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TWO DIATOM HORIZONS IN THE OLIGOCENE AND (?) LOWER MIOCENE OF THE POLISH OUTER CARPATHIANS

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Abstract: Two older of the three diatom-rich horizons in the Menilite–Krosno series of the Skole nappe, and their diatoms, are described. Futoma horizon occurs in lower part of Menilite Beds. It consists mostly of laminated diatomites and diatomaceous shales. It is more than 10 m thick in some small areas (SSE of Rzeszów, W and E of Przemyśl) and very thin or absent in between. It was accumulated in local depressions of the basin slope, during a period of basin shallowing. The diatom assemblage is almost autochtonous, slightly redistributed by bottom currents, carrying also some freshwater diatoms. It is neritic-sublittoral, indicative of an Early Oligocene age. Piątkowa horizon occurs at the transition between Menilite and Krosno Beds, in the Niebylec shales. It consists of many thin, laterally discontinuous turbidite shales with diatoms, dispersed within few tens of metres (or less) of the host strata. Diatom assemblage is allochtonous, neritic-sublittoral interpreted as latest Oligocene-earliest Miocene in age.

Key words: diatoms, diatomites, laminated diatomites, black shales, stratigraphy, taxa descriptions, bottom currents, turbidity currents, Oligocene, Lower Miocene, Northern Carpathians, Poland.

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INTRODUCTION

Diatom-rich rocks occur at several horizons in Tertiary deposits of the Skole nappe, the external tectonic and facies unit of the Polish Outer Carpathians (Kotlarczyk, 1958, 1966, 1982; Żgiet, 1961, 1963; Jerzmańska & Jucha, 1963). They occur mainly in the youngest Oligocene–Lower Miocene, part of the Skole nappe sequence (distinguished informally as the Menilite–Krosno series) at three main horizons: (i) Futoma horizon in the lower part of the Menilite Beds, (ii) Piątkowa horizon at the transition between the Menilite and Krosno Beds, mainly in the Niebylec shales, and (iii) Leszczawka horizon in the top part of the Krosno Beds (Fig. 1).

