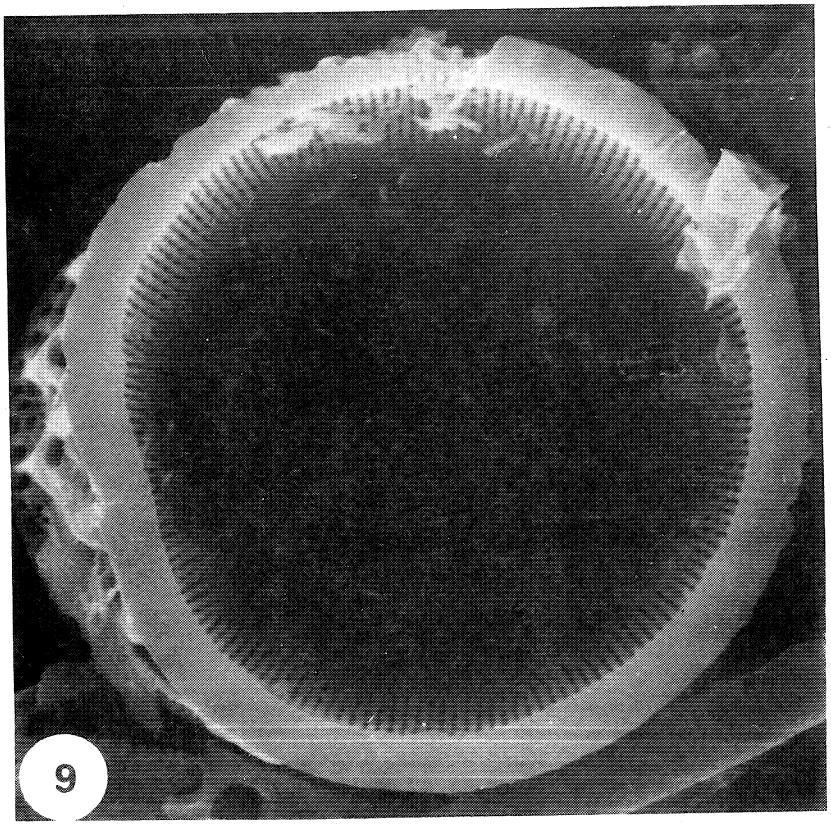

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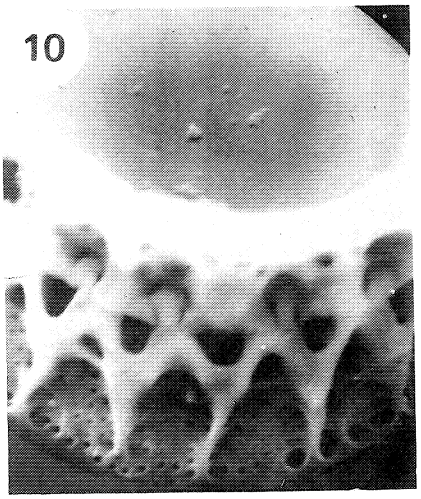

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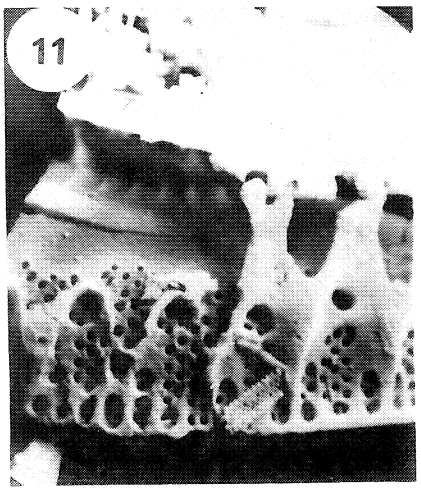

