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DIATOMS FROM THE HOLOCENE SEDIMENTS OF LAKE STEKLIN (DOBRZYŃ LAKE DISTRICT)

Okrzemki z holoceńskich osadów Jeziora Steklińskiego (Pojezierze Dobrzyńskie)

ABSTRACT. Five diatom phases (S1—S5) have been distinguished on the basis of a diatom analysis of an 8.2-metre sediment profile from Lake Steklin. They represent Holocene sediments, from the Boreal up to the Sub-Atlantic. The planktonic diatoms *Cyclotella* and *Stephanodiscus* were dominant in the lower part of the profile (S1—S3), the genera *Amphora* and *Synedra* being also very numerous, whereas the littoral flora of *Fragilaria* prevailed in the upper part (S4 and S5). Three stages of eutrophication of the lake (diatom phases S3—S5) are indicated by the diatom succession in the sediments examined.

INTRODUCTION

Steklin Lake is situated in the South-eastern part of the Dobrzyń Lake District in Northern Poland (Fig. 1A). The core was obtained from a reference site selected for palaeoecological studies in the Dobrzyń—Chełmno Lake District. The studies were conducted by B. Noryśkiewicz under the International Geological Correlation Programme (IGCP), Project 158 B. I received samples of the sediment core from Lake Steklin for a diatom analysis through the kindness of Prof. W. Niewiarowski and Dr. B. Noryśkiewicz of the Institute of Geography, Mikołaj Kopernik University at Toruń.

Numerous studies have been devoted to the Dobrzyń—Chełmno Lake District. They concern its geomorphology, geology, hydrography, climate, soils, settlement, as well as geo- and palaeobotany, and permit a detailed characterization of the young glacial relief of the last glaciation (Vistulian), the development of modern and fossil floras, the population of the area and the climatic changes (Niewiarowski 1957, 1973, Oszast 1957, Kępczyński 1960, 1969, 1973, Kwiatkowska 1963, Wójcik & Wójcikowa 1973). An investigation on the origin of the lakes in this district has been carried out over long period of time (Nechay 1932).

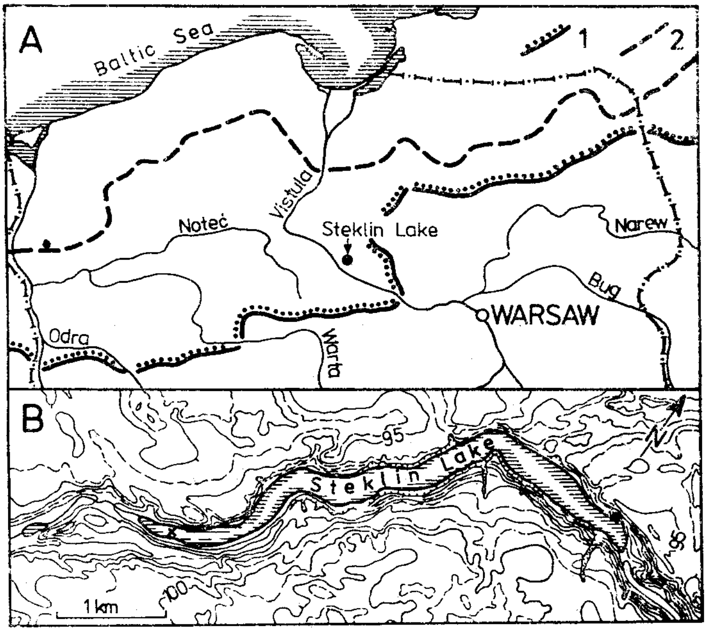

Fig. 1. Location of the investigated profile against the extent of the Vistulian glaciation (A) and within the channel of Lake Steklin (B)

Lake Steklin (Fig. 1B), of the channel type, is situated in a morainic plateau (92—94 m a.s.l.), 25 m below its surface. It is 340 m wide, 5000 m long and 112.3 ha in area. The deepest point (18.5 m) is in the eastern part of the lake. Two terraces have developed on the lake shore, the lower one reaching a height of 4 m and the upper one 10 m above the present water level. The upper terrace slopes down towards the valley of the Vistula, indicating the presence of an outflow in the past, Lakelet Wygoda being its vestige, whereas the present outflow into the Gnilszczyzna developed later.

MATERIAL AND METHOD

The sediment core from Lake Steklin the subject of the present diatom analysis also provided the samples for palynological, chemical and physical studies and those on plant, molluscs and fishes macrofossils (Noryśkiewicz 1982). Samples were taken using Więckowski's (1961) piston sampler (from the bottom surface) at a water depth of 750 cm in the eastern part of the lake (Fig. 1B). The simiplified macroscopic lithological description of the profile can be presented as follows (after Noryśkiewicz 1982):

0—860 cm — grey to black-grey calcareous gyttja,
860—910 cm — black-grey gyttja with clay,

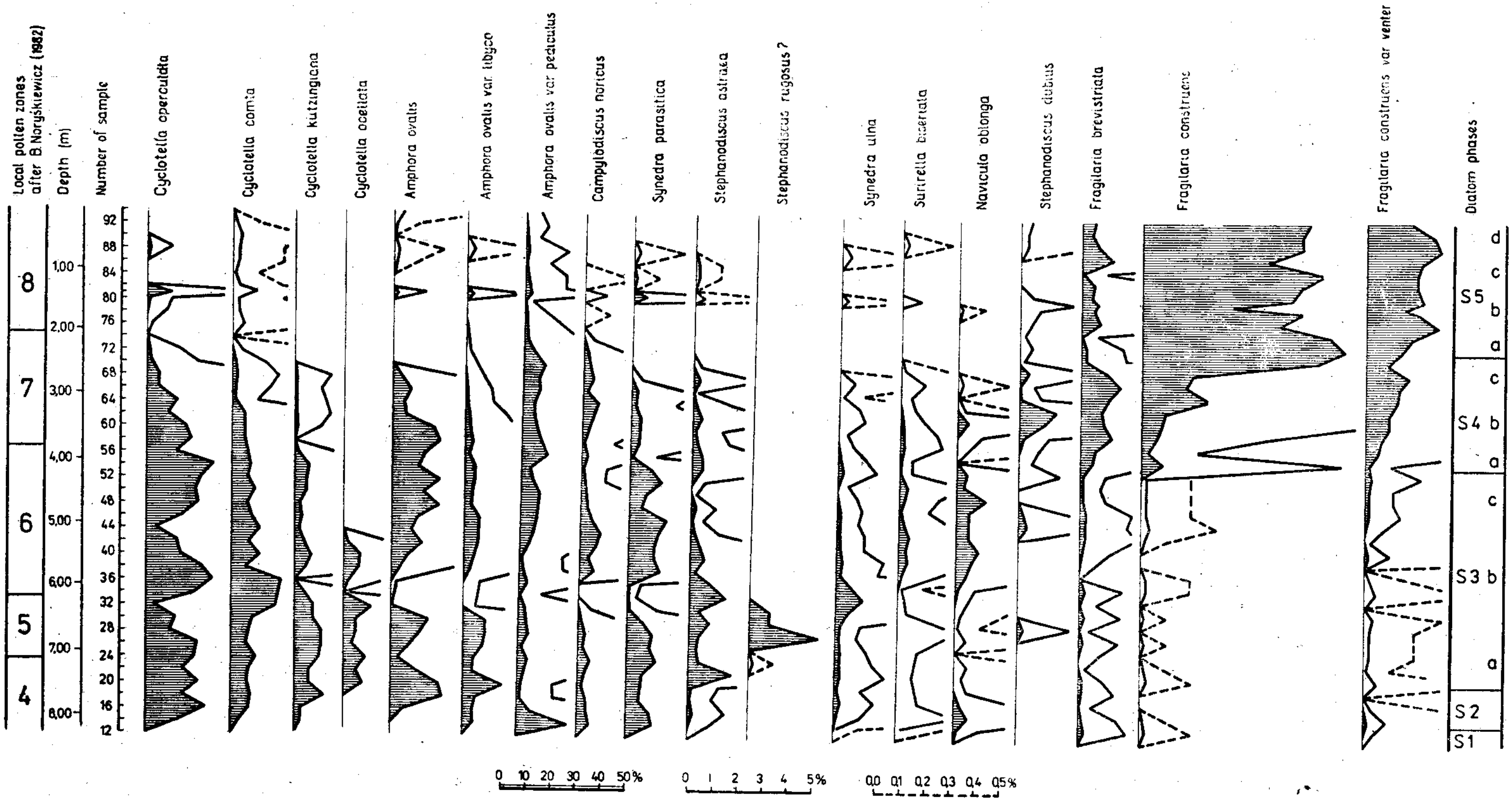

Fig. 2. Diagram showing dominant diatoms in the profile of sediments of Lake Stoklin

910—915 cm — light-grey lacustrine chalk with shells of molluscs,
915—920 cm — almost black silt with plant detritus,
920—930 cm — fine- and medium-grained sand with silt and organic matter,
930—940 cm — well-graded fine- and medium-grained sand.