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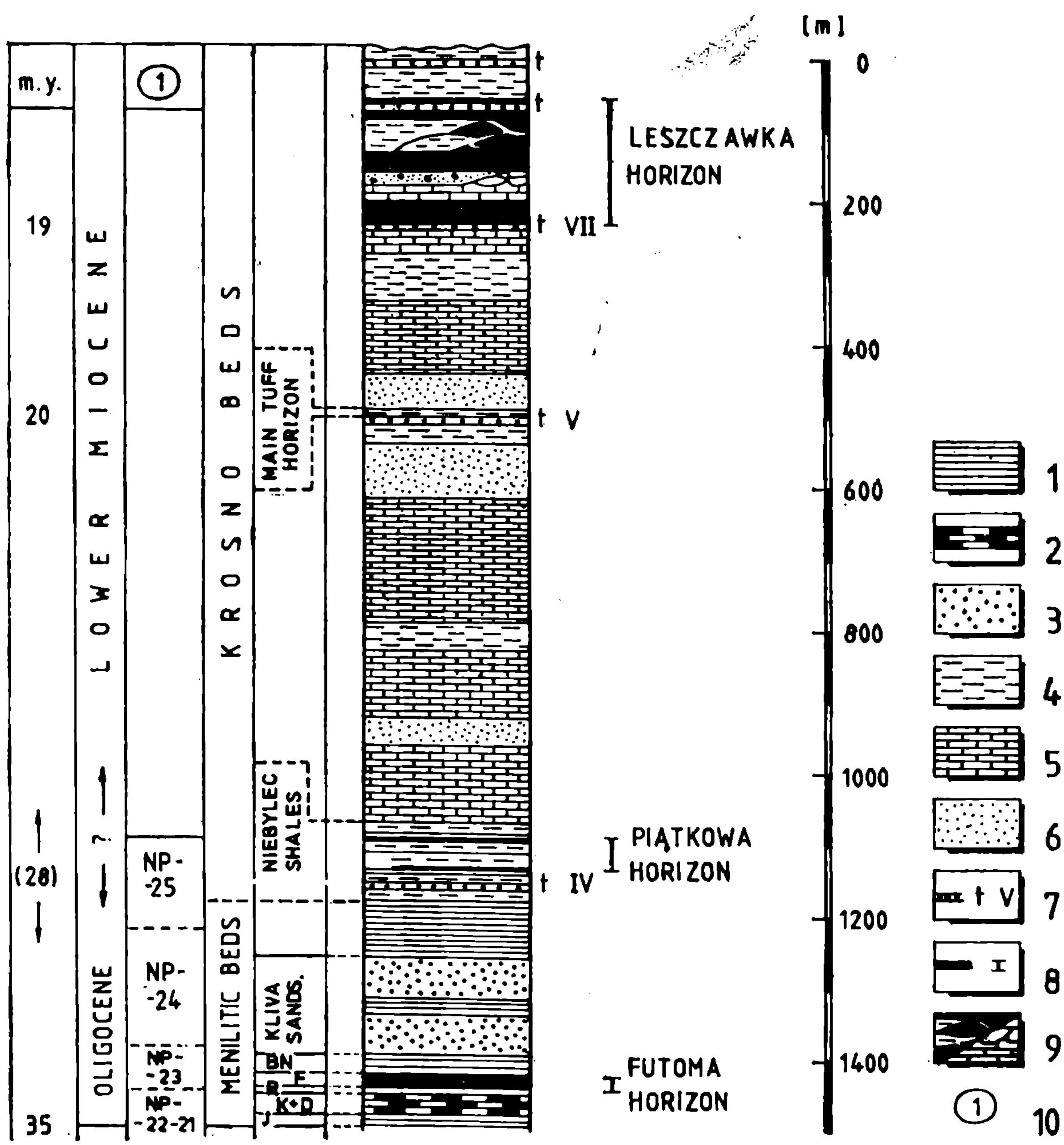

Fig. 1. Stratigraphical position of diatom horizons in area of Błażowa and Bircza (after Kotlarczyk, 1985, slightly modified). *1* — brown clayey-siliceous shales (*J* — unit 1, Jamma member; *BN* — unit 6, Borek Nowy member), partly with thin intercalations of sandstones (*R* — unit 4, Rudawka member); *2* — cherts (*K* — unit 2, Kotów member) and siliceous marls (*D* — unit 3, Dynów member); *3* — thick bedded quartzarenites; *4* — grey marly shales; *5* — normal flysch; *6* — thick bedded calcareous sandstones; *7* — tuff horizons (numbers after Sikora *et al.*, 1959); *8* — diatom horizons and their stratigraphical extents; *9* — olisthostromes; 10 — nannoplankton zones

Two types of diatom-rich rocks are distinguished: diatomites (> 40 volume per cent of diatom frustules and/or their fragments) and diatomaceous shales (< 40%). Some diatom frustules and poor diatom assemblage were occasionally found in black, bituminous, argillaceous-siliceous shales, the distinctive lithology of the Menilite Beds.

Other microfossils (foraminifers and nannoplankton) are very rare in the Menilite Beds, so that precise biostratigraphic correlation or zonation of these strata is impossible. Diatoms have been successfully used for biostratigraphical purposes in many sequences (Barron, 1975; Dzinoridze *et al.*, 1976; Hajos, 1976; Makarova & Kozyrenko, 1966; Proshkina-Lavrenko *et al.*, 1974; Sawamura & Yamaguchi, 1963; Schrader & Fenner, 1976), including the shales of the Maikop series of the Caucasus (Sheshukova-Poretskaya & Gleser, 1962), very similar to the Menilite shales. The occurrence of diatoms has been considered potentially useful for the biostratigraphy of the Menilite-Krosno series in the Skole nappe.