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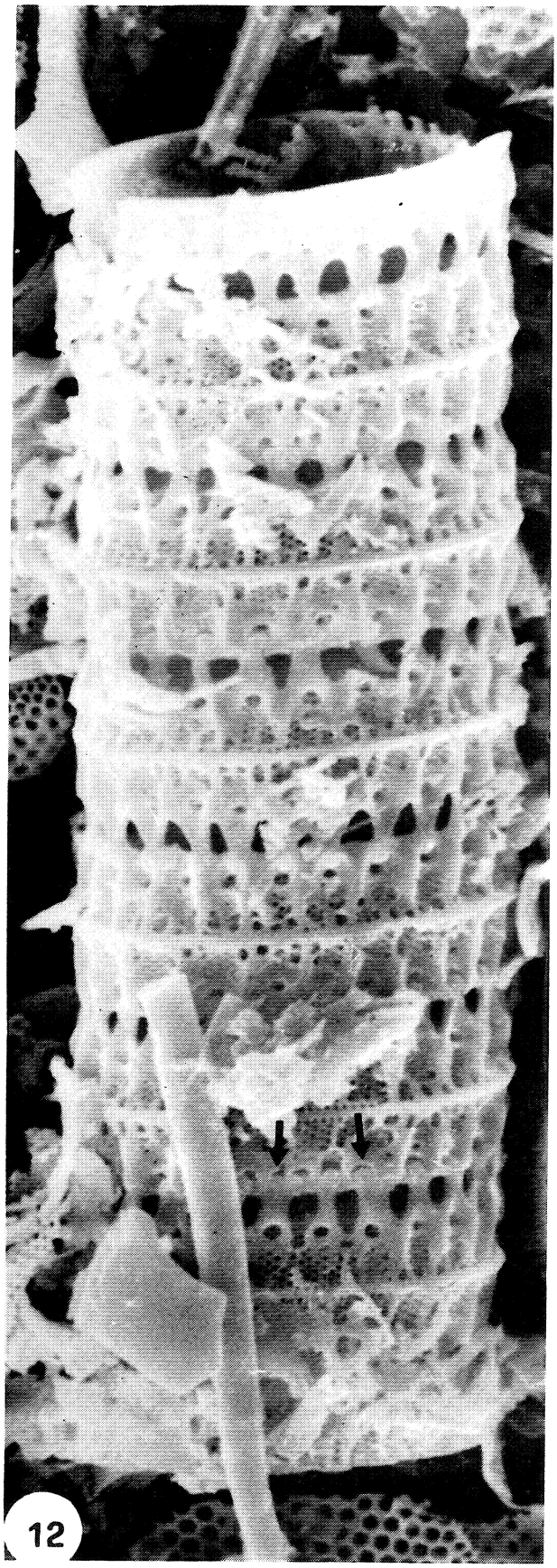
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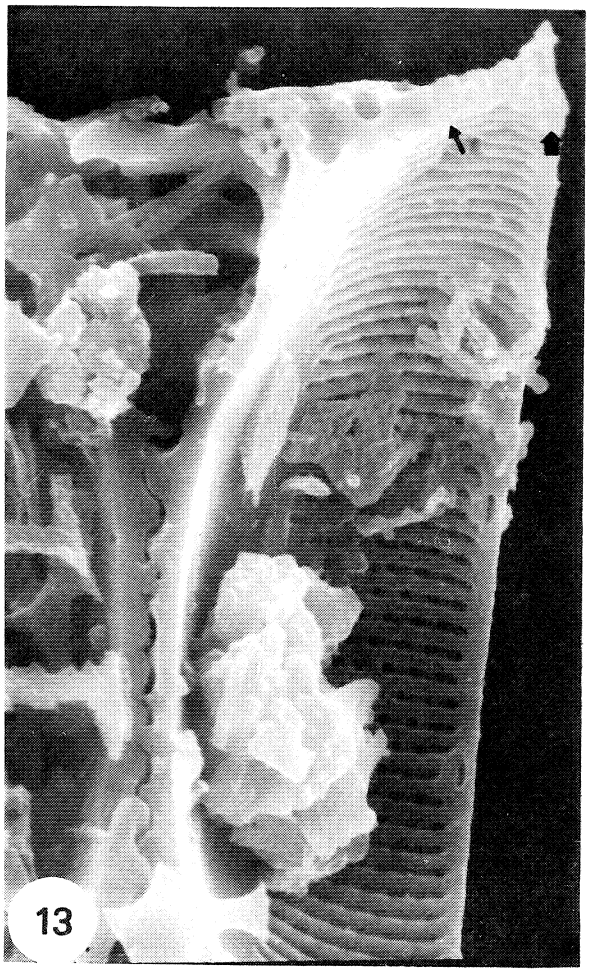
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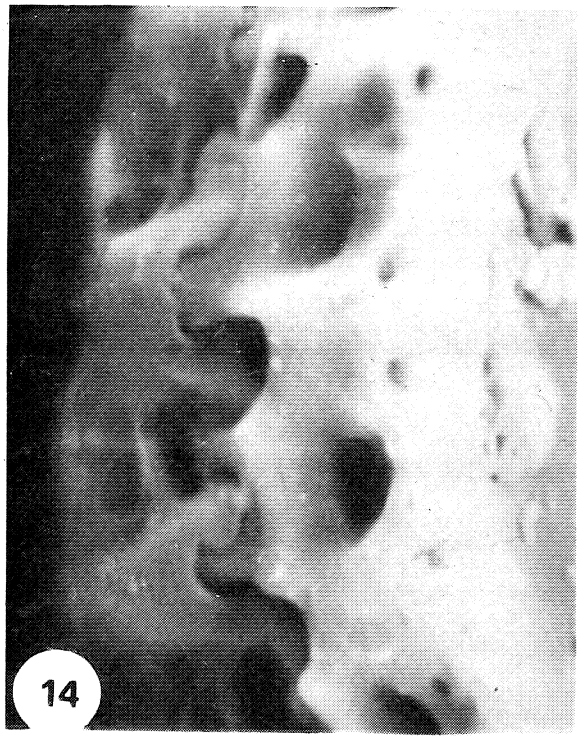
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EXPLANATION OF PLATES — OBJAŚNIENIA PLANSZ