Eight local pollen zones have been distinguished in the profile on the basis of palynological studies; they are Late Glacial (zones 1 and 2) and Holocene (zones 3—5) sediments. The age of the oldest organogenic sediments of Lake Steklin, determined by the ^{14}C method, is 11630±110 BP (Noryśkiewicz 1982).

Diatom quantitative analyses were made for 42 samples taken at a depth from 820 cm to the top of sediments in the profile examined, mostly every 20 cm. After counting about 1000 specimens in each sample I made diagrams for dominant (Fig. 2), subdominant and less numerous diatoms (Figs. 3, 4 and 5).

REMARKS ON THE OCCURRENCE AND STATE OF PRESERVATION OF THE DIATOMS

In the lowest layer of sediments (820—940 cm) the diatoms were not numerous, and they occurred sporadically whereas in the remaining 820 cm part of the profile the diatoms were very abundant. Although they bore marks of damage and corrosion, the structure of most specimens was well seen under the light microscope (LM). In order to illustrate the state of preservation and variation of the diatoms in the sediments examined, the microphotographs (LM) of those species fairly often encountered are presented in Plates I—IV; they are species of the genera *Cyclotella* (Pl. I, figs. 1—20), *Stephanodiscus* (Pl. II, figs. 1—20), *Fragilaria*, *Synedra* (Pl. III, figs. 1—37) and *Cocconeis*, *Achnanthes* and *Diploneis* (Pl. IV, figs. 1—18). These sediments are characterized by a high $CaCO_3$ content (60—85%) and a narrow range of pH values (7.4—7.9) (Noryśkiewicz 1982).

Although we must be prepared for the loss of a certain number of diatoms owing to the solution of their opaline valves in carbonate sediments, yet in Lake Steklin the disturbances in qualitative and quantitative relations are probably small as is also indicated by the abundant occurrence of diatoms, very small in size and with very finely ornamented frustules, as seen in the SEM electron microscope. Plates V—VII show the of SEM microphotographs diatoms occurring in the lower and the upper part of the profile and belonging to the genera *Cyclotella* (Pl. V, figs. 1—6), *Fragilaria*, *Synedra* (Pl. VI, figs. 1—6), *Cocconeis*, *Achnanthes*, *Diploneis*, *Navicula* and *Amphora* (Pl. VII, figs. 1—6).

The composition and abundance of diatoms met with in lacustrine sediments cannot fully reflect the quantitative relations prevailing in natural assemblages, for there was a possibility of their displacement from various zones and layers of the lake waters to others and of the solution of part of the valves still in water and later in the sediments. The nature of the sediments and the course of the

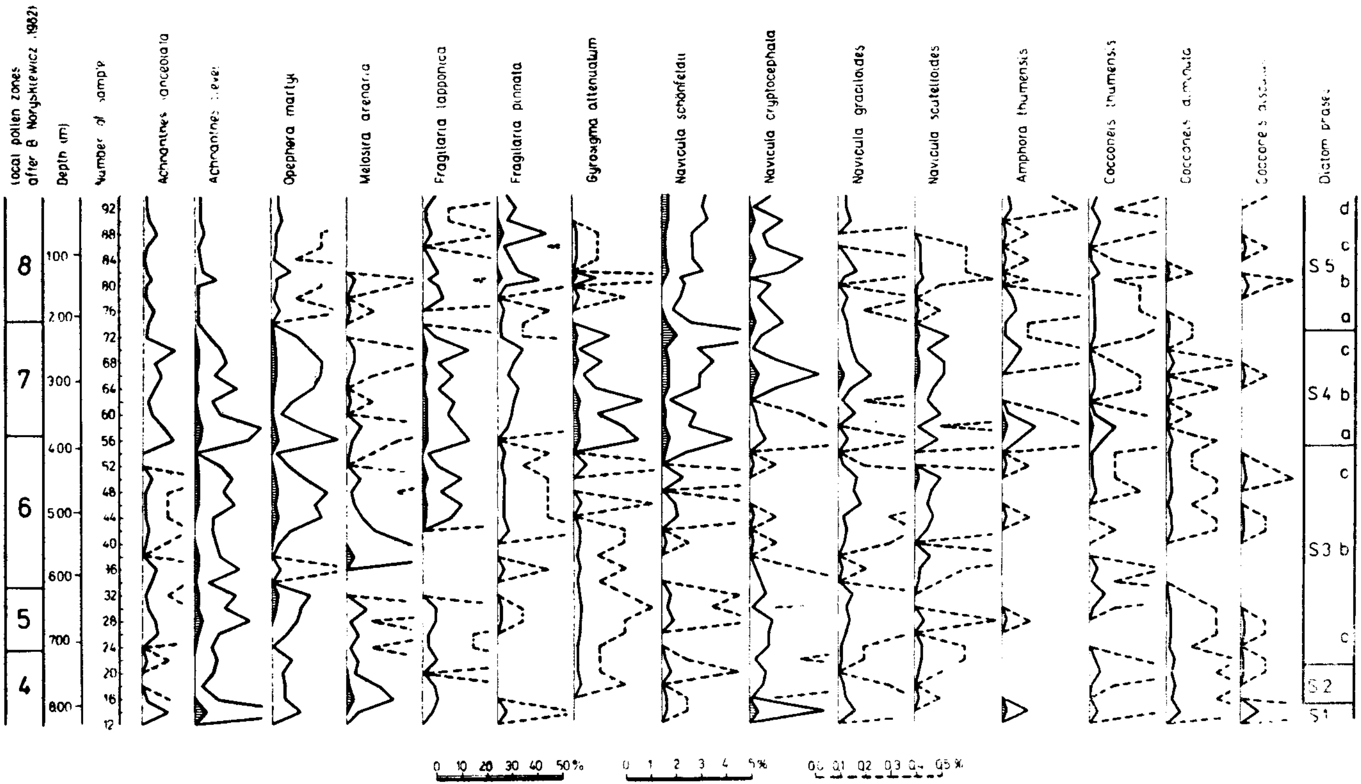

Fig. 3. Diagram showing subdominant diatoms in the profile of bottom sediments of Lake Steklin

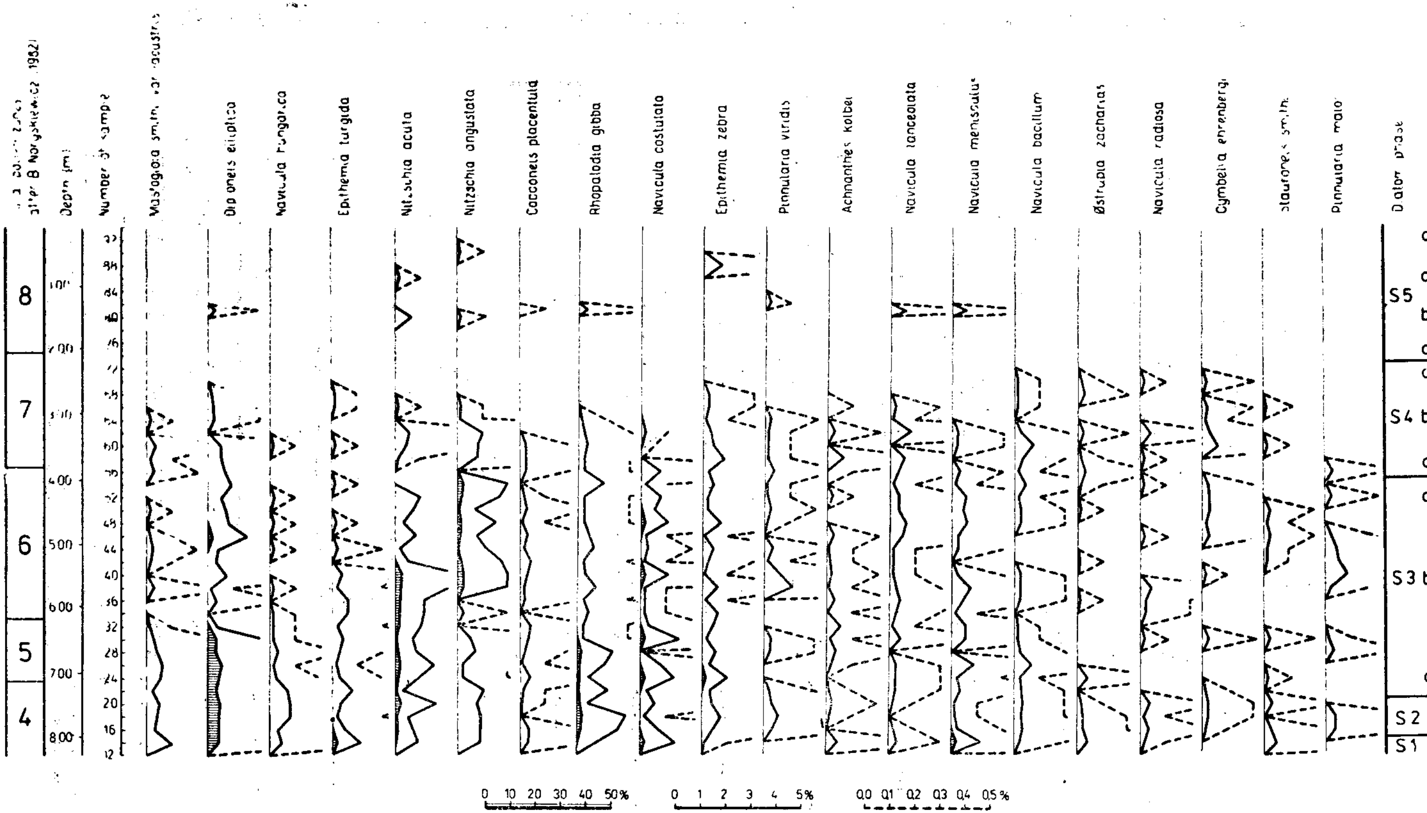

Fig. 4. Diagram showing diatoms occurring mainly in the sediments of the lower part of the profile of Lake Steklin

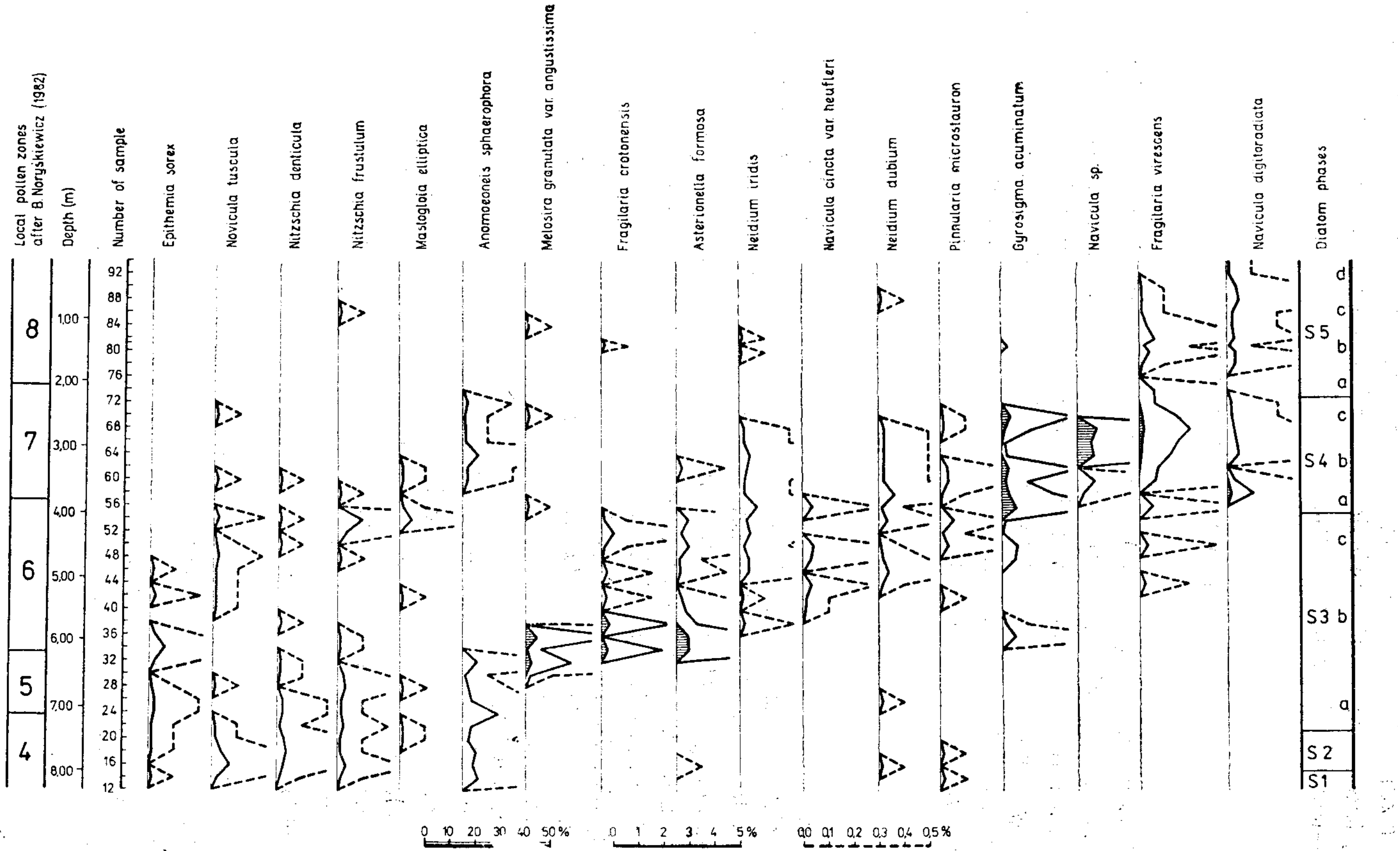

Fig. 5. Diagram showing characteristic diatoms of development phases of Lake Steklin in the Holocene

process of sedimentation and diagenesis, the structure of diatom frustules and, especially, the degree of their silification influence much the state of preservation of diatoms in lake sediments.

DIATOM SUCCESSION

Five diatom phases (S1—S5) have been distinguished on the basis of the qualitative and quantitative analyses of the samples. These diatom phases agree in great measure with the palynological zonation given by Noryśkiewicz (1982). They correspond with the local pollen zones 4—8, which embrace the Holocene sediments from the Boreal to the Sub-Atlantic. The Boreal is represented by two phases of diatom succession, S1 and S2.

Diatom phase S1

As regards dominant diatoms, in the sediments studies, diatom phase S1 was distinguishable by the highest occurrence of *Amphora ovalis* var. *pediculus*, a considerable percentage of *Synedra parasitica* and *Cyclotella operculata* and a lower frequency of *Campylodiscus noricus*, *Amphora ovalis* var. *libyca*, *Cyclotella comta* and *C. kützingiana* (Fig. 2). The group of subdominant diatoms included *Diploneis elliptica*, *Achnanthes clevei*, *Navicula cryptocephala*, *N. costulata* and *Epithemia turgida* (Figs. 3, 5), whereas *Cocconeis disculus*, *Mastogloia smithii* var. *lacustris*, *Navicula menisculus*, *Stauroneis smithii* and *Amphora thumensis* (Figs. 3, 4) belong to the diatoms which were less numerous but typical of phase S1.

The composition of the group of dominant and characteristic diatoms presented above indicates the prevalence of alkaliphilous and alkalibriontic (pH above 7), oligohalobian, freshwater forms living mainly at the bottom of the littoral zone and epiphytes. On the other hand, the planktonic diatoms, notably the euplanktonic ones, living in the pelagic zones of mostly stagnant and sluggishly flowing bodies of water, consitute a small proportion of this group.

In the phase under discussion, special attention should be given to the presence of *Cocconeis disculus*, which often occurs in the lakes of the Baltic region, particularly in the sediments of Lake Ancylus (Jousé 1936, Siemińska 1964, Mölder & Tynnii 1972). It has also been recorded from the first developmental stage of Lake Iwiń (U.S.S.R.), where *Amphora ovalis* var. *pediculus* is also very numerous. In Lake Iwiń this stage comprises the end of the Sub-Arctic and the beginning of the Boreal, when the diatom flora, was typical for the cool, pure waters of deep lakes (Jousė 1939).

In Lake Steklin this short phase (diatom phase S1), in which the littoral diatom flora predominated, was probably connected with a lower water level in the lake and so with unfavourable conditions for the development of planktonic forms. In the light of pollen analysis that stage occurred at the beginning of the Boreal (Noryśkiewicz 1982).

Diatom phase S2

This diatom phase is characterized by an increase in the abundance of the nannoplanktonic diatoms, i.e. *Cyclotella operculata* (to 22%), *C. kützingiana* (to 12%) and *C. comta* (c. 10%), the appearance of *C. ocellata* towards the end of this phase and an appreciable proportion of *Amphora ovalis* et var. *libyca* (Fig. 2). In comparison with the preceding phase, there is a large decrease in the frequencies of *Amphora ovalis* var. *pediculus*, *Achnanthes clevi*, *Navicula cryptocephala* and other species typical of S1, like *Cocconeis disculus* and *Amphora thumensis*. The percentages of *Diploneis elliptica*, *Fragilaria lapponica* and *Fragilaria brevistriata* remain at similar levels and there is a small increase in the number of littoral diatoms of the genera *Navicula*, *Rhopalodia*, *Epithemia*, *Pinnularia* and *Nitzschia* (Figs. 2—5).

The foregoing changes in the composition of the group of dominant diatoms and, in particular, the development of a *Cyclotella* flora, may be related to the widening the littoral and pelagic zones in the lake and to an increase of phytoplankton. These changes also evidence the attainment of a balance between the development of oligohalobian (indifferent) nannoplanktonic diatoms and the percentage occurrence of epiphytic diatoms and those living at the bottom of the lake. The development of periphytic, chiefly alkaliphilous diatoms indicates the overgrowing of the littoral zone of the lake where also elements characteristic of shallow, somewhat peaty water reservoirs appeared. On the other hand, the alkalibiontic diatoms are less numerous in this phase than in S1.

In the pollen diagram, phase S2 corresponds to zone 4 (Boreal), in which the birch-pine forests with a gradual development of *Corylus* predominated. The presence of aquatic plants (*Nymphaea*, *Nuphar*, *Myriophyllum spicatum*, *Batrachium*, *Sparganium*) and *Sphagnum* at that time is also noted (Noryśkiewicz 1982).

Diatom phase S3

Diatom phase S3 is strongly differentiated with respect to the composition and numbers of both dominant and subdominant as well as less numerous diatoms. It is divided into 3 subphases (S3a, S9b and S3c).

Subphase S3a is marked by a considerable increase in the percentage of *Stephanodiscus astraea* (mainly *S. astraea* var. *minutulus*) and next by the short-lived, explosive development of *Stephanodiscus rugosus*? (*S. hantzschii*) (Fig. 2).

In subphase S3b the *Stephanodiscus* flora is accompanied by *Cyclotella* species *(C. operculata, C. kützingiana, C. comta* and *C. ocellata)* and by *Amphora ovalis* et var. *libyca, Diploneis elliptica* and *Synedra parasitica* (Figs. 2, 4).

Subphase S3b at first shows a marked increase in the percentages of *Stephanodiscus astraea* (mainly *S. astraea* var. *minutulus*) and *Synedra ulna*, a rapid decline followed by a slight increase in occurrence of *Cyclotella kützingiana, C. ocellata, Aphora ovalis* var. *libyca, Synedra parasitica, Campylodiscus noricus* and *Navicula oblonga*. The diatoms rarely recorded from the older sediments, i.e. *Asterionella formosa, Melosira granulata* var. *angustissima* and *Fragilaria crotonensis* (Fig. 5) also appeared at that time. These species indicate an optimum phase in the development of diatoms in Lake Steklin. Their occurrence is connected with the climatic optimum (Atlantic), when *Nuphar* turned up in the lake flora, as noted in zone 6 in the pollen diagram (Noryśkiewicz 1982).

Subphase S3c is marked by a further rise in the percentages of *Cyclotella operculata, Amphora ovalis, Synedra parasitica* and *Navicula oblonga*, a decrease in the numbers of *Campylodiscus noricus, Stephanodiscus astraea, Asterionella formosa* and *Fragilaris crotonensis* and a nearly complete disappearance of *Cyclotella ocellata* and *Melosira granulata* var. *angustissima*. Moreover, the group of dominants includes also *Cyclotella comta, C. kützingiana, Amphora ovalis* var. *pediculus* and *Opephora martyi*.

A rapid increase in the number of different *Stephanodiscus* species, observed in the sediments of Lake Steklin at the beginning of phase S3, no doubt reflects the gradual increase of the alkalinity and trophic status of the lake in Atlantic time. Apart from the diatoms occurring frequently in the plankton of the littoral and pelagic zones of the lake in this phase, an increase was observed also in the frequencies of halophilous and alkalibiontic forms (e.g. *Anomoeoneis sphaerophora, Epithemia sorex, E. zebra* and *E. turgida*) usually connected with a high concentration of mineral salts and nutritive components in the environment of littoral communities. A rise in the alkalinity and eutrophication of water in the littoral zone of the lake coincided with the intense development of the aquatic vegetation observed in zones 5 and 6 in the pollen diagram (Noryśkiewicz 1982).

The eutrophication of lakes is often linked to the appearance of man and his settlement in their vicinity but evidence of the presence of man in the region of the Dobrzyń Lake District in the Mesolithic are fragmentary and unreliable. And so the eutrophication of the lake in the older part of Atlantic can at present of the lake in connection with the improvement of climatic and environmental conditions or with the flow of water rich in nutritive components into or through the lake.

Diatom phase S4

This diatom phase is characterized by a gradual development of the *Fragilaria* flora as evidenced in its 3 subphases (S4a, S4b and S4c).

In subphase S4a, the diatoms dominating in the previous phases — *Cyclo-*

tella (C. operculata and *C. comta)* and *Amphora ovalis* are still fairly numerous, whereas the *Fragilaria* flora *(F. brevistriata, F. construens* et var. *venter)* and *Amphora ovalis* var. *pediculus* occur here in the group of subdominants. At the same time there is a considerable fall in the percentage occurrence of *Cyclotella kützingiana* and *Synedra parasitica* and also of the diatoms less numerous but typical of the preceding phase, *Fragilaria crotonensis* and *Asterionella formosa* (Figs. 2, 5).

Subphase S4b is distinguished by an increase in the relative frequency of *Stephanodiscus dubius*, which is a probably halophilous species occurring in the plankton of the pelagic zone of stagnant or sluggishly flowing water bodies (Siemińska 1964). In addition, in subphase S4b the numbers of *Campylodiscus noricus*, *Navicula oblonga* and several other species of the genus *Navicula* rise slightly, while a decrease is noted in the percentages of *Cyclotella* and *Amphora ovalis*.

In subphase S4c the littoral alkaliphilous *Fragilaria* flora (chiefly *F. construens* et var. *venter* and *F. brevistriata*) becomes prevalent and later on is accompanied by *Amphora ovalis* var. *pediculus* and numerous species of *Navicula*. A fairly rapid decrease in the occurrence or the complete disappearance of many diatoms of the genera *Cyclotella*, *Mastogloia*, *Diploneis*, *Rhopalodia*, *Pinnularia*, *Stauroneis*, *Surirella*, *Synedra* and others (Figs. 2—5) takes place parallel to the development of the *Fragilaria* flora in subphase S4c.

Among the diatoms which are not very numerous nearly throughout the whole profile under study, *Achnanthes lanceolata*, *A. clevei*, *A. kolbei*, *Amphora thumensis*, *Cocconeis thumensis*, *Melosira arenaria*, *Fragilaria lapponica*, *F. pinnata*, *Navicula schönfeldii* and *N. cryptocephala* (Figs. 3—5) show a small increase in their percentage occurrence in phase S4. *Gyrosigma attenuatum*, *G. acuminatum*, *Navicula digitoradiata* and *Anomoeneis sphaerophora* may also be included among the typical diatoms of this phase. They are for the most part alkaliphilous and alkalibiontic diatoms living in the littoral zone of fresh and brackish waters, frequently at the bottom of stagnant or sluggishly flowing water bodies.

The changes in the composition and numbers of diatoms (dominant, less numerous and characteristic) presented above give evidence of intense transformations of the water environment in both the pelagic and littoral zones of the lake in phase S4. In the light of the pollen analysis they fall in the Sub-Boreal (Noryśkiewicz 1982).

The process of diatom succession indicates that in subphase S4a there was a certain lowering of the water level in the lake and concentration of mineral salts, which was particularly distinctly reflected in the littoral zone, namely, by a rise in the percentage of alkalibiontic species. The development of *Stephanodiscus dubius*, taking place in subphase S4c, suggests the further enrichment of water in the pelagic zone of the lake, a higher water level or the inflow of river water richer in nutrient components. On the other hand, towards the end of this phase (subphase S4c) the percentage of planktonic diatoms falls dramatically and the composition of the diatom flora undergoes a general impoverishment. The increasing predominance of the diatoms which are frequent in the littoral zone of lakes (periphyton) in subphase S4c is probably connected with the prevalence of other algae in the plankton, the expansion of the littoral zone and marked decrease in depth of Lake Steklin towards the close of the Sub-Boreal.

Both the climatic changes (intensification of continentality, cooling) and human activity (colonization of the Dobrzyń Lake District), which may have been responsible for the enhancement of the eutrophication of the lake, particulary marked in subphase S4b, were possibly the cause of the great variation in the composition and frequency of diatoms in phase S4. Neolithic settlements in the early Sub-Boreal are manifested in the pollen diagram by the appearance of indicator plants of man's agricultural activity, whereas in its later period the influence of the Lusatian culture is very distinct in the 3rd and 4th periods of the Bronze Age (Noryśkiewicz 1982).

Diatom phase S5

This diatom phase is represented by the *Fragilaria* flora (chiefly *F. construens* et var. *venter*), which reaches its maximum occurrence in the sediments under study in subphase S5a. At the same time there is a drop in the frequencies of many diatoms characteristic (more or less numerous) of the previous diatom phases and belonging to the genera *Cyclotella, Amphora, Campylodiscus, Synedra, Stauroneis* and *Anomoeoneis* (Fig. 2). Subphase S5a contains also diatoms which are not very numerous but are present in nearly the whole profile, belonging to the genera *Achnanthes, Opephora, Gyrosigma, Navicula* and *Cocconeis* (Figs. 3, 5).

The following short-lived developmental stage of diatoms (subphase S5b) is characterized by an increase observed again in the numbers of some of the planktonic forms (*Cyclotella operculata, C. comta, Stephanodiscus dubius* and *S. astraea*), accompanied by the genera *Amphora, Achnanthes, Navicula, Synedra, Campylodiscus* and *Opephora*. At the same time there was also a small fall in the percentage of *Fragilaria construens* (Fig. 2).

An inconspicuous rise in *Fragilaria construens* and *F. brevistriata* as well as in *Synedra, Achnanthes, Amphora, Navicula* and *Epithemia* occurs again in subphase S5c. As regards the planktonic diatoms, only a few specimens of *Cyclotella operculata, C. comta* and *Stephanodiscus astraea* are encountered (Fig. 2).

Only small quantitative changes have been observed in the group of dominants towards the close of this phase (S5d). The frequency of *Fragilaria construens* remains at a similar high level as in the previous phases, the number of *F. construens* var. *venter* rises, whereas the occurrence of *F. brevistriata* diminishes a little. Moreover, in subphase S5d the group of less numerous diatoms shows the presence of *Stephanodiscus dubius, Amphora ovalis, A. thunensis,* *Opephora martyi* and some species of *Achnanthes* and *Navicula* (Figs. 2, 3). Most of these taxa belong to the constant elements of the diatom flora occurring almost continuously through out the whole profile from Lake Steklin.

In phase S5, falling — according to Noryśkiewicz (1982) — in the Sub-Atlantic, there is a rapid drop in the frequency, or a complete lack of many diatom species which in the preceding phases (S1—S4) are frequent and belong to the rich and very varied flora typical of the pelagic and littoral zones of fairly deep lakes. Instead, the littoral flora, poor in species and little diversified, becomes dominant here, indicating the general impoverishment and the beginning of degradation of the pelagic zone of Lake Steklin. The maximum development of the genus *Fragilaria*, taking place in the Sub-Atlantic, may indicate a considerable fall in the water level and be linked with the expansion of other algae (*Cyanophyceae* and *Chlorophyceae*) which usually occur abundant in the phytoplankton of eutrophic lakes. The last stage of eutrophication noted in the studied sediments of Lake Steklin in the Holocene is connected, above all, with man's increasingly intense husbandry, which, as can be seen from the pollen diagram, reaches its greatest intensity in subzone f of the Sub-Atlantic (Noryśkiewicz 1982).

DISCUSSION

Five diatom phases, S1—S5, have been distinguished on the basis of a diatom analysis of an 8.2-metre-long profile of sediments from Lake Steklin. They cover the Holocene sediments, starting from the Boreal up to the Sub-Atlantic, i.e. local pollen zones 4—8 (Noryśkiewicz 1982).

Diatom phase S1 constitutes a short-lived developmental stage of diatoms, with *Amphora ovalis* var. *pediculus* occurring most numerously. The *Cyclotella* flora prevails in phase S2, in which *Amphora ovalis* et var. *libyca* is also very abundant. Diatom phase S3 shows an increase in the percentage of *Stephanodiscus* (mainly *S. astraea* var. *minutulus* and *S. rugosus? (S. hantzschii)* and *Synedra*, while *Melosira granulata* var. *angustissima*, *Asterionella formosa* and *Fragilaria crotonensis* make their appearance in its middle part (S3b). Diatom phase S4 is characterized by a rise in the number of *Stephanodiscus dubius* (subphase S4b) and the gradual development of *Fragilaria*, which in the next phase, S5, reaches its maximum frequency in the examined sediments of Lake Steklin.

A similar diatom succession has been reported from a 37.25-metre profile of sediments in Lake Somino (Jaroslav area, U.S.S.R.), especially in its lower part, in which initially (zone V and VI) the *Cyclotella* flora prevailed and next, in an 11-metre-thick layer (zone IV), *Stephanodiscus astraea* var. *minutulus* became dominant. Zone IV coincides here with a period of occurrence of deciduous forests, the further development of which is referred to a consecutive stage of diatom succession (zone III), with the predominance of *Melosira granulata*. In Lake Steklin this stage is comparable with the appearance of *Melosira granulata* var. *angustissima* in the middle part of diatom phase S3 and the enrichment of planktonic diatom flora with *Asterorionella formosa* and *Fragilaria crotonensis*. In Lake Somino the role of littoral diatoms increases in the upper portion of sediments and the mass occurrence of the *Fragilaria* flora is noted in the last zone (I) (Kozyrenko 1961).

Despite a certain similarity between the diatom successions in these lakes, the eutrophication process seems to be more distinct in Lake Steklin, especially in the three younger diatom phases, S3—S5.

The *Cyclotella* flora is still prevalent in diatom phase S2. It is usually abundant in oligo- and mesotrophic lakes, in weakly mineralized, cool water rich in oxygen; it often occurs in the first developmental stage of postglacial lakes (cf. Jousé 1961, Kozyrenko 1961).

On the other hand, an increase in the percentage frequencies of *Stephanodiscus*, *Synedra*, *Asterionella formosa*, *Fragilaria construensis* and *Melosira granulata* var. *angustissima* takes place in diatom phase S3.

The development of the above-mentioned diatoms in the modern lakes of Europe and North America is often connected with a rise in the trophic status induced by man's husbandry (Battarbee 1978, Bradbury & Waddington 1978).

As regards Lake Steklin, the stage of eutrophication taking place in the Atlantic was probably conditioned mainly by natural factors, for little evidence of Mesolithic and early Neolithic settlement has as yet been found in the Dobrzyń Lake District (Noryśkiewicz 1982).

The second stage of eutrophication of Lake Steklin in marked in diatom phase S4, notably in subphase S4b, by an increase in the percentage of *Stephanodiscus dubius*. It is also characterized by the gradual development of the *Fragilaria* flora and marked changes in the composition of the diatom assemblages, which may be explained by the decreasing depth of the lake in the Sub-Boreal.

The third stage of eutrophication (diatom phase S5) is reflected by the increase of the *Fragilaria* flora (S5a), the development of which may indicate a further and more rapid lowering of the water level in comparison with the preceding phase and the overgrowing of the lake, leading to the complete disappearance of planktonic forms and the general impoverishment of the diatom flora in subzone f of the Sub-Atlantic, when the most conspicuous traces of human activities appear in the pollen diagram (Noryśkiewicz 1982). This stage should rather be referred to the initial degradation of the aquatic environment in the pelagic part of Lake Steklin in the youngest Holocene.

Although many data concerning the development of lakes have been collected, it is hard to distinguish the processes conditioned by natural factors from those influenced by human activities. Cores of lacustrine sediments comprising as full a history of the given lake as possible, from its origin up to the present times, are particularly valuable and will permit the determination of the changes induced by man's influence.

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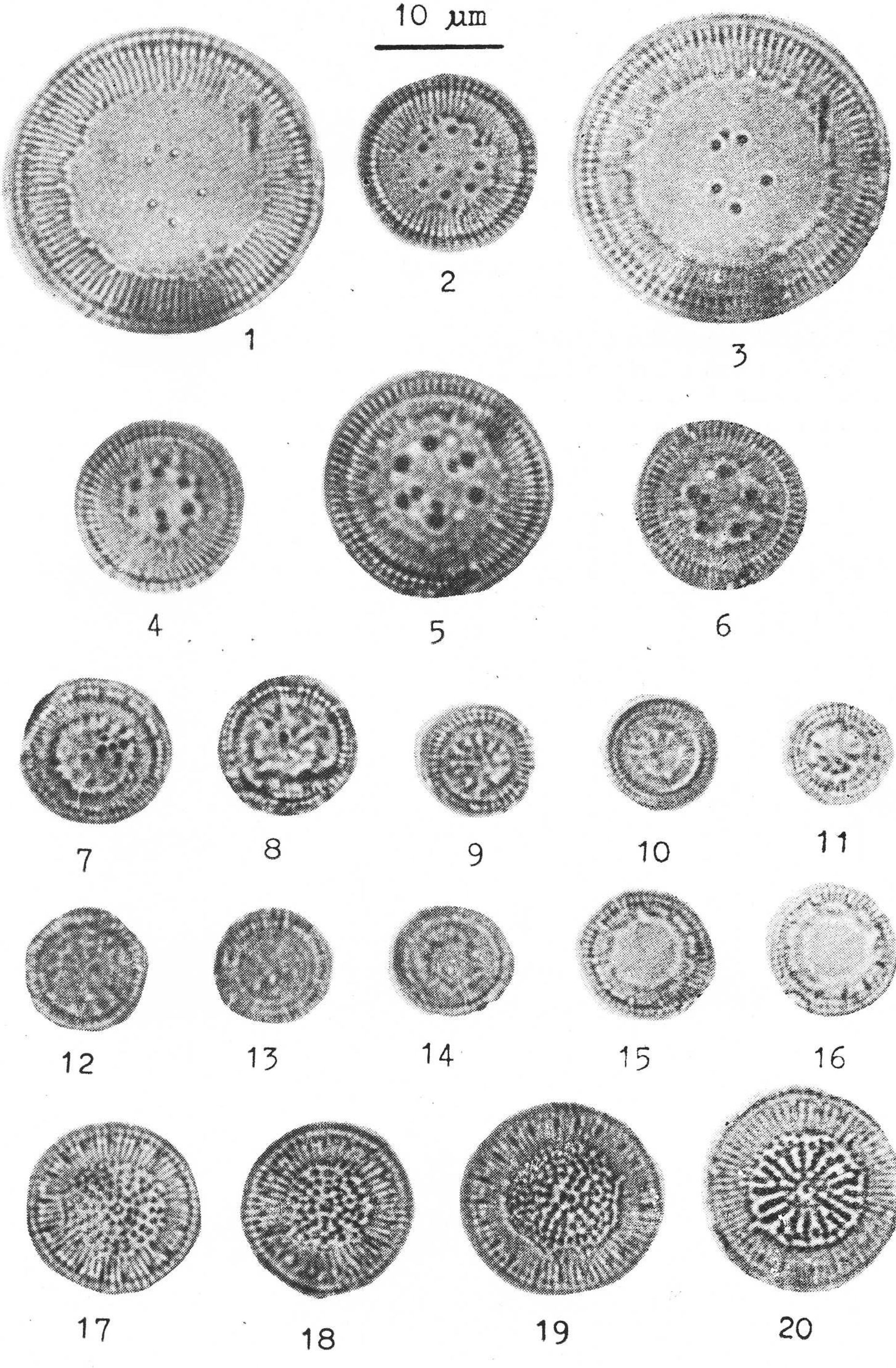
Plate I

1— 3. *Cyclotella kützingiana* Thw.
4— 6. *C. ocellata* Pant.
7—11. *C. operculata* (Ag.) Kütz.
12—14. *C. operculata* var. *unipunctata* Hust.
15—16. *C. operculata* var. *mesoleia* Grun.
17—20. *C. comta* (Ehr.) Kütz.



B. Marciniak

Plate II

1— 7. *Stephanodiscus dubius* (Fricke) Hust.
8—13. *S. astraea* var. *minutulus* (Kütz.) Grun.
14—16. *S. rugosus?* Siem. et Chud.
17—20. *S. hantzschii* Grun.

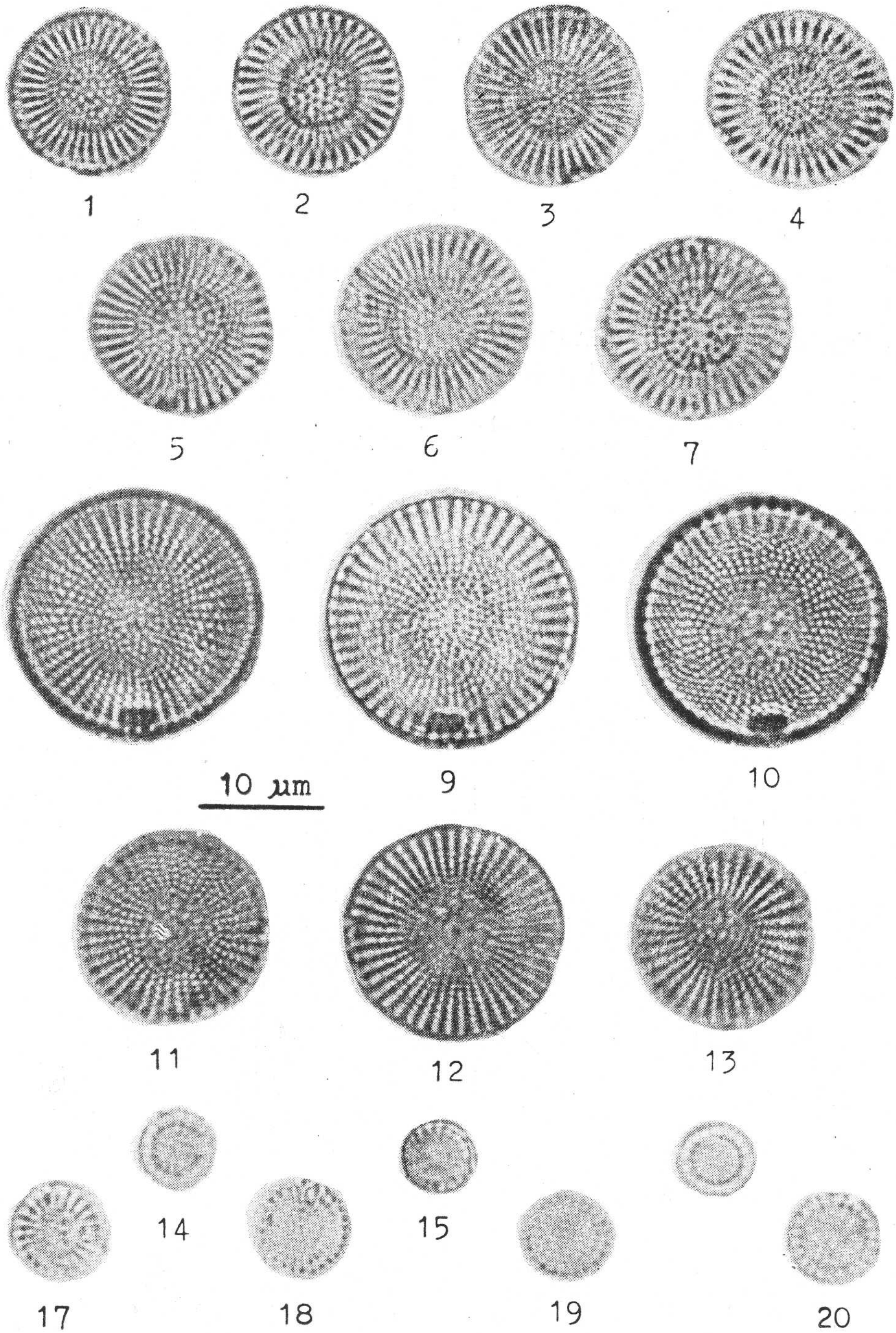

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Plate III

1— 9. *Fragilaria construens* (Ehr.) Grun.
10—18. *F. construens* var. *venter* (Ehr.) Grun.
19, 20. *F. pinnata* Ehr.
21, 22. *F. pinnata* var. *lancettula* (Schum.) Hust.
23—27. *Fragilaria brevistriata* Grun.
28—31. *Synedra parasitica* (W. Sm.) Hust.
32. *S. parasitica* var. *subconstricta* Grun.

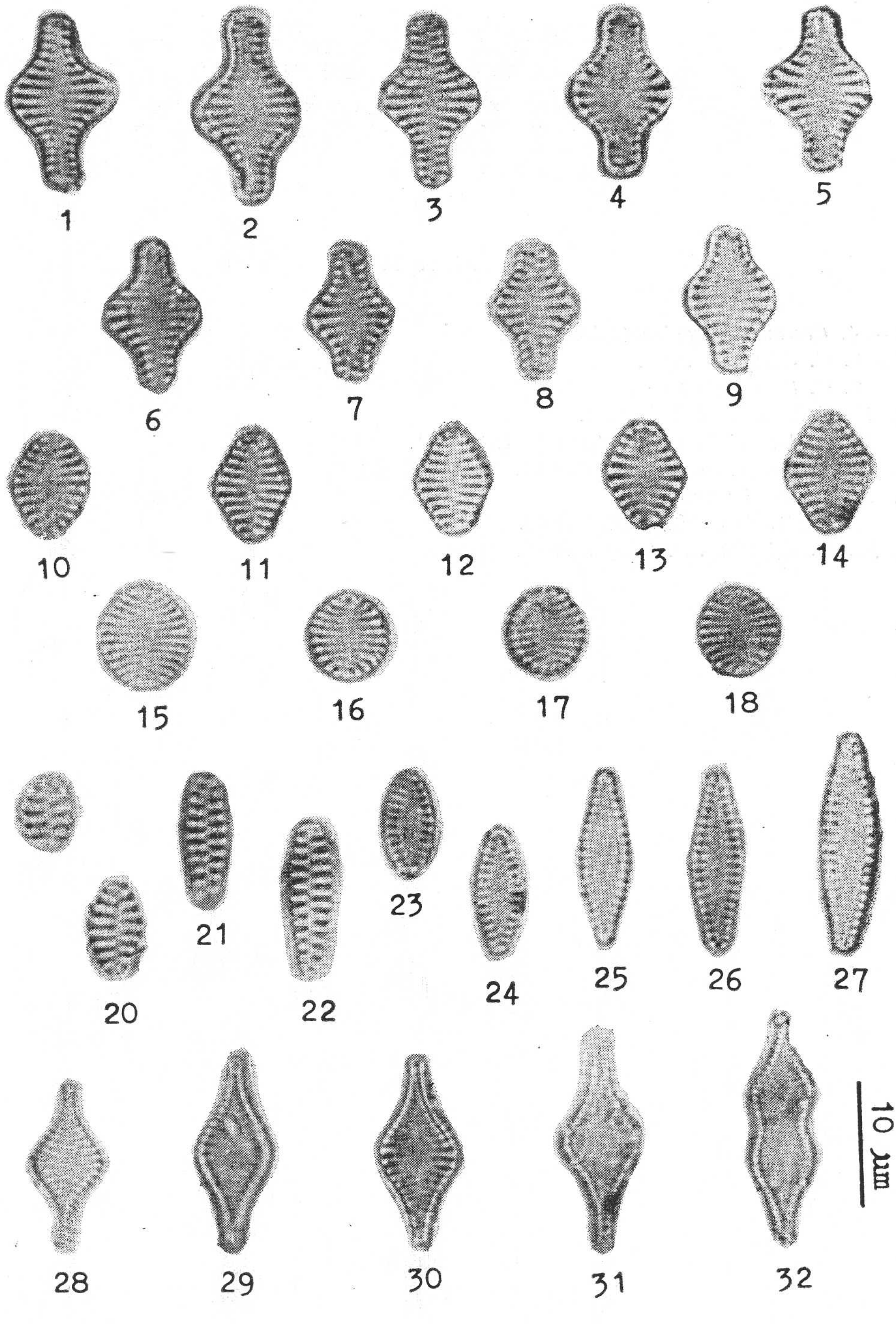
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Plate IV

