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IRENA KACZMARSKA and W. KILARSKI

THE FINE STRUCTURE OF *ACTINOPTYCHUS SENARIUS* (EHR.) EHR. FRUSTULES (*BACILLARIOPHYCEAE*) FROM THE LOWER OLIGOCENE DIATOMITES AT FUTOMA (SE POLAND)

Ultrastruktura pancerzyków *Actinoptychus senarius* (Ehr.) Ehr. (*Bacillariophyceae*) z dolnooligoceńskich diatomitów z Futomy

ABSTRACT. Morphological analysis of the frustule structure allowed three valve face types to be distinguished: the first has a well-formed lattice of the external costae on the sector surfaces; the second has on the sector surfaces irregulary disposed protuberances; the third has flat sector surfaces. The observed frustules have a wider range of ornamentation variability than contemporary ones.

The differences observed in the structure of the areoles suggest somewhat simpler structure of the Futoma frustule than that of contemporary ones.

Many important similarities and the absence of criteria that would clearly and consistently differentiate species of the genus of *Actinoptychus* and *Aulacodiscus* indicate the necessity of a critical study of the taxonomical position of many of their species.

INTRODUCTION

The neritic diatom *Actinoptychus senarius* (Ehr.) Ehr. is found both in contemporary and fossil marine basins from the Paleocene of almost all the climatic zones. Frequent and cosmopolitan it has rarely been examined in the electron microscope.

Owing to the complicated ornamentation and strong silification of the frustule, the transmission electron microscope did not enrich the knowledge of its structure. In the scanning electron microscope only the areole structure of contemporarily living specimens (the locality is not indicated, Sydov & Christenhuss 1972) have been observed. Other SEM observations of the contemporary (from the Gulf of California, Fryxell & Hasle 1973) and Late Miocene (from Monterey Formation, California, Wornardt 1971) frustules also failed to give complete information on all the details of their structure and the variability of their ornamentation. Nevertheless, some of these details, e.g. structure and location of the processes, may be important for classification of the *Actinoptychus* genus (Ross & Sims 1973). Comparative morphological analysis was therefore undertaken both in the light and scanning electron microscope, in order to examine whether variability of the structure and ornamentation of the frustule has taxonomic significance.

The fossil frustules of some long geological range species differ from those of contemporary specimens; these differences were noted in the light microscope (Jousé 1948; Proshkina-Lavrenko 1949–1950). In *Actinoptychus senarius* frustules such differences have not been noted, hence observations were made in order to study whether any differences would be detectable under the scanning electron microscope.

MATERIAL AND METHOD

The presented material originated from the diatomites deposited in the bottom part of Menilite Beds in the Skole Nappe (Polish Carpathian Flysh) from the Futoma stratotype outcrop localized in the eastern part of the Carpathian Highlands (Kotlarczyk 1979).

For light and electron (SEM JSM-35) microscope investigation the frustules were prepared in the same way as described in our earlier work (Kaczmarska & Kilarski 1979).

OBSERVATIONS IN THE LIGHT AND SCANNING ELECTRON MICROSCOPES

Observed from the girdle band side the frustule is an almost flat drum shape, 20–83 μm in diameter. In the same frustule, valves are joined by the girdle band. Each theca has one hyaline cingulum. The frustule is built of one basal siliceous layer.

The valve faces, characteristically divided into three concave and three convex sectors, are perforated by poroid apeoles (Pl. I, figs. 1–3). They are more or less compactly disposed, on the convex sectors 16–22 poroid areoles in 10 μm, 10–15 in 10 μm on concave ones. The tops of the sectors do not reach the valve face centre, and leave a circular central area. The external and the internal surfaces of the central area are not ornamented.

On the edge, between the valve face and the valve margin runs the external circumferential costa. The valve margin is also perforated by poroid areoles, as densely as the concave sectors.

Poroid areoles on the valve face as well as on the valve margin are hexagonally arranged (Pl. I, figs. 5–7). This being seen both on the external and internal valve surfaces. The poroid areoles are porforations of the basal siliceous layer (Pl. I, fig. 4). They are cylindrical in the cross-section of this layer.

Their external openings have no additional structures, in contrast to internal ones, which are closed by a velum perforated by one porellus in the centre.