Plate I — Plansza I

Fig. 1, 2. Ornamentation of the "f. radiolata" valve; Fig. 1, × 750, Fig. 2, × 1850
Fig. 1, 2. Ornamentacja okrywy „f. radiolata"; fig. 1, × 750, fig. 2, × 1850
Fig. 3. Ornamentation of the "f. coronata" valve; × 1500
Fig. 3. Ornamentacja okrywy „f. coronata"; × 1500
Fig. 4. Ornamentation of the external surface of the "f. radiolata" valve face; × 4000
Fig. 4. Ornamentacja zewnętrznej powierzchni tarczki „f. radiolata"; × 4000
Fig. 5. Internal surface of the mantle. Side view of the labiate processes (arrows); × 10 000
Fig. 5. Wewnętrzna powierzchnia płaszcza. Widok boczny wyrostków wargowych (strzałki); × 10 000
Fig. 6. Ornamentation of the external surface of the "f. coronata" valve face. The valve face arms of the three-armed marginal structure of the valve are grown together (arrows); × 4000
Fig. 6. Ornamentacja zewnętrznej powierzchni tarczki "f. coronata". Ramiona trójramiennych struktur brzegowych tarczki są zrośnięte (strzałki); × 4000

Plate II — Plansza II

Fig. 7. Ornamentation of the external surface of the "f. radiata" valve face with arms of the three-armed marginal structures of the valve face (arrows); × 4200
Fig. 7. Ornamentacja zewnętrznej powierzchni tarczki „f. radiata". Zaznaczono trójramienne struktury brzegowe tarczki (strzałki); × 4200
Fig. 8. The fourth type of the external sufrace of the valve face ornamentation which is probably confused with "f. radiolata" as seen under the light microscope; × 4000
Fig. 8. Ornamentacja zewnętrznej powierzchni tarczki czwartego typu zaliczanego prawdopodobnie w obserwacjach pod mikroskopem świetlnym do „f. radiolata"; × 4000
Fig. 9. Ornamentation of the internal surface of the valve; × 4400
Fig. 9. Ornamentacja wewnętrznej powierzchni okrywy; × 4400
Fig. 10. Two neighbouring frustules. The nodulous broadened teeth of the one valve are meshed with the corresponding holes in the valve above; × 4300
Fig. 10. Dwa sąsiadujące pancerzyki. Główkowato rozszerzone ząbki okrywy dolnej wchodzą w odpowiadające zagłębienia okrywy sąsiedniego pancerzyka; × 4300
Fig. 11. Two neighbouring frustules. The bifurcate teeth of the one valve are meshed with the corresponding holes in the valve above; × 3900
Fig. 11. Dwa sąsiadujące pancerzyki. Rozdwojone na końcach ząbki wchodzą w odpowiadające zagłębienia w okrywie sąsiedniego pancerzyka; × 3900

Plate III — Plansza III

Fig. 12. Filamentous colony of M. sulcata. A, B and C are types of the frustule. Bifurcate teeth (arrows); × 2400
Fig. 12. Nitkowata kolonia M. sulcata. A, B i C oznaczają typy pancerzyków. Strzałki wskazują rozdwojone na końcach ząbki; × 2400

Fig. 13. Cross-section through two valves. Fine arrow marks punctum and coarse arrow marks labiate processes; × 7800

Fig. 13. Przekrój poprzeczny przez dwie okrywy. Cieńsza strzałka wskazuje na perforację płaszcza a grubsza strzałka na przekrój poprzeczny przez wyrostek wargowy; × 7800

Fig. 14. Direct coupling of the arms of three-armed marginal structures of the valve face; × 10 000

Fig. 14. Bezpośrednie połączenie ramion trójramiennych struktur brzegowych tarczki; × 10 000