This paper presents the descriptions of the Futoma and Piątkowa horizons and their diatom assemblages. Diatom taxa were determined by I. Kaczmarska.

The stratigraphical use of diatoms must be based on well defined assemblages rather than on individual taxa. For this reason the interpretation of the age and environmental conditions of deposition of the diatom-rich horizons are based on abundant taxa, i.e. those occurring in greatest numbers.

SAMPLING

The diatom-rich rocks are very similar to the argillaceous-siliceous shales typical of the Menilite Beds and for this reason it is difficult to identify them in the field. The consistent position of the diatom-rich rocks in the lithological succession helped to locate them in the outcrops.

Detailed sampling was done in all sections where diatom-rich rocks were observed macroscopically, or where their presence was expected from the position in the lithological succession. Samples for maceration and sometimes also for thin sections, were taken from all layers of shales similar to the diatom-rich shales. In the Piątkowa horizon all layers of black (or dark) shales were sampled. In total 259 samples were taken from both horizons.

They were all disintegrated and placed in water-glycerine suspension. The presence of diatom frustules and their fragments was checked under a microscope. In the Futoma horizon 69 preparations, out of 117, included diatoms. For the Piątkowa horizon, this proportions is 52 of 142. The Piątkowa horizon was found in 11 sections of the 24 investigated.

Water-glycerine preparations and thin sections were used to determine the vertical extents of the diatomite horizons in each section (see Figs 3, 5). Permanent slides for detailed investigations were made of 29 samples with diatoms; 12 from the Futoma and 17 from the Piątkowa horizon.

LABORATORY TREATMENT

The studied rocks were strongly lithified and contaminated, so that satisfactory slides could not be obtained by the use of standard methods. Special methods had to be applied and these are described below.

For the soft diatomites and diatom-bearing shales a combination of the methods described by Jouse (1966) and Mandra *et al.*, (1973) was used. Samples of few grams of disintegrated rock were left in distilled water for 1/2 to 1 month, then decanted and treated with 10% HCL and left for one or two days. Then the samples were washed several times in distilled water until the pH became neutral, heated several times on water bath, treated with 5% sodium carbonate and heated while a few mililitres of 30% H_2O_2 were being cautiously added. The solution was kept boiling for several tens of minutes, then cooled, decanted and several times washed in distilled water. The more resitant samples, which still contained non-disintegrated rock fragments, were divided in two parts. The part with non-disintegrated material was boiled in 2% solution of NaOH for 5 minutes, then quickly cooled and washed in distilled water to prevent dissolution of the slightly silicified frustules in the alkaline medium. After each decantation and washing, decanted water was checked up under a microscope (at magnification 600 times or more) if all frustules settled down.

The diatomaceous shales, and also some diatomites included fine mineral particles, which obscured details of diatom frustules and precluded their identifications. The finest particles were eliminated by decantation, repeated up to 70 times. The heavier particles were eliminated by flotation which was used also for samples containing small numbers of diatoms.

Hard diatomites were prepared in a somewhat different way. The samples were treated with distilled water, then with HCl, and washed in distilled water until the pH of the liquid was neutral, just as described above. Then the samples were treated with 30% H_2O_2, mildly warmed several times, cooled and each time decanted. If nonmacerated particles still persited in the solution, they were separated from the sample and boiled in 10% NaOH or KOH from 10 to 30 minutes. The further procedure was the same as for the soft samples.

Three permanent slides were made from each residuum by fixing it in pleurax — a highly refractive medium.

Other methods of maceration were also tested, but appeared less useful. For instance the methods used by Filipescu & Krestel (1959) for the Carpathian diatomites, consisting in repeated freezing and defreezing, or impregnation (e.g. with Na_2So_4), crystallization and later solution of the crystallizing substance, appeared highly destructive for the diatom frustules.

FUTOMA HORIZON

LITHOSTRATIGRAPