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Late-Glacial diatom phases in western Pomerania

ABSTRACT: Succession of diatom phases in Late-Glacial lacustrine deposits at Niechorze, western Pomerania, Poland, permits recognition of two main stages in development of the basin. The early stage (Oldest Dryas, Bølling, and the beginning of Older Dryas) is distinctive in discontinuities in diatom distribution resulting from sedimentary disturbances, and in poorly preserved and species-poor diatom assemblages dominated by *Fragilaria pinnata*. Diatoms were very abundant at the late stage (the decline of Older Drays, Allerød, and Younger Dryas) and their ubiquity indicates an increased stability in the pattern of limnic sedimentation. At the late stage of basin development, the diatom assemblage was dominated by *Fragilaria construens* var. *venter* and *F. brevistriata*, but the contribution of *Synedra* spp. and *Melosira italica* was increasing towards the end of Younger Dryas.

INTRODUCTION

Organogenic deposits exposed in a cliff by Niechorze, western Pomerania, Poland (Text-fig. 1) are representative of two ice-melting basins, 0.5 km in distance from each other, developed during deglaciation in depressions of a post-glacial upland built up mostly by tills of

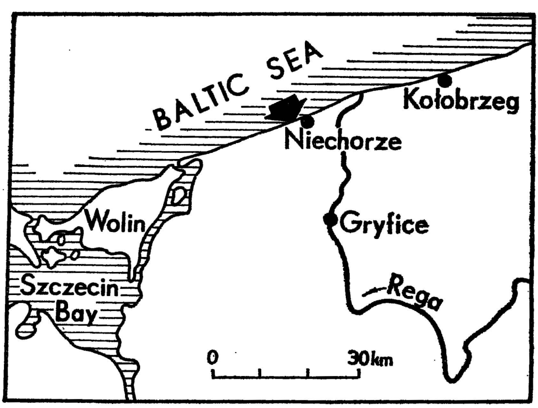


Fig. 1
Location map of the investigated section (*arrowed*) exposed in a cliff by Niechorze, western Pomerania

the Pomeranian Phase of the Vistulian Glaciation (Kopczyńska-Lamparska & *al.* 1980, 1981).

As dated by means of radiocarbon (Kopczyńska-Lamparska 1976) and palynologic methods (Brykczyńska 1978), the deposits accumulated in the smaller one of the two basins, called as Niechorze *I*, range in age from the Oldest Dryas to the Subboreal period. The diatoms (Marciniak 1979), malacofauna (Skompski *in*: Kopczyńska-Lamparska & *al.* 1980, 1981), cladocerans (Szeroczyńska *in:* Kopczyńska-Lamparska & al. 1980), and geochemistry (Cieśla *in*: Kopczyńska-Lamparska & *al.* 1981) of those deposits also were investigated.

In the section Niechorze *I* diatom-bearing deposits include (*see* Text--fig. 2) lithologically variable silts with a loamy-peaty intercalation, ranging in age from the Oldest Dryas to the Preboreal period. The overlying silts and peats did not yield any diatoms. The section was subdivided into diatom phases and subphases (Marciniak 1979), the subdivision being correlated with palynologic zonation scheme (Brykczyńska 1978). The section Niechorze *I* has been recognized for the standard one for the present study of the neighboring section Niechorze *I-bis*.

The section Niechorze *I-bis* (Text-fig. 2) was sampled in 1978; it represents the exposure at Niechorze with its wall displaced less than 1 m landwards relative to 1974 when the section Niechorze *I* was sampled (Kopczyńska-Lamparska & *al.* 1980).

METHODS OF INVESTIGATION

In order to recognize the diatom succession in the section Niechorze *I-bis*, 36 samples were taken from the lower part of the section (*see* Text-figs 2—3). Flotation was applied to enrich the samples in diatoms (*cf.* Juse 1966) because the investigated deposits are very rich in mineral components. Diatoms have been found in 21 samples (Nos *6*, *11*, and *18—36*).

Quantitative analysis of the diatom assemblages was undertaken, with a thousand specimens per sample having been considered. The assemblages include in total 138 diatom taxa. Per cent proportions of the dominant and subdominant taxa in particular samples are shown in form of a diatom diagram (Text-fig. 3). A representative group of the recorded diatoms are presented in photomicrographs (Pls 1—10).

Successive diatom phases and subphases have been recognized in the investigated section (Text-fig. 3) following the methodology outlined in earlier papers (Marciniak 1973, 1979), with the succession of diatom taxa, their distributional patterns and ecology taken into account. The diatom phases and subphases refer to phases (phytophases) and stages recognized by Różycki (1964) for units of the third and fourth rank, respectively, in the climatostratigraphic pattern of the Pleistocene. Their nomenclature, in turn, resembles that applied by Haworth (1976) who established several Diatom Assemblage Zones (*DAZ*) by analogy to the commonly accepted Pollen Assemblage Zones (*PAZ*).

SUCCESSION OF THE DIATOM ASSEMBLAGES

DIATOM PHASE *I-BIS N1*

This diatom phase is represented (sample *6*) by a species-poor diatom flora (19 forms), 8 elements of which are considered in the diatom diagram (Text-fig. 3). The most abundant forms include *Fragilaria pinnata* (ca. 50%) of the assemblage) and *F. construens* var *venter* (ca. 24%), associated with *F. brevistriata* and *F.*

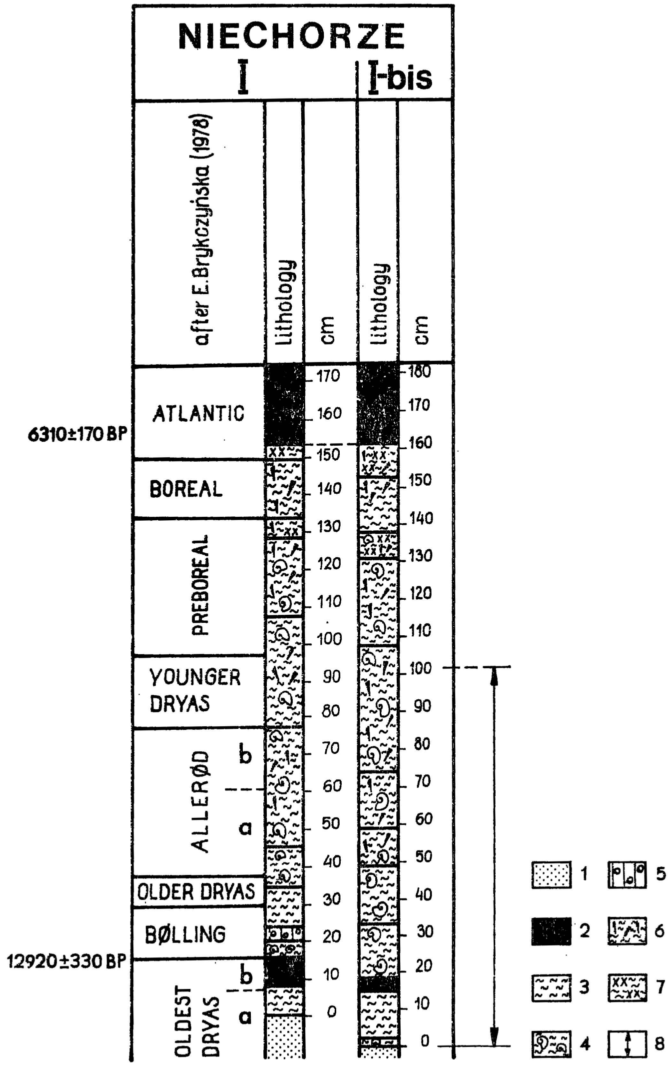


Fig. 2. Sections *I* (cf. Kopczyńska-Lamparska 1976, Text-fig. 3) and *I-bis* of the investigated lacustrine deposits at Niechorze

1 sands, 2 peat, 3 silts, 4 mollusk-bearing silts, 5 delluvial clay, 6 silts with plant debris, 7 peaty silts, 8 sequence sampled for diatoms

virescens; there are also minor amounts of *Synedra, Navicula, Cymbella, Achnanthes*, and others.

The diatom phase *I-bis N1* coincides with the maximum abundance of *Cyclotella antiqua* (0.8%o of the assemblage) which is indicative of Late-Glacial deposits (*e.g.* Hustedt 1948, Simonsen 1957). The occurrence of *C. antiqua* (halophobous, acidophilous, boreal-alpine form) points to severe climatic and trophic conditions. A slight increase in abundance of this species in Late-Glacial sections of Poland was observed in deposits equivalent to the Dryas periods (Kaczmarska 1973, Marciniak 1973) and the Phases *d* and *e* of the Eemian Interglacial (Marciniak & Kowalski 1978).

An increase in abundance of *Cyclotella antiqua* was recorded in the Younger Dryas (Repo & Tynni 1967, Robertsson 1973) and the Early Holocene (Florin 1977) in some sections in southern Sweden and Finland. In northern Scotland, Denmark, and Byelorussia this species rather frequently occurred also during the Allerød (Foged 1965, Khursevich 1976, Haworth 1976); while in northern GFR it is frequent throughout Late-Glacial sections (Simonsen 1957).

The species-poor diatom assemblage dominated by chiefly littoral forms of the genus *Fragilaria* with very few planktic forms of the genus *Cyclotella* (too few to be considered in the diatom diagram) is indicative of the basin having been shallow, presumably oligo-mesotrophic, with alkalic to circum-neutral water. The assemblage resembles fragmentarily preserved diatoms recorded in the lower part of the section Niechorze *I* (diatom phase *I N1*). The diatom phase *I N1* is time-equivalent to the Oldest Dryas (*cf.* Marciniak 1979) and hence, one may claim that this is also the time range of the diatom phase *I-bis N1*.

It is noteworthy that the species *Fragilaria pinnata* prevailed over its congeners at the earliest, initial stage of the basin Niechorze *I*. According to Haworth (1976), the species of *Fragilaria* are pioneer forms, as it is evidenced by their appearance at the initial stages of aquatic basins irrespective of their topography. This is indeed corroborated by the pattern of distribution of *Fragilaria* in several sections of Late-Glacial deposits (Haworth 1976), as well as in present-day basin; for instance, *Fragilaria pinnata* accounts for more than 90% of the diatoms assemblage recorded in the Post-Glacial freshwater sediments of the Klare Lake, Greenland (Foged 1972). This is also partly corroborated by diatom analyses of Late-Glacial deposits of northern Poland (Marciniak 1973, 1979) where *Fragilaria* spp. predominates throughout the section (Niechorze *I*, Niechorze *I-bis*, Niechorze *II*) or in the Dryas periods (Mikołajki Lake); as well as by research on the interglacial deposits of Nidzica where *Fragilaria construens* and *F. brevistriata* occur abundantly mainly in the early phases of the Eemian Interglacial (Marciniak & Kowalski 1978).

Nevertheless, a predominance of *Fragilaria* spp. commonly is related first of all to morphometric, bathymetric, and/or edaphic characteristics of lakes (*cf.* Crabtree 1971, Kaczmarska 1976). In Druzno Lake the genus *Fragilaria* was at its peak (up to 90% of the assemblage) during the Early Holocene when the area represented a peat bog; later on, the genus was associated with predominance of epiphytic diatoms indicative of the basin having been rather swampy (Przybyłowska-Lange 1976). The Late Holocene proliferation of *Fragilaria* spp. in Woryty lake also coincided with a considerable overgrowing of the basin (Marciniak 1979). According to Florin (1970), the changes in abundance of *Fragilaria* spp. (*F. construens, F. pinnata, F. brevistriata* varieties) recorded in the Late-Glacial deposits of Kirchner Marsh, Minnesota, were controlled mostly by a variation in hydrologic pattern and water chemistry.

One may conclude that the effects of climatic conditions and the associated hydrological and chemical parameters on diatom assemblages can hardly be estimated after cosmopolitan, eurythermic, eurytrophic, and eurytopic diatoms, while these are the most abundant diatom groups. To investigate climatic changes through time one has to analyse in detail the indicator taxa, while these diatoms occur very infrequently even within their present-day geographic ranges (Hustedt 1948). The indicator diatoms include arctic, subarctic, arctic-alpine, boreal-alpine, boreal, terrestrial, aerobiontic, aerophilous, and other groups of limited ecologic tolerance. Indicator diatoms occur fairly frequently *e.g.* in the Late-Glacial deposits of Druzno Lake (Przybyłowska-Lange 1976) and Kirchner Marsh (Florin 1970) where euterrestrial diatoms have been recorded, indicative of a xerotic biotope at the initial, pre-limnic stage.

The basin Niechorze *I* is of kettle hole origin, as it is the case also with the basin of Kirchner Marsh, but nonetheless terrestrial diatoms did never predominate at Niechorze. Aerobiontic and aerophilous diatoms, confined to aerial, extremely dry habitats (*e.g.* soil, xerotic mosses, dry lichens), are absent even from the earliest diatom phase. One may conclude that the basin of Niechorze developed under more humid conditions, probably because of an oceanic-climatic influence (Marciniak 1979). An increase in humidity may mitigate climatic stress because the action of climatic agents is considerably attenuated by aquatic environment, even under conditions of a shallow-water, ice-melting basin. Consequently, the habitat is more stable which permits a preponderance of limnophilous diatoms over xerophilous ones.

DIATOM PHASE *I-BIS N2*

This diatom phase (sample *11*) is characterized by a diatom assemblage resembling very closely in composition and structure (frequency of dominant and subdominant taxa) the assemblage recorded at the initial stage of the basin. The most abundant forms are *Fragilaria pinnata* and *F. construens* var. *venter* (see Text-fig. 3). The contribution of *Cyclotella antiqua* is a little decreased (down to 0.4%), while *C. comta* is somewhat more abundant (2.6%) than in the previous phase, and a few specimens of *C. distinguenda* do appear. This slight increase in proportion of planktic diatoms of the genus *Cyclotella*, which remain nevertheless too rare to be considered in the diatom diagram, seems suggestive of a climatic and environmental amelioration, as well as of a slight deepening of the basin. The two processes could more or less coincide, having been induced by the Bølling warming; this was indeed claimed for the diatom phase *I N2* of the section Niechorze *I* (Marciniak 1979).

It is noteworthy that no diatoms have been found in some samples representative of the considered diatom phase (those taken from the layer overlying the sample *11*, 20 cm in thickness), which made impossible tracing a boundary with the successive diatom phase. The deposits without any diatoms seem to be attributable to the Bølling and a part of the Older Dryas. They may be time-equivalent to the delluvial clay developed by soilflow in the section Niechorze *I* (Kopczyńska-Lamparska 1976), within deposits attributable after their palynologic characteristics mostly to the Bølling and contacting the Older Dryas (Brykczyńska 1978). Similar gaps in diatom distribution in Pre-Allerød deposits were observed *e.g.* in Geuallt section, northern Wales, in the pollen zones *Ia* and *Ic*, supposedly equivalent to the Dryas periods, and periodically in the pollen zone *Ib* (Crabtree 1971).

DIATOM PHASE *I-BIS N3*

This diatom phase is represented by a diatom assemblage (samples *18—19*) dominated by *Fragilaria pinnata* (less abundant than in the previous phases), *F. brevistriata* (more abundant than previously), and *F. construens* var. *venter* (as frequent as previously). The forms *Amphora ovalis* var. *libyca* and *Fragilaria construens* var. *binodis* also considerably contribute to the assemblage. The latter form first appears in this diatom phase, which is also the case with several other diatoms (various species of the genera *Navicula, Synedra, Pinnularia, Achnanthes, Caloneis, Cocconeis, Nitzschia,* and others). These are mostly cosmopolitan forms, eurytopic, widely distributed in the littoral zone of highly variable aquatic basins, most commonly benthic or epiphytic, only sporadically belonging to the plankton.

The observed predominance of *Fragilaria,* decrease in frequency of planktic diatoms of the genus *Cyclotella,* and rapid appearance of benthic and/or epiphytic forms are entirely consistent with the pattern recorded in the section Niechorze *I* in the diatom phase *I N3* equivalent to the Older Dryas (Marciniak 1979). The recorded changes in diatom assemblage relative to the preceding diatom phase are suggestive of a slight shallowing of the basin, as well as of a detorioration of climatic and trophic conditions caused by a cooling.

As pointed out by Haworth (1976), a low nutrient supply during the Late-Glacial cool period presumably induced development of ecosystems close to present-day arctic or alpine lakes characterized by a low sedimentation rate, low algal (mostly nannoplanktic) productivity, and diatom flora being restricted to well lit, mainly benthic microhabitats.

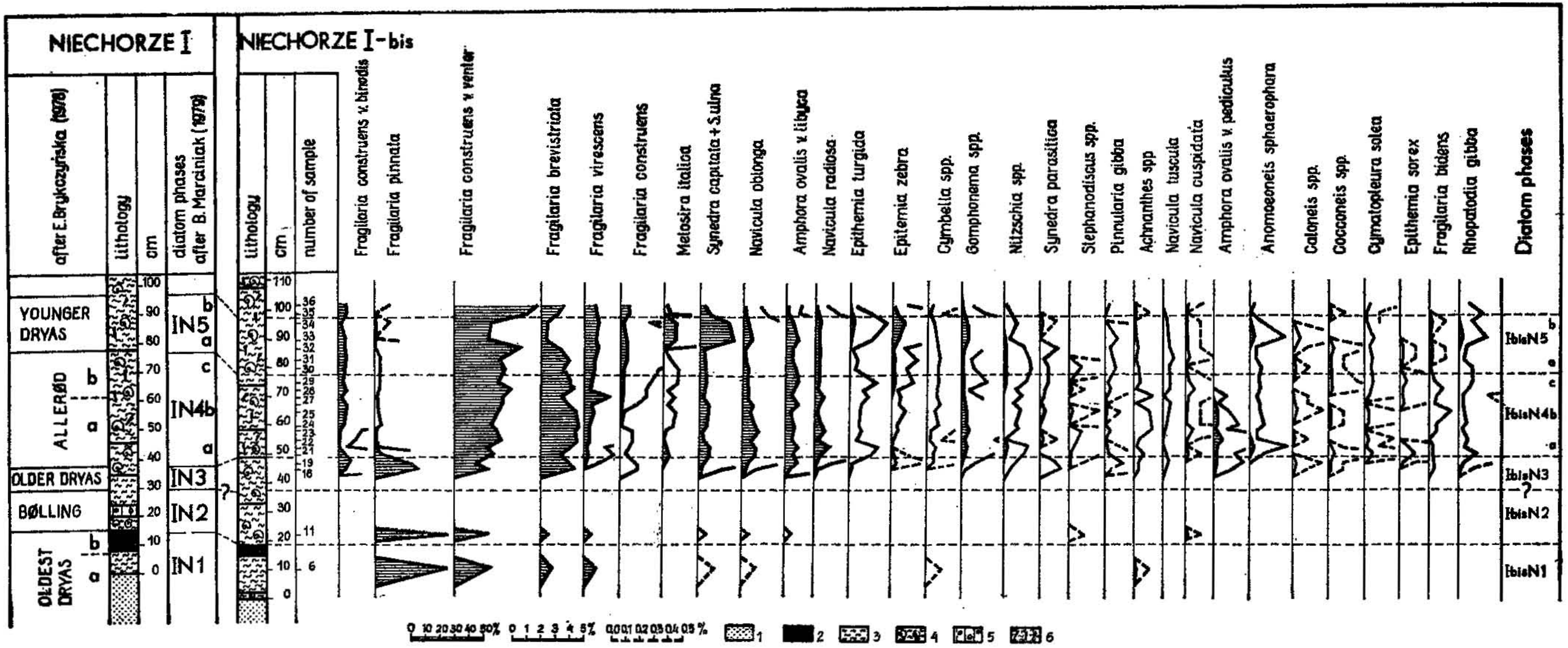
DIATOM PHASE *I-BIS N4*

This diatom phase can be subdivided into three subphases. The earliest one, the diatom subphase *I-bis N4a,* is distinctive in large contributions of *Fragilaria construens* var. *venter* and *F. brevistriata* to the diatom assemblage, as well as in an increase in abundance of various species of *Navicula, Synedra, Amphora, Gomphonema, Epithemia, Rhopalodia, Nitzschia,* and other genera that first appeared in the preceding diatom phase, and a considerable decrease in abundance of *Fragilaria pinnata* and *F. construens* var. *binodis.* The beginning of the subphase, and by implication of the whole phase, is marked also by the appearance of *Cyclotella meneghiniana,* a freshwater to oligohalobous (halophilous), cosmopolitan form, widely distributed especially in the littoral zone of variable aquatic basins (*cf.* Siemińska 1964). In the investigated section this species is probably represented by *C. meneghiniana* var. *laevissima* (van Goor) Hust. reported previously exclusively from the Netherlands, northern GFR, and coastal lakes near Helsinki in Finland (Mölder & Tynni 1968).

The successive diatom subphase, the subphase *I-bis N4b,* is characterized by a diatom assemblage with dominant forms being the same as in the preceding subphase, viz. *Fragilaria construens* var. *venter, F. brevistriata,* and several other littoral species, mostly epiphytic or benthic, confined to more or less stagnant, alkaline waters. In turn, the proportion of oligohalobous (halophilous) diatoms is decreased and the species *Cyclotella meneghiniana* is absent.

At the final subphase, the diatom subphase *I-bis N4c,* the proportions of *Fragilaria construens* var. *venter* and *F. virescens* are increased, while the contribution of *F. brevistriata* to the assemblage is slightly decreased (*see* Text-fig. 3). There is also a further increase in abundance of various epiphytic and/or

Diatom diagram of the section Niechorze *I-bis*



1 sands, *2* peat, *3* silts, *4* mollusk-bearing silts, *5* delluvial clay, *6* silts with plant debris benthic aquatic diatoms, especially those adapted to the littoral zone of meso--eutrophic (nutrient-rich) basins with alkaline water. The diatom assemblage is thus indicative of a further overgrowing of the basin with plants induced probably by its shallowing or an expansion of the littoral zone.

A similar succession of diatom assemblages has been recorded in the section Niechorze *I* in the diatom phase *I N4* equivalent to the Allerød subdivisible into three subphases (Marciniak 1979). There is a considerable increase in abundance of *Cyclotella meneghiniana* var. *?laevissima* at the beginning of the phase *I N4*, indicative of a increase in water salinity. One may, however, hardly argee with Kopczyńska-Lamparska (1976) that this increase in water salinity during the Early Allerød was due to an influence by the Late-Glacial Yoldia sea of Baltic area. A considerable abundance of halophilous or even mesohalobous diatoms, found commonly in brackish nearshore marine environments and saline lakes, may or may not be indicative of marine influences.

As demonstrated by diatomological analyses of Late-Glacial deposits, an increase in water salinity may be due to evaporation under increased climatic aridity. This is evidenced by the flourishment of halophilous diatom species in lakes during warm and cool Late-Glacial periods, as well (Kaczmarska 1973, Khursevich 1976). One may also recall some other examples to show considerable amounts of halophilous to mesohalobous diatoms in freshwater sediments of Allerød age; for instance, large amounts of *Mastogloia elliptica* var. *dansei* (ca. 25%) of the assemblage) were recorded in Denmark (Foged 1965), and a considerable proportion of *Anomoeoneis sphaerophora* var. *sculpta* (12%) at Skurup in Sweden (Robertsson 1976). These cases make the evidence for an increase in water salinity during the Allerød, due mainly to changes in hydrological characteristics of the basins. In contrast, sporadic occurrences of mesohalobous diatoms in Late-Glacial freshwater basins may well be explained *e.g.* by their input by birds (*cf.* Simonsen 1957).

DIATOM PHASE *I-BIS N5*

The last diatom phase can be subdivided into two subphases, the earlier of which, the subphase *I-bis N5a*, is characterized by a further increase in abundance of *Fragilaria construens* var. *venter* and a considerable proportion of *F. brevistriata*. The frequency of the latter two forms is considerably decreased in the succeeding subphase, the diatom subphase *I-bis N5b*, while the species *Synedra ulna*, *S. capitata*, and *Melosira italica* attain their peak abundance. These changes in diatom assemblage indicate that the shallowing of the basin persistent up to the diatom subphase *I-bis N5a* was inhibited during the subphase *I-bis N5b* when a slight deepening of the basin and an expansion of the littoral zone took place. Similar changes in diatom assemblages were recorded in the upper part of the section Niechorze *I*, in the diatom phase *I N5* equivalent to the Younger Dryas (Marciniak 1979).

The uppermost two samples (Nos *35—36*) collected above the diatom phase *I-bis N5* (Text-fig. 3) show again an increase in frequency of *Fragilaria construens* var. *venter* and a decrease in abundance of *Synedra ulna*, *S. capitata*, and *Melosira italica*. This indicates that the two samples probably belong to the overlying diatom phase possibly attributable to the beginning of the Holocene. In fact, a similar diatom assemblage was recorded in the section Niechorze *I* in the diatom subphase *I N6a*, the lowermost one attributable to the Preboreal period (Marciniak 1979).

Further environmental changes induced by the temperature increase and aridization, reflected in pollen diagrams for the decline of the Preboreal period (Brykczyńska 1978), probably resulted in a rapid shallowing of the basin which eventually became transformed into a peat bog. In fact, diatoms only sporadically occur in deposits time equivalent to the Boreal period in the section Niechorze *I*.

DISCUSSION

The section Niechorze *I-bis* resembles the section Niechorze *I* (Marciniak 1979) in a great abundance of littoral diatoms predominated by *Fragilaria* spp., this characteristic being indicative of a small size and shallow-water nature of the basin.

The genus *Fragilaria* is dominant in the diatom assemblages representative of all the five developmental stages of the investigated basin. The stages are equivalent each to a successive diatom phase (*I-bis N1* to *I-bis N5*); the phases are, in turn, correlatable with diatom phases recognized in the standard section Niechorze *I* (Marciniak 1979) which can be referred each to one of the successive Late-Glacial periods: the Oldest Dryas, Bølling, Older Dryas, Allerød, and Younger Dryas.

The slight increase in frequency of planktic diatoms observed in the diatom phases *I-bis N2*, *I-bis N4*, and *I-bis N5* is indicative of a deepening of the basin during the Bølling, Allerød, and Younger Dryas.

The diatom assemblages representative of the diatom phases *I-bis N1* and *I-bis N2*, in the lower part of the section Niechorze *I-bis*, are species-poor and dominated by *Fragilaria pinnata* (50% of the assemblage). In the diatom phase *I-bis N3* the latter species is associated with large amounts of *F. brevistriata* and *F. construens* var. *venter*. The latter two species are dominant also in the diatom phase *I-bis N4* when the frequency of *F. pinnata* is considerably decreased; they are associated with several diatom genera (*Synedra, Navicula, Amphora, Gomphonema, Epithemia, Achnanthes, Cymbella,* and others) absent from the underlying diatom phases. The contribution of *Fragilaria* to the diatom assemblages is decreased only towards the end of the diatom phase *I-bis N5,* when the species *Synedra ulna, S. capitata,* and *Melosira italica* are increased in abundance.

Most of the Late-Glacial diatoms from Niechorze are very common forms, cosmopolitan, eurythermic, and eurytopic. At present, these forms most commonly occur in more or less stagnant waters, first of all in eutrophic lakes.

When compared to the diatom floras from previously investigated Late-Glacial deposits from the Mazury Lakeland in northern Poland (*cf.* Marciniak 1973, 1979; Przybyłowska-Lange 1976), the considered diatom assemblages from the basin Niechorze *I* show much less variation in composition over the successive periods of climatic deterioration and amelioration. This may be due to morphometric and typologic peculiarities of the basin, induced by its origin, geological situation, and various physical-chemical factors, as well as to oceanic-climatic influences responsible for a partial attenuation of climatic severity in the western Pomerania. Nevertheless, climatic oscillations must have been strongly accentuated just after the deglaciation in this area. This is indicated by a variability in diatom distribution in the Late-Glacial deposits, permitting recognition of two main developmental stages of the basin Niechorze *I*.

Considerable environmental oscillations at the early stage of the basin development (diatom phases *I-bis N1*, *I-bis N2*, and the lower part of diatom phase *I-bis N3*) are reflected by species-poor diatom assemblages preserved only in single samples, as it is the case also with the Geuallt section in northern Wales (*cf.* Crabtree 1971). The absence of diatoms from some parts of the section equivalent to the Oldest Dryas, Bølling, and early Older Dryas resulted probably from a disturbance in sedimentation pattern, as well as from rapid hydrologic and climatic changes which could considerably affect this small aquatic basin. Under conditions of unstable shore and discontinuous vegetational cover of the adjacent land, especially during Dryas periods when tundra biota were developing in that area (*cf.* Brykczyńska 1978), diatoms could proliferate only periodically because the basin appears to have been astatic in nature. Furthermore, the sedimentation rate was very low, as it is typical of present-day arctic and alpine lakes. The successive main developmental stage of the basin Niechorze *I* started at the decline of the Older Dryas. It is characterized by a continuous accumulation of diatom assemblages persistent throughout the Allerød and Younger Dryas and up to the Preboreal period.

The diatomological analysis of the sections Niechorze *I* and *I-bis* demonstrates the potential of fossil diatoms for use in paleoecological reconstruction of a basin, recognition of sedimentary conditions, and stratigraphic correlation of Late-Glacial organogenic deposits, the latter being especially profitable where any other biostratigraphic method cannot be successfully applied.

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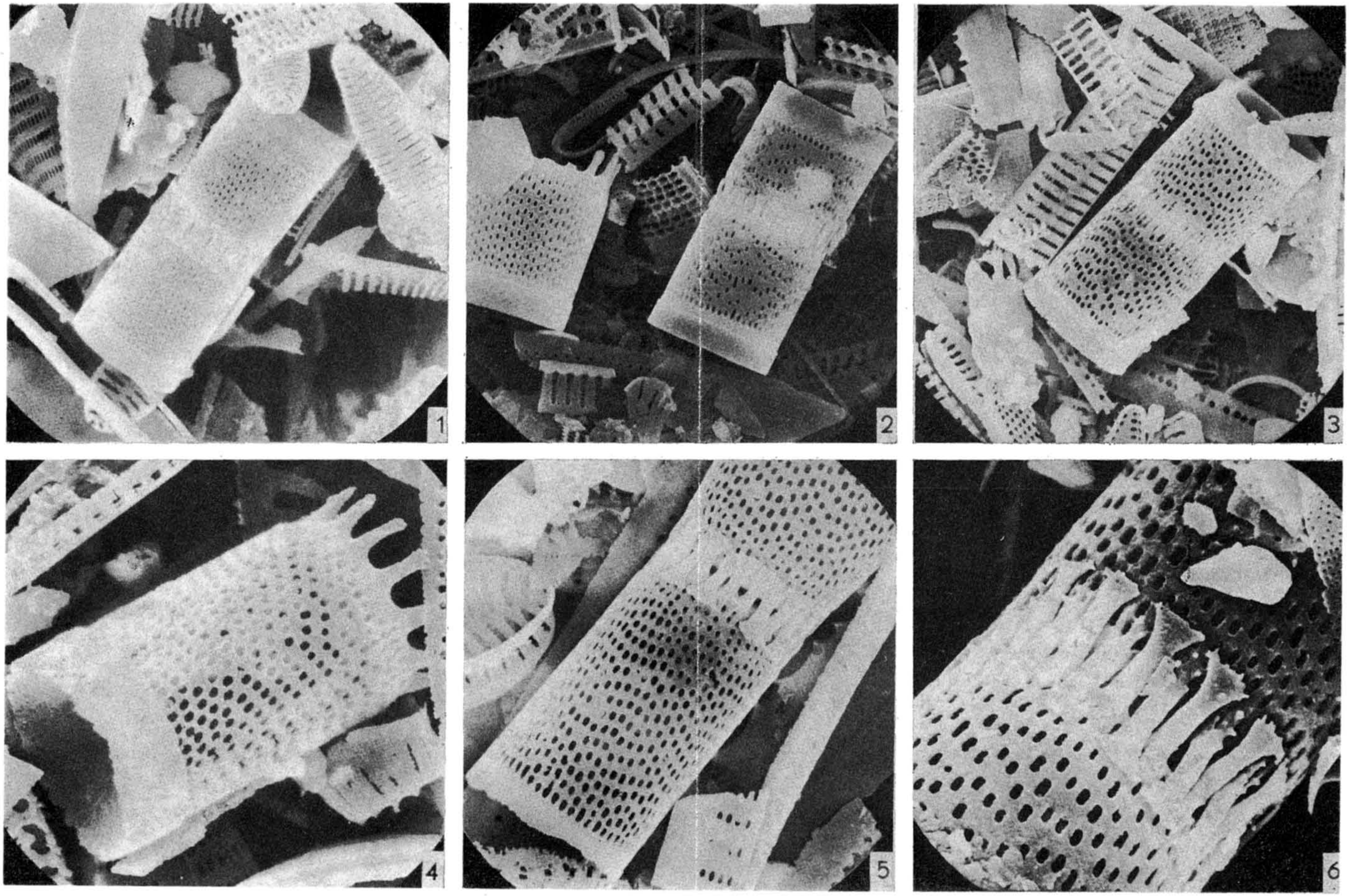
B. MARCINIAK

PÓŹNOGLACJALNE DIATOMOFAZY W PROFILU NIECHORZA NA POMORZU ZACHODNIM

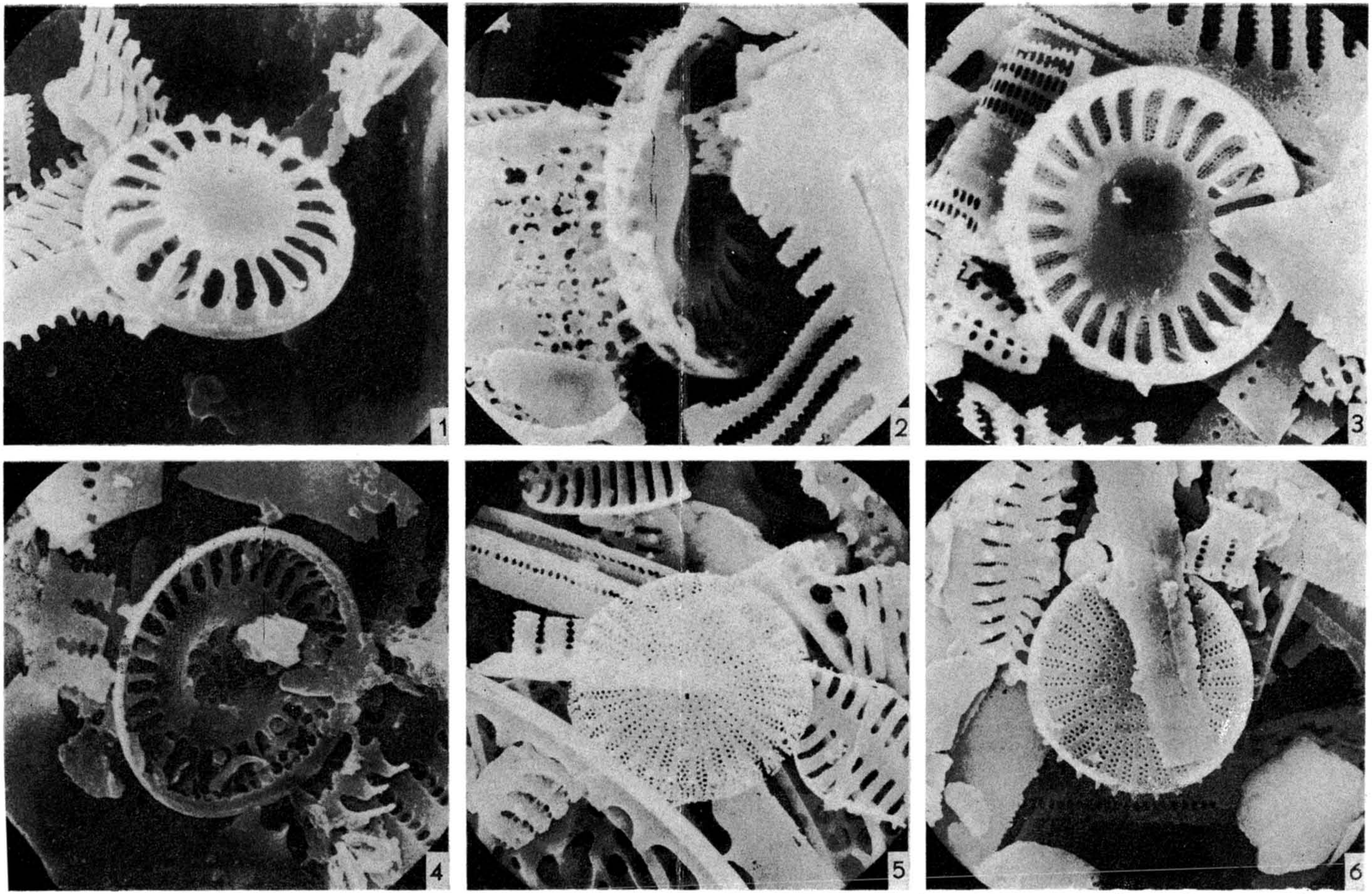
(Streszczenie)

Przedmiotem pracy jest analiza okrzemek z późnoglacjalnych osadów limnicznych odsłoniętych w klifie koło Niechorza (fig. 1—2). Na podstawie sukcesji okrzemek z dwóch profilów (Niechorze *I* oraz *I-bis*) przedstawionej w pięciu diatomofazach wyróżniono dwa główne stadia rozwoju zbiornika (fig. 3). Pierwsze stadium (Najstarszy Dryas, Bølling i początek Starszego Dryasu) charakteryzuje się nieciągłym występowaniem okrzemek spowodowanym zaburzeniami sedymentacji oraz słabo zachowanymi, ubogimi w gatunki zespołami okrzemek, wśród których przeważa *Fragilaria pinnata.* W drugim stadium (schyłek Starszego Dryasu, Allerød i Młodszy Dryas) okrzemki są bardzo liczne, a ich występowanie jest ciągłe i niezaburzone, co świadczy o ustabilizowanych warunkach sedymentacji. W stadium tym początkowo dominują *Fragilaria construens* var. *venter* i *F. brevistriata,* a pod koniec Młodszego Dryasu wzrasta udział *Synedra* spp. i *Melosira italica.*

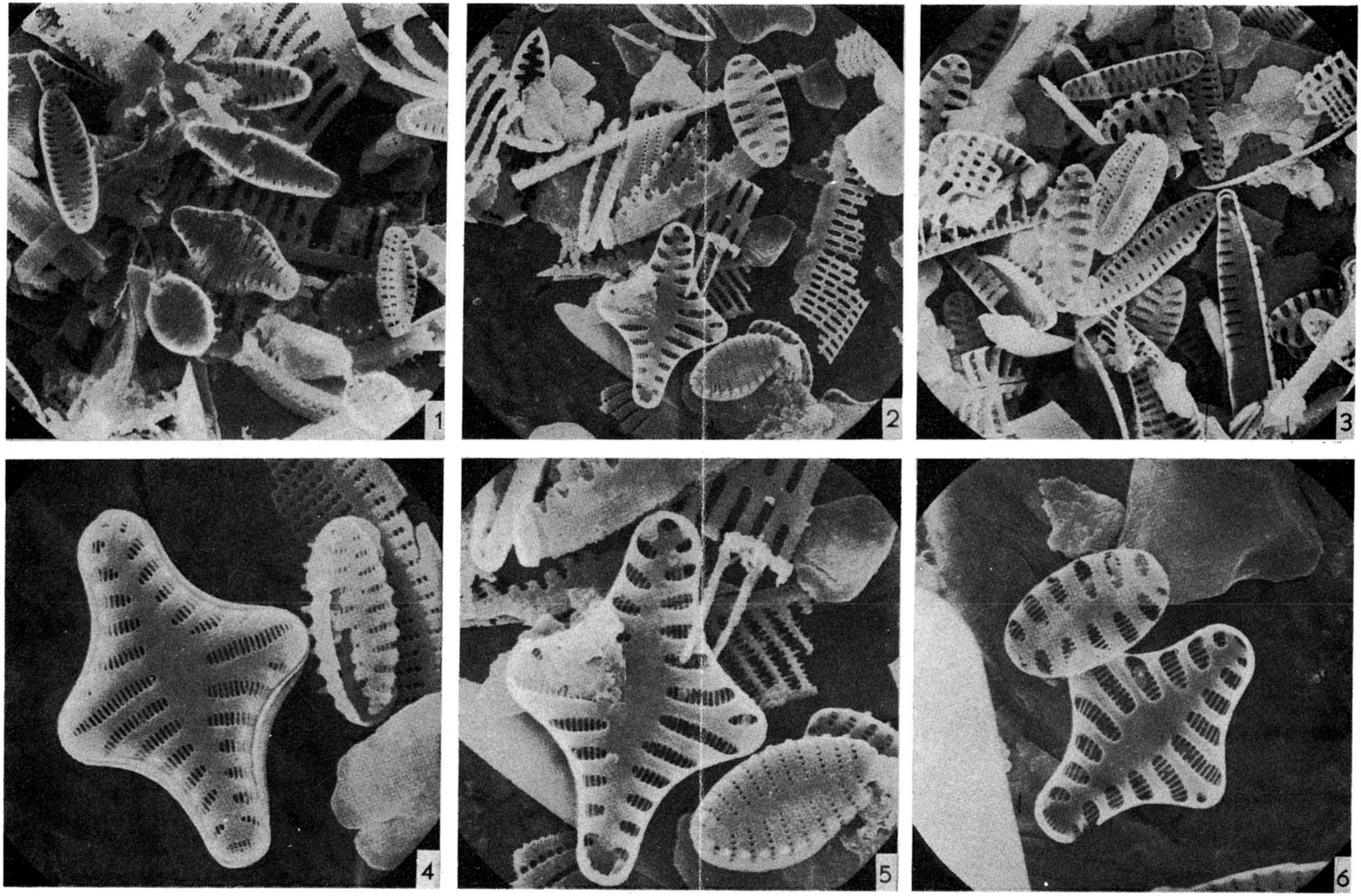
Większość rozpoznanych okrzemek (138 taksonów) to formy bardzo pospolite (patrz pl. 1—10), o dużych zdolnościach adaptacyjnych, kosmopolityczne i eurytermiczne, oraz często występujące w rozmaitych zbiornikach o różnych typach wód. W środowiskach dzisiejszych formy te są najczęściej spotykane w wodach stojących i wolno-płynących, o odczynie zasadowym, głównie w zbiornikach o charakterze eutroficznym.



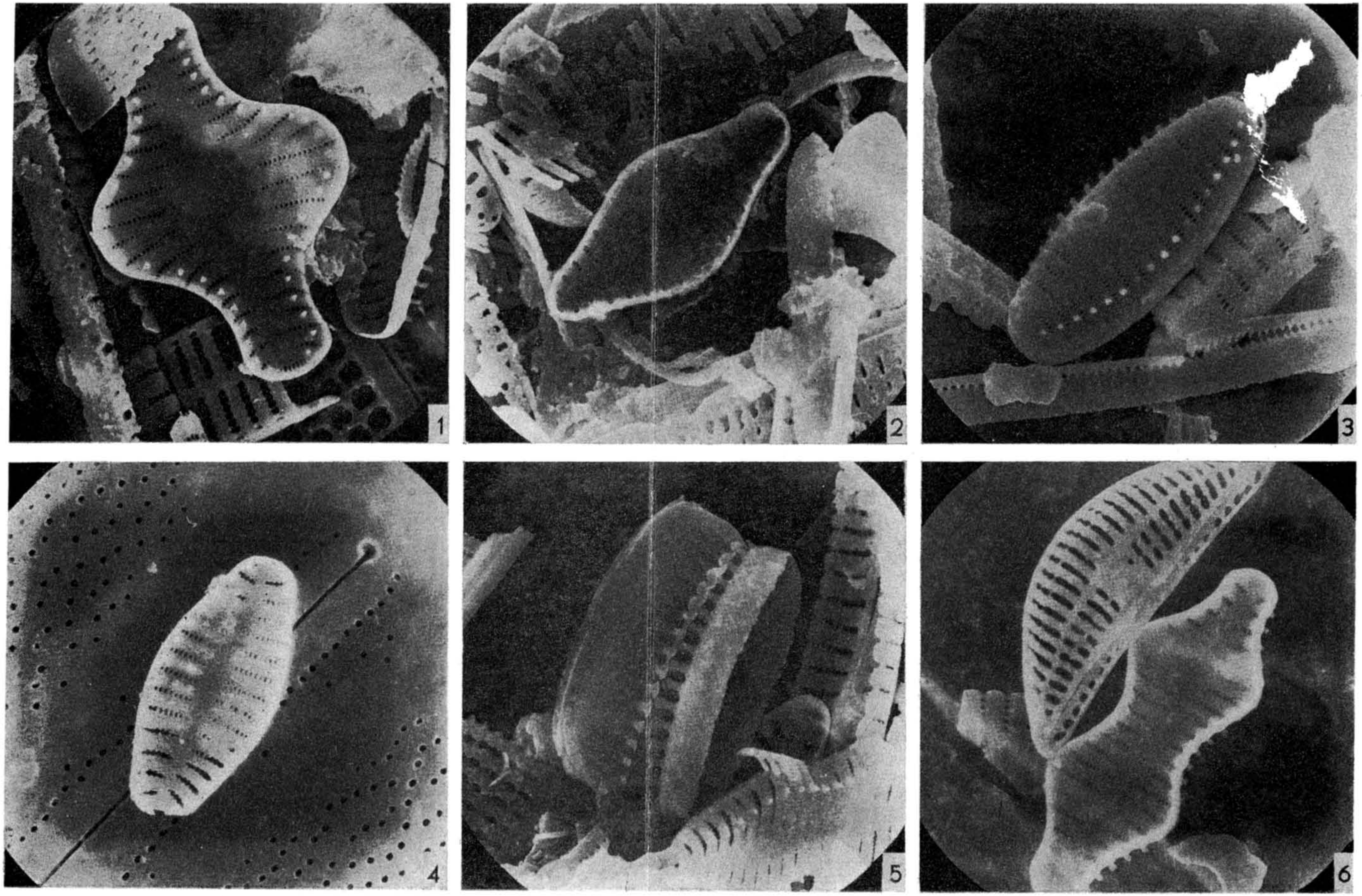
— *Melosira italica* (Ehr.) Kütz.: Figs *1—3* taken ×3000, Figs *4—5* ×6000, and Fig. *6* ×10000



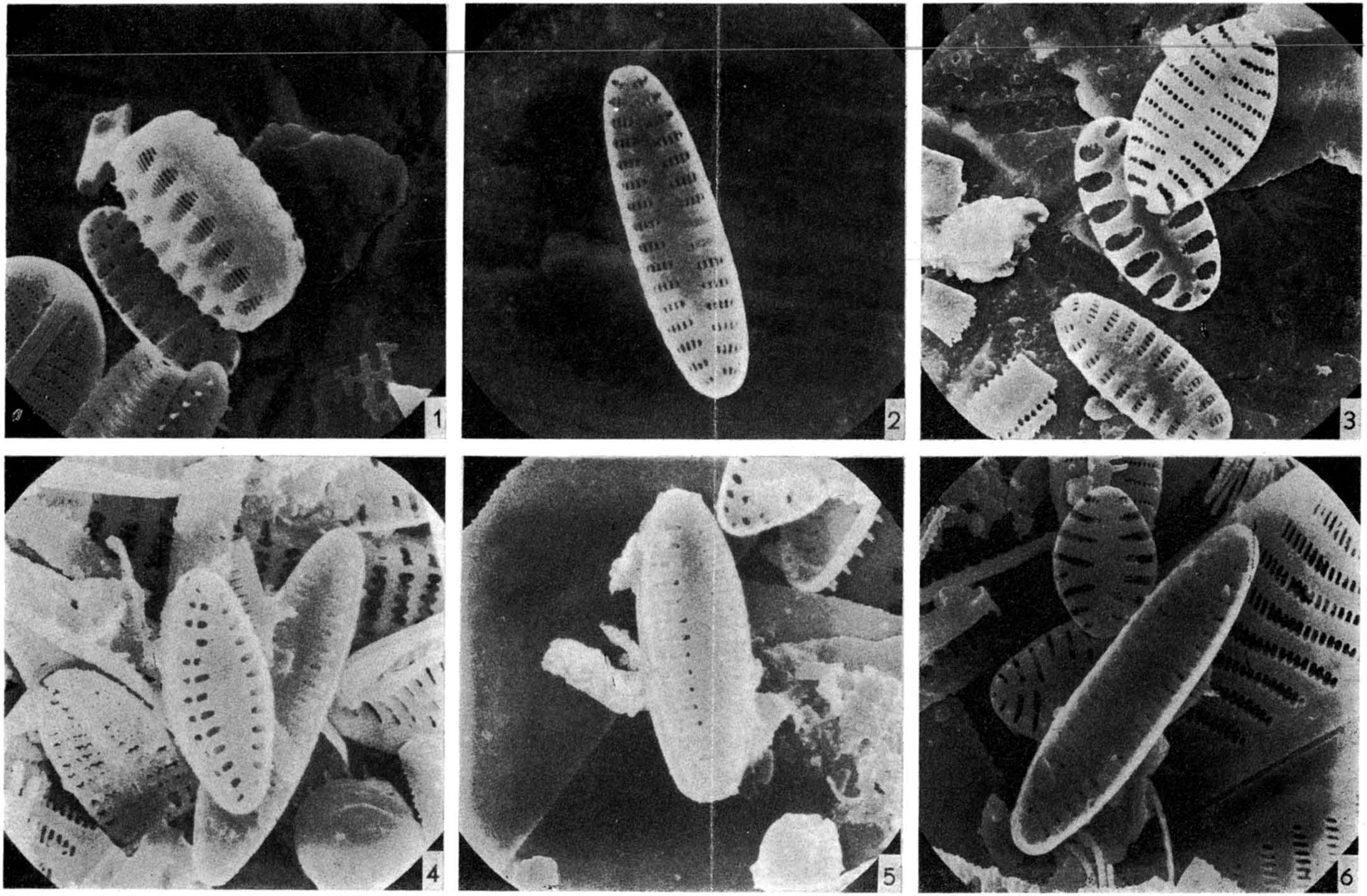
1—3 — *Cyclotella meneghiniana* var. *?laevissima* (van Goor) Hust., ×6000; 4 — *Cyclotella* cf. *stelligera* Cl. & Grun., ×10000; 5—6 — *Stephanodiscus nantzschii* Grun., ×6000



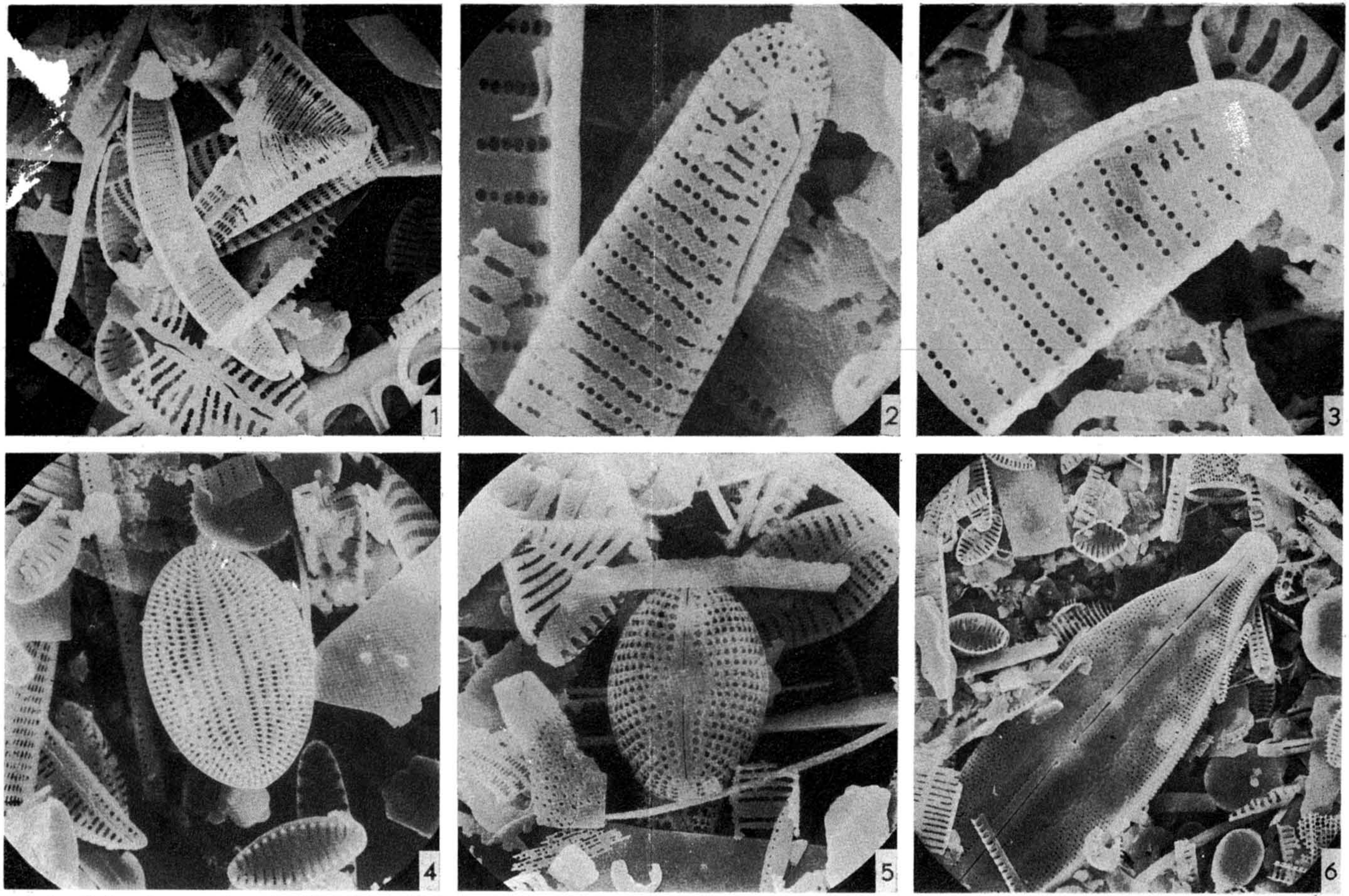
1—3 — *Fragilaria* spp., ×3000; **4—6** — *Fragilaria leptostauron* (Ehr.) Hust., ×6000



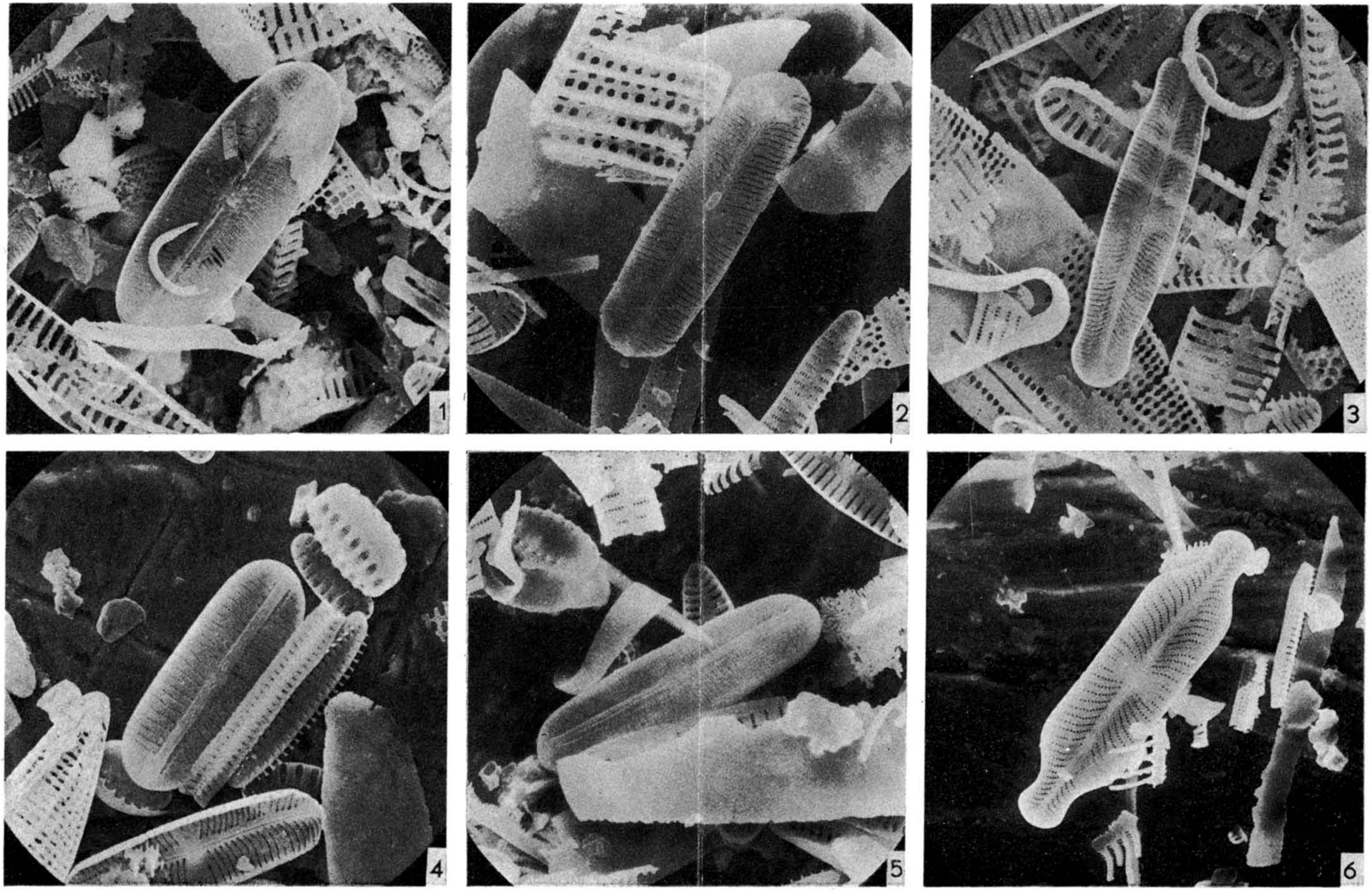
1 — *Fragilaria construens* (Ehr.) Grun., ×6000; **2—5** — *Fragilaria construens* var. *venter* (Ehr.) Grun., ×6000; **6** — *Fragilaria construens* var. *binodis* (Ehr.) Grun., ×6000



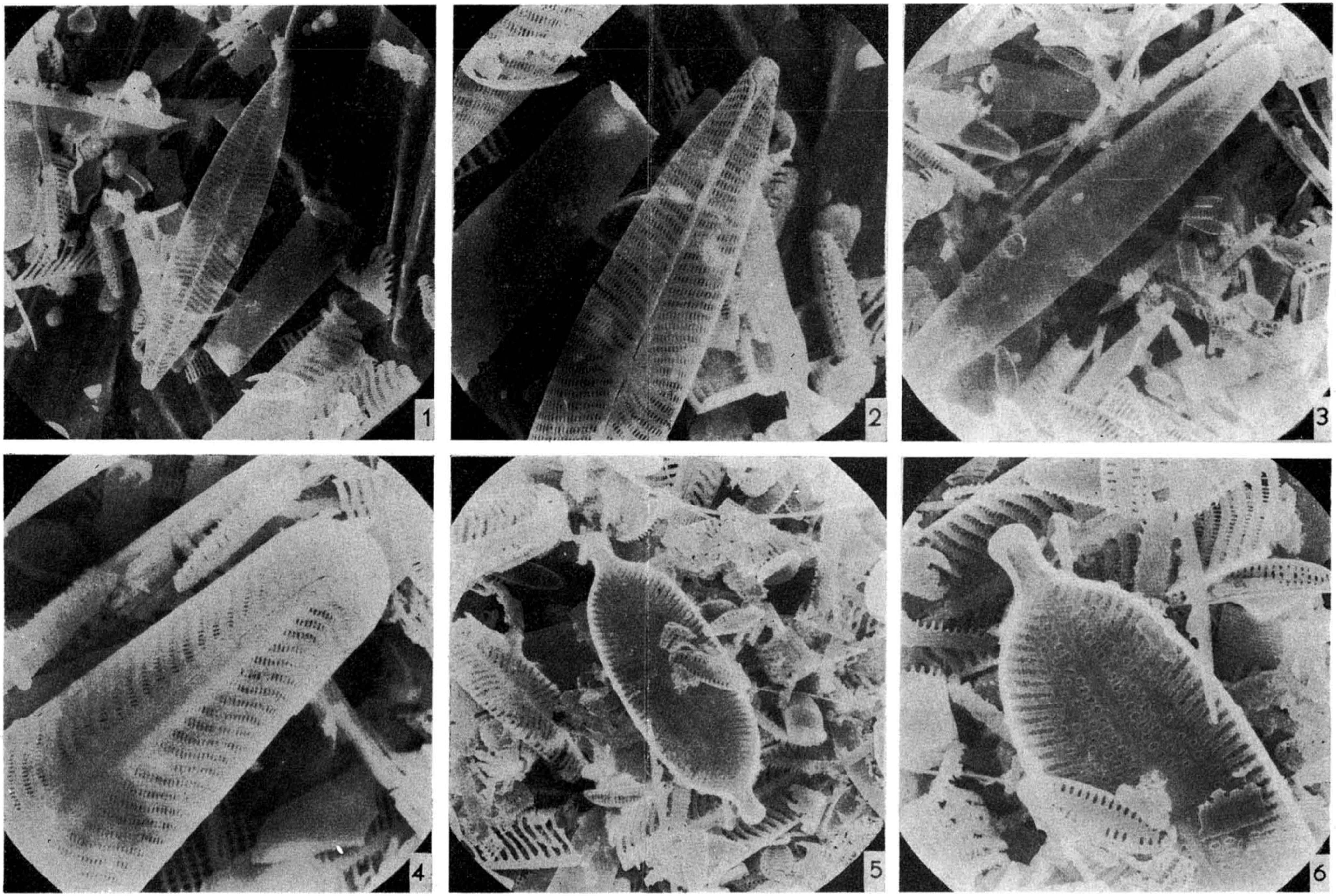
1—3 — *Fragilaria pinnata* Ehr., ×6000; **4—6** — *Fragilaria brevistriata* Grun., ×6000



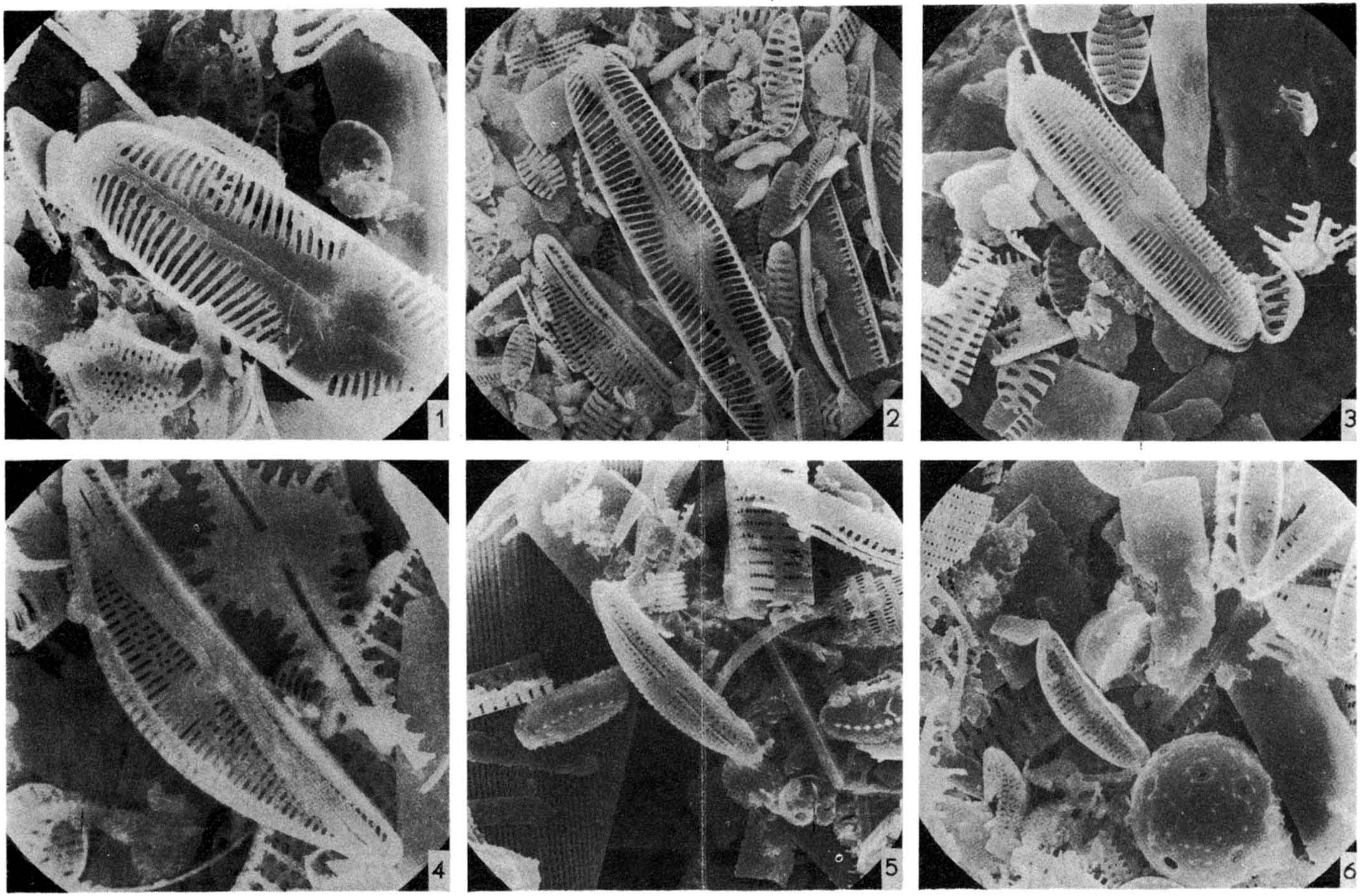
1 — *Eunotia lunaris* var. *subarcuata* (Näg.) Grun., ×3000; **2—3** — *Eunotia lunaris* (Ehr.) Grun., ×10000; **4** — *Cocceneis placentula* var. *lineata* (Ehr.) Cl., ×3000; **5** — *Diploneis elliptica* (Kütz.) Cl., ×3000; **6** — *Anomoeoneis sphaerophora* (Kütz.) Pfitz., ×1500



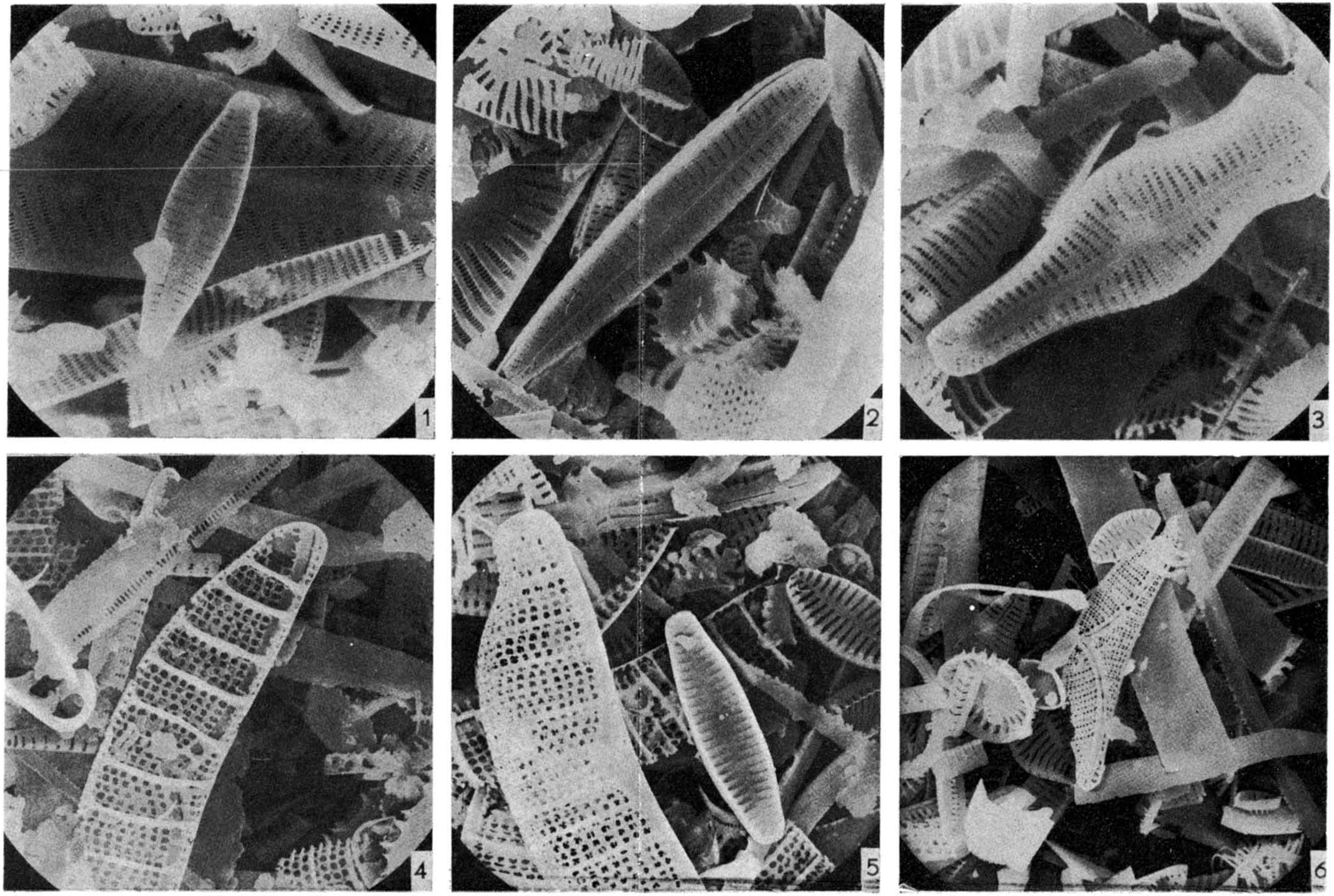
1 — *Navicula bacillum* Ehr., ×3000; **2** — *Navicula pupula* var. *rectangularis* (Greg.) Grun., ×3000; **3** — *Navicula pupula* var. *capitata* Hust., ×3000; **4—5** — *Navicula bacilliformis* Grun., ×3000; **6** — *Navicula abiskoensis* Hust., ×2000



1—2 — *Navicula radiosa* Kütz.: Fig. *1* taken ×1500, Fig. *2* ×3000; **3—4** — *Navicula oblonga* Kütz.: Fig. *3* taken ×1000, Fig. *4* ×3000; **5—6** — *Navicula tuscula* (Ehr.) Grun.: Fig. *5* taken ×1500, Fig. 6 ×3000



1 — *Pinnularia microstauron* (Ehr.) Cl., ×3000; **2** — *Pinnularia viridis* var. *sudetica* (Hilse) Hust., ×2000; **3** — *Caloneis bacillum* (Grun.) Mer., ×3000; **4** — *Amphora ovalis* var. *libyca* (Ehr.) Cl., ×3000; **5—6** — *Amphora ovalis* var. *?pediculus* Kütz., ×3000



1 — *Gomphonema parvulum* (Kütz.) Grun., ×3000; **2** — *Gomphonema intricatum* Kütz., ×3000; **3** — *Gomphonema constrictum* Ehr., ×3000; **4** — *Epithemia zebra* var. *saxonica* (Kütz.) Grun., ×3000; **5** — *Epithemia zebra* var. *porcellus* (Kütz.) Grun., ×3000; **6** — *Epithemia sorex* Kütz., ×2000