1— 4. *Cocconeis disculus* (Schum.) Cl.
5— 8. *C. diminuta* Pant.
9. *C. thumensis* Hust.
10, 11. *Achnanthes kolbei* Hust.
12. *A. lanceolata* var. *rostrata* (Østr.) Hust.
13. *A. lanceolata* var. *elliptica* Cl.
14, 15. *A. clevei* Grun.
16. *Diploneis elliptica* (Kütz.) Cl.
17, 18. *D. elliptica* var. *ladogensis* Cl.

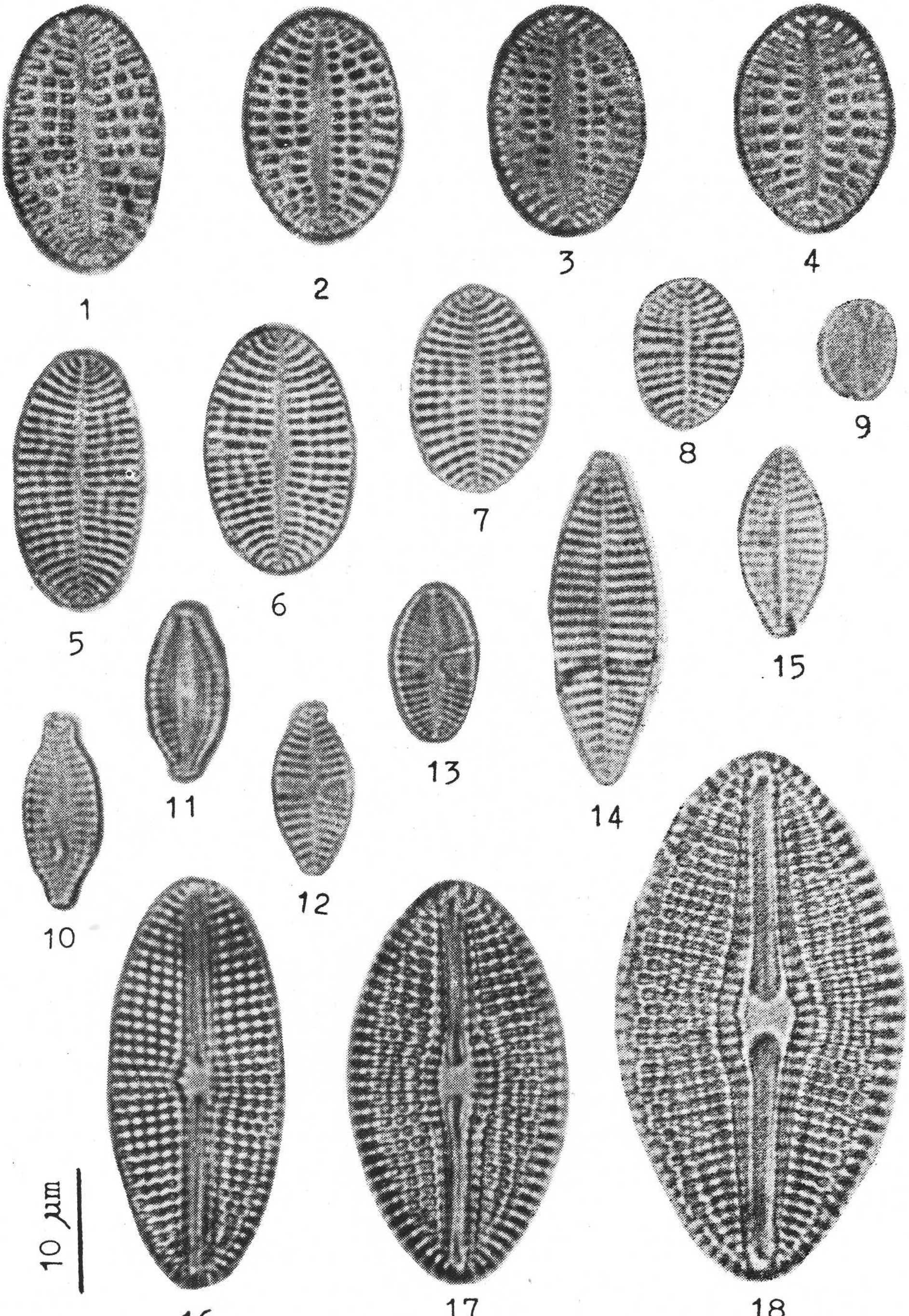
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Plate V

1—4. *Cyclotella operculata* (Ag.) Kütz.

5, 6. C. comta (Èhr.) Kütz.

Scale — 2 μm

Plate V

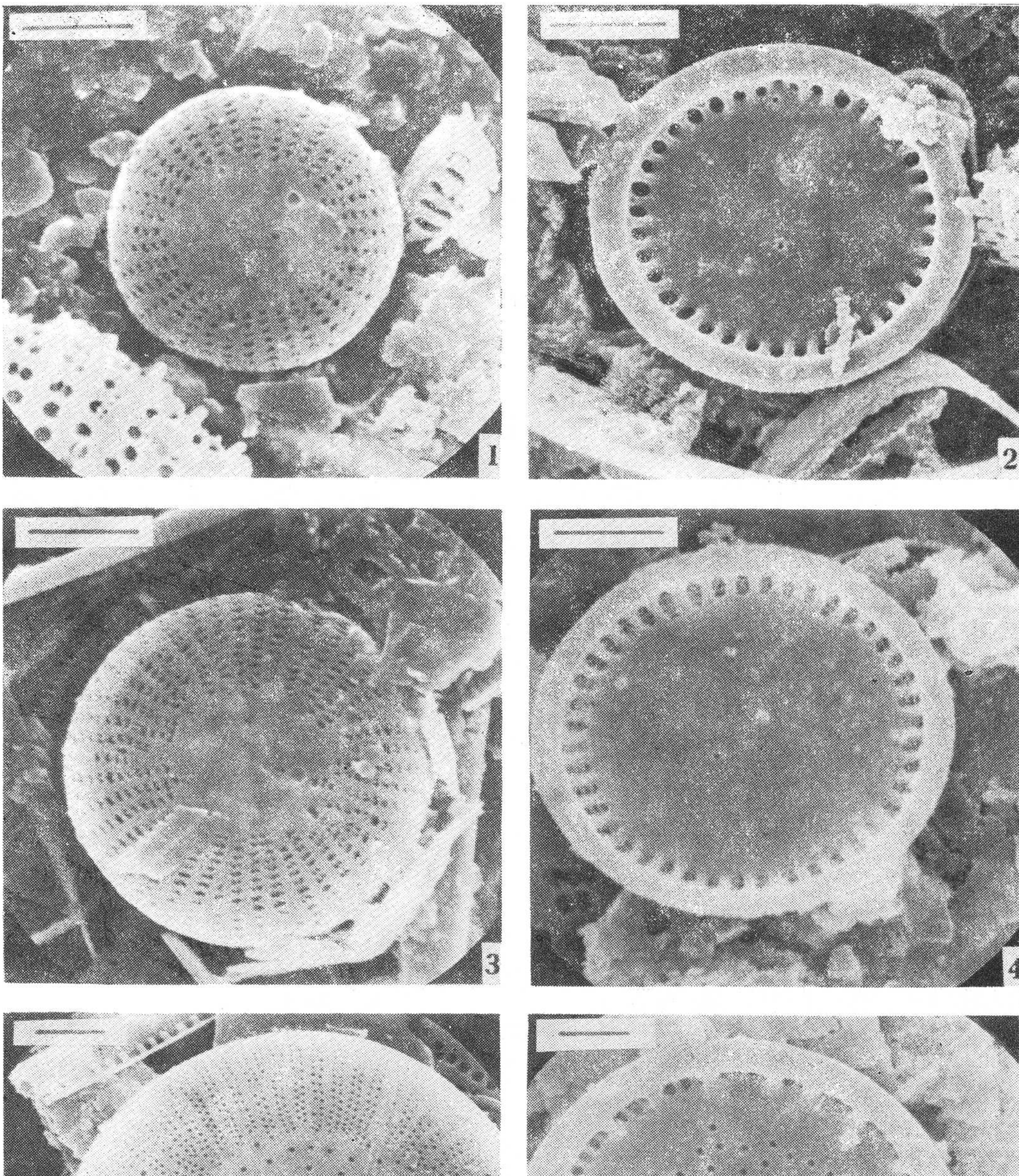

Plate VI

1, 2. *Fragilaria construens* (Ehr.) Grun.
3, 4. *F. construens* var. *venter* (Ehr.) Grun.
5, 6. *Synedra parasitica* (W. Sm.) Hust.

Scale — 2μm

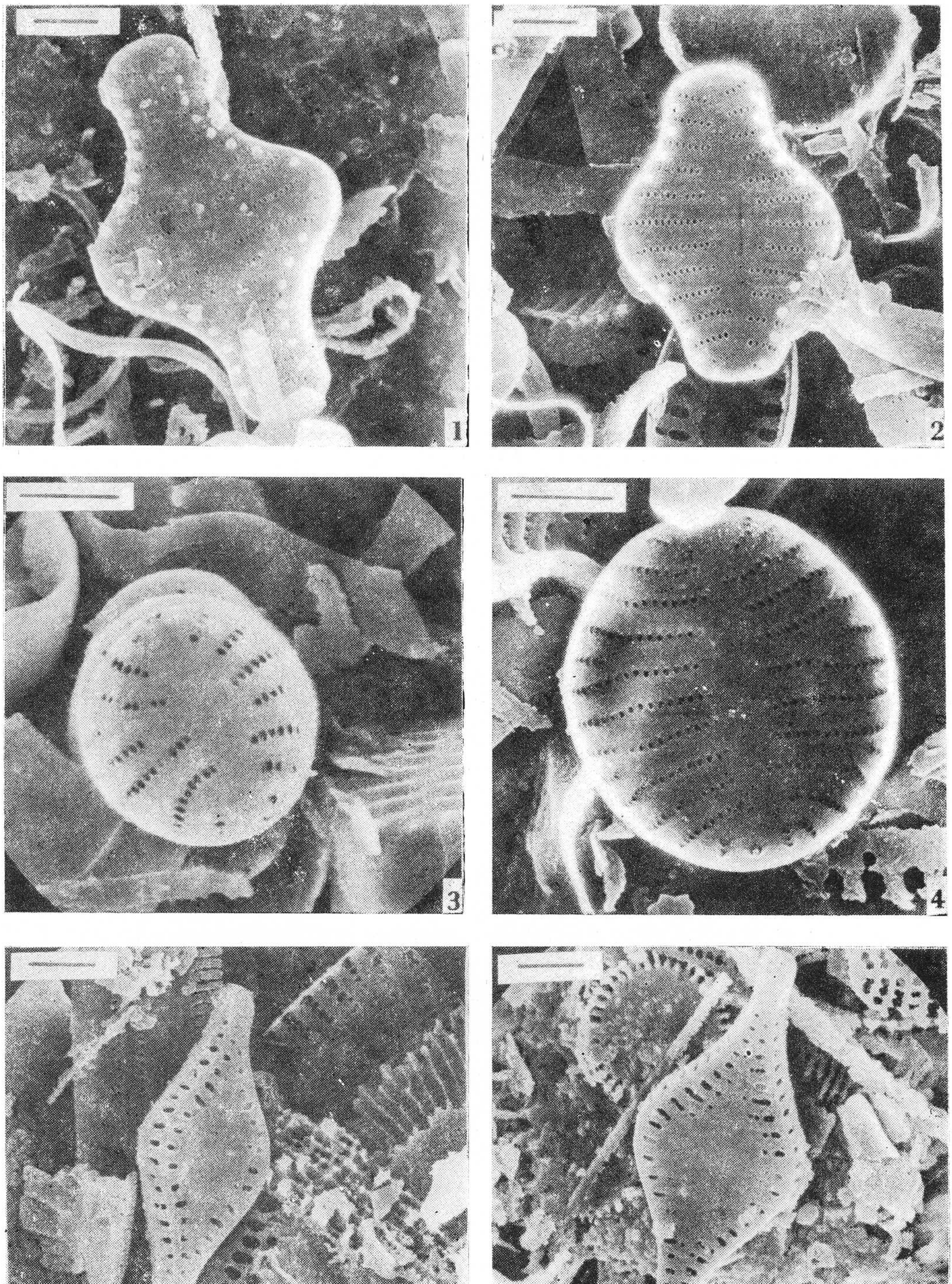
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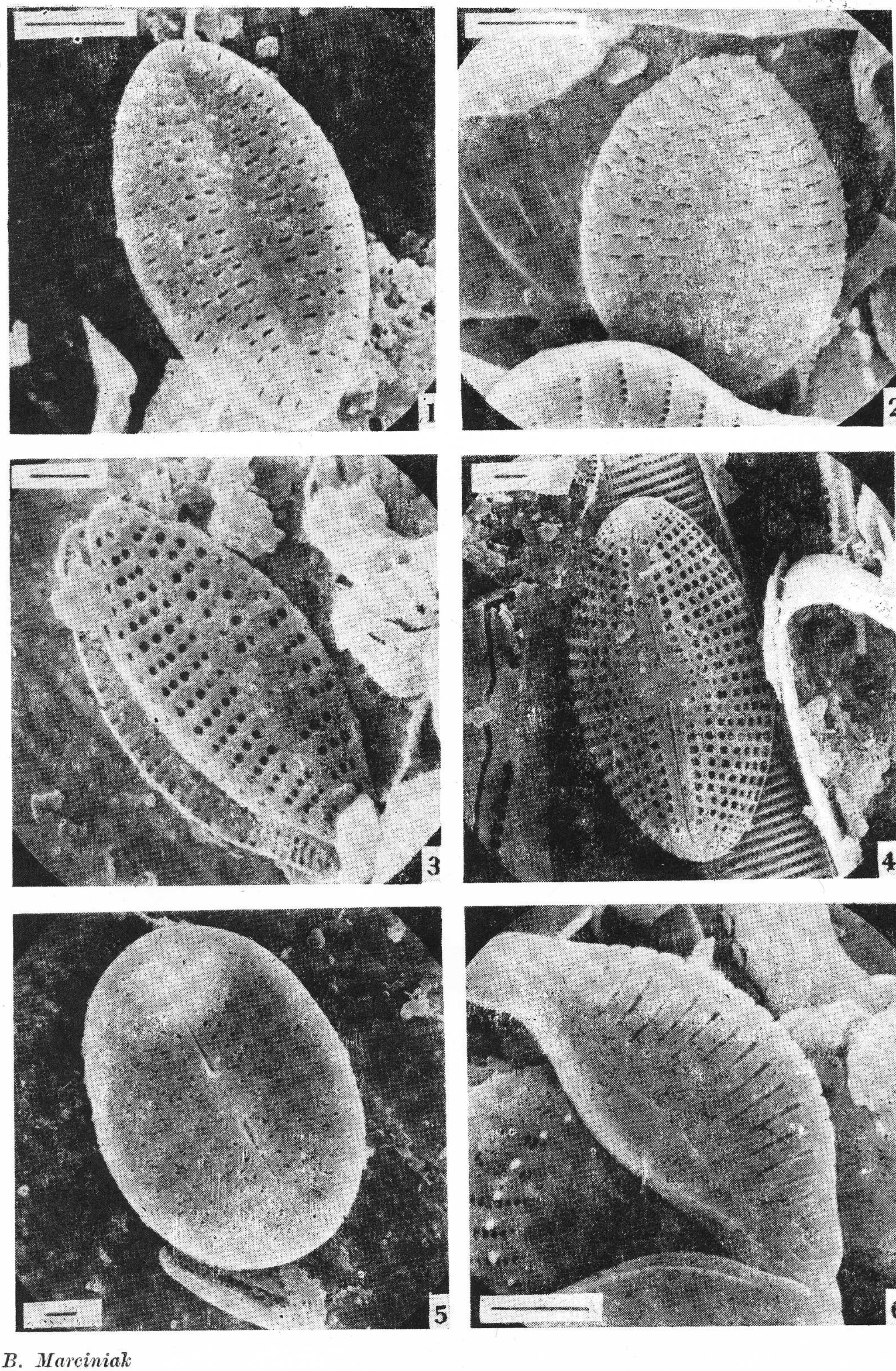
Plate VII

1, 2. *Cocconeis thumensis* Mayer
3. *Achnanthes clerei* Grun.
4. *Diploneis elliptica* (Kütz.) Cl.
5. *Navicula scutelloides* W. Sm.
6. *Amphora thumensis* (A. Mayer) A. Cl.

Scale — 2 μm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