In the middle of the convex sector basis a processes are placed (Pl. II, fig. 8). Their external ends are tubes, varying in length, while the internal ones are labiate processes. The latter are radially arranged and variable in shape. On some valves they are straight, on others more or less arcuate. The labiate process is a short, roll-like thickening that looks like a collar surrounding the narrow slit (Pl. II, figs. 11–13). The slit narrows like a funnel to the canal, which passes into the basal siliceous layer and then into the external tube. Around the processes are small oval hyaline areas.

The details of the structure and ornamentation of the valves described above apply to all of the examined specimens. Besides, some ot the valve faces often bear other, additional ornamentation. This ornamentation is due to changes in the thickness of the basal siliceous layer at particular points of the valve face, and is seen as protuberances on the external valve face surface. Three types of valve face have been distinguished, according to the way of differentiating these thickenings.

The first has a lattice of low, roll-like thickenings on the external sector surfaces, arranged more or less regularly (Pl. II, figs. 8 and 10). This lattice may cover some or all of the external openings of the poroid areoles lying underneath it. Then, especially in the latter case, the lattice gives the impression that it is placed on the flat sector surface (Pl. II, fig. 9). This type of valve face was very common in the studied material.

The second type also does not have flat sector surfaces but one intersparsed with isolated, low, raised thickenings, irregularly arranged. This protuberances are small at the base and so do not cover the external openings of the poroid areoles (Pl. I, fig. 6). This type of valve face was infrequent in the studied material.

There are also valves whose faces have convex sectors ornamented as in the first type but the concave ones ornamented as the second type of valve face. These valves are almost as frequent as the first type.

The third type of valve face has flat sector surfaces owing to the absence of changes in thickness of the basal siliceous layer (Pl. I, fig. 5). This type, like the second, is infrequent in the studied material.

In the light microscope it is difficult to differentiate the second and third types.

The continuous variation between all three valve face types were observed.

DISCUSSION

The three differentiated types of the Lower Oligocene valve faces reflect successive steps of complication in their external surfaces and demonstrate a continuous and wider range of variability than that noted from the contemporary localities.

The first one, characteristic for the species, bears a well developed lattice of thickenings on the sectors. This type is known from a contemporary as well as from fossil marine basins. The original descriptions and drawings given by Ehrenberg (1838, 1841), and also numerous further data (Schmidt 1874—; Van Heurck 1880–1885; Hustedt 1930; Cleve-Euler 1951) indicate among characteristic features, the distinctly formed lattice of "areoles", generally clearly visible in the light microscope. The specimen of *A.* cf. *senarius* demonstrated by Fryxell and Hasle (1973) seems also to fit the range of variability of the first type of the valve face. It bears a distinct lattice of thickenings, which, in contrast to the Futoma specimens, are completely perforated by poroid areoles. This lattice does not disturb the regular, hexagonal arrangement of the poroid areoles. Such a manner of valve face ornamentation was not found in the examined material.

The second type of valve face seems to be an intermediate form between the first and third types. Neither has yet been recorded in the literature.

Because of the continuous variation between differentiated types of valve face ornamentation, it is possible to observe transitional forms. Nevertheless, even in the most complicated form they do not fit the criterion of the loculate areoles (Anonymous 1975). We are therefore of the opinion that *A. senarius* has no areoles in the sense of Hustedt's (1930) interpretation. These structures, are in our opinion identical with the external costae, described in *Aulacodiscus reticulatus* frustules (Anonymous 1975).

Our own observations and the data available in the literature (Sydov & Chriestenhuss 1972; Fryxell & Hasle 1973) allowed a comparison of the structure of the Lower Oligocene and contemporary frustules. No basic differences in frustule structure and type of ornamentation was found that would justify a possible separation of the Lower Oligocene frustules of this taxon as an independent unit. The observed wide and continuous variation of the ornamentation we would interpret as a infraspecific variability.

In the light microscope the frustules of this species coming from the different geological periods are indistinguishable. Under the scanning electron microscope differences between them are visible in the areole structure and in that of the labiate processes.

In the observed material poroid areoles (somewhat not typical because of one only porellus in the velum) are always cylindrical, in contrast to the contemporary frustules which areoles balloon out at two levels. From the available electronograms (Wornardt 1971), no conclusions can be drawn as to struture of the areoles in the Late Miocene ones. The labiate processes of the Futoma frustules are also slightly different, are more open owing to the collar-like thickening surrounding the slit in such a manner as to leave a space between the labia.

The frustules of the long geological range species which come from the older periods often differ from the contemporary specimens. These differences may be seen in the light microscope, or under SEM only, and may be important in the case of redeposition, when it is necessary to denote the same species frustule of different geological age.

Similarities in the frustule structure, particularly between some of the *Aulacodiscus* species and diatoms of the genus *Actinoptychus*, were noted by Ross and Sims (1973). These authors regarded the two genera as closely related on account of their similar external costae and the presence of a circumferential external costa.

Now one can see that there are also similarities in the following details: the presence of girdle bands; the ornamentation of the internal valve face surface; the same type of processes (labiate with external tubes) and their location, most frequently connected with the valve face protuberances; the manner of differentation of the external costae, which varies to the same degree in the two genera. In *Actinoptychus senarius* it also differs from specimen to specimen. The typical *Actinoptychus* valves have convex sectors no narrower than the concave ones, in contrast to the *Aulacodiscus* valves, whose convex sectors are narrower than the concave ones. This feature most frequently distinguished the two genera, but it is variable and cannot be a final criterion. Species of the *Actinoptychus* genus are known whose convex sectors are narrower than the concave ones in the manner characteristic for the genus of *Aulacodiscus*, e.g. *Actinoptychus atlanticus* Kein et Schulz, *A. crepido* A.S., *A. mosaica* Brun, *A. simbriscianus* A.S. On the other hand, there occur species in the latter genus whose valve faces are divided into sectors of equal width, e.g. *Aulacodiscus distunguendus* Hust., *A. erectus* Long, Fuge et Smith, *A. alternans* Long, Fuge et Smith.

Since there are many significant similarities between the frustule structure of the genera *Actinoptychus* and *Aulacodiscus* and there is a lack of criteria which would differentiate one genus from the other the necessity arises for a detailed. critical study of the taxonomical position of many of their species.

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Institute of Botany of the Polish Academy of Sciences, Department of Phycology, 31-512 Kraków, ul. Lubicz 46

Institute of Zoology of the Jagiellonian University, Scanning Microscope Laboratory, 30-060 Kraków, ul. Karasia 6

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STRESZCZENIE

ULTRASTRUKTURA PANCERZYKÓW *ACTINOPTYCHUS SENARIUS* (EHR.) EHR. (*BACILLARIOPHYCEAE*) Z DOLNOOLIGOCEŃSKICH DIATOMITÓW Z FUTOMY

W mikroskopie świetlnym i elektronowym mikroskopie skaningowym obserwowano budowę pancerzyków *Actinoptychus senarius* (Ehr.) Ehr. pochodzących ze stratotypowego profilu dolnooligoceńskich diatomitów w Futomie. Diatomity te osadzone zostały w dolnej części łupków menilitowych jednostki skolskiej we fliszu karpackim.

Morfologiczna analiza budowy pancerzyków (Pl. I, figs. 1–3) pozwoliła wyróżnić trzy typy tarczek. Pierwszy ma dobrze wykształconą sieć żeberek zewnętrznych na sektorach (Pl. II, figs. 8–10). Drugi typ ma na sektorach nieregularnie rozsiane wzgórkowate wzniesienia (Pl. I, fig. 6). Trzeci typ ma sektory płaskie (Pl. I, fig. 5). Badane pancerzyki wykazały szerszy niż w pancerzykach współcześnie żyjących osobników zakres zmienności ornamentacji. Zaobserwowano różnice w budowie poroidalnych areol (Pl. I, fig. 4) oraz wyrostków wargowych (Pl. II, figs. 11–13), które wskazują na prostszą budowę pancerzyków z Futomy w porównaniu ze współczesnymi.

Wiele istotnych podobieństw i brak kryterium dobrze i konsekwentnie odróżniającego rodzaje *Actinoptychus* i *Aulacodiscus* wskazują na konieczność ich krytycznego opracowania.

Plate I

1, 2, 3. *Actinoptychus senarius* (Ehr.) Ehr., the same valve different focused; × 1500
4. Cross-section through the basal siliceous layer, poroid areoles cross-section; × 7800
5. External surface of the first type of the valve face, cingulum (arrow); × 3600
6. External surface of the second type of the valve face; × 1350; insert, the same valve fragment; × 2700
7. Internal surface ornamentation of the valve face; × 1200

Plate I

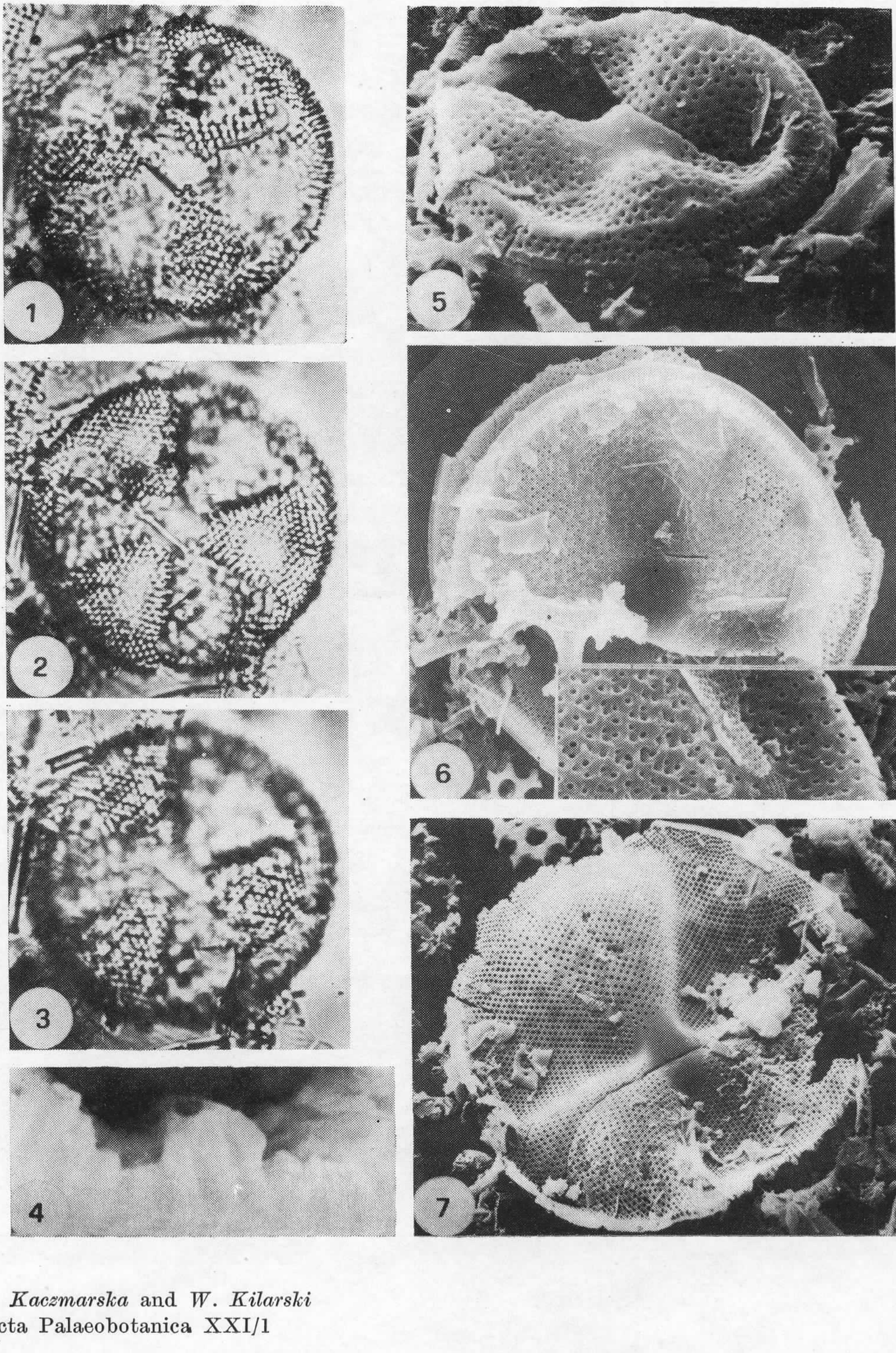
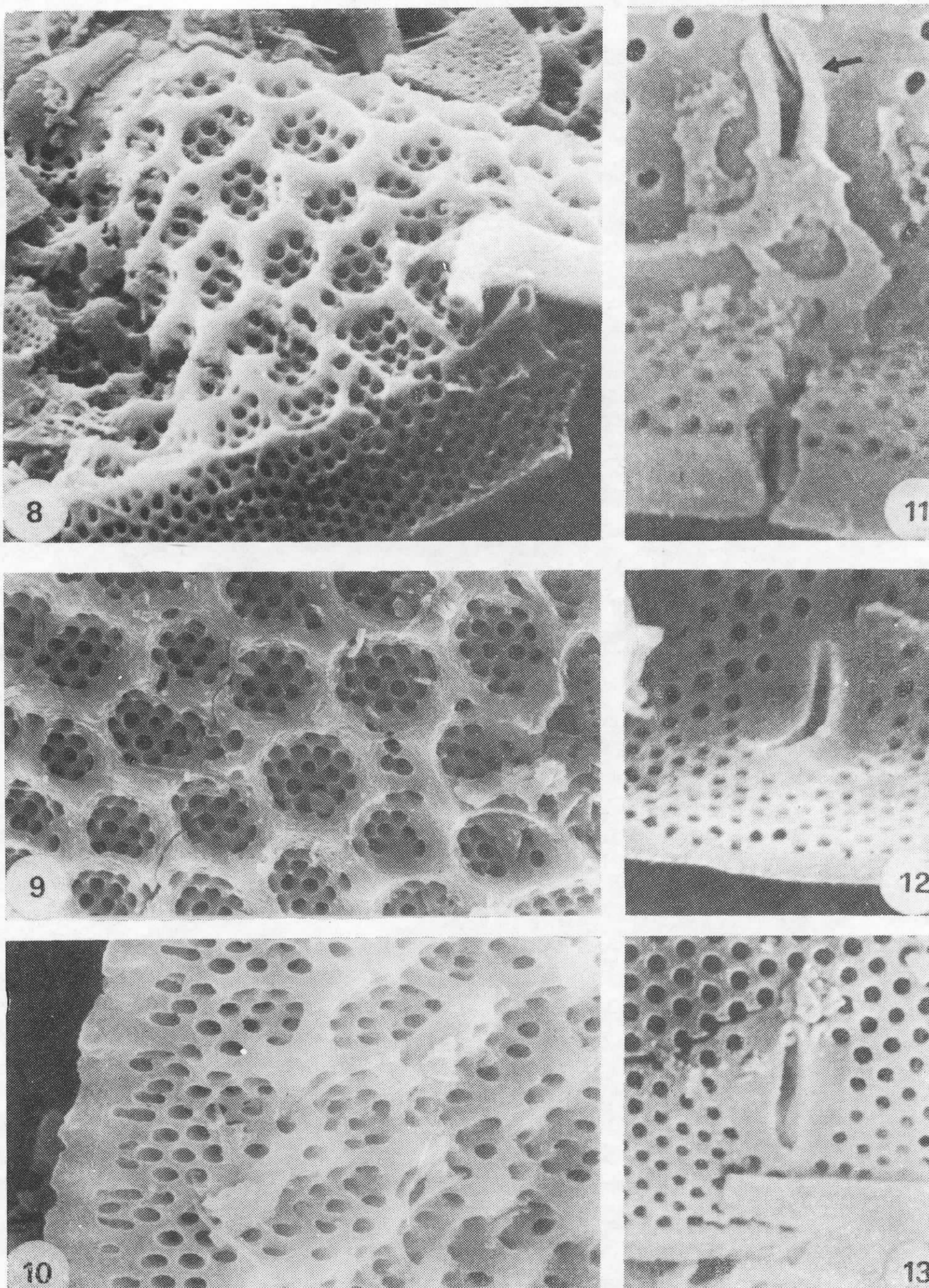


Plate II

8. Fragment of the third type of the valve face; × 4800
9. Hexagonal lattice of the external costae; × 5400
10. Fragment of the valve face margin; × 6000
11. Labiate processe, collar (arrow); × 10 000
12. Slit of the arcuate labiate processe; × 7200
13. Slit of the straight labiate processe; × 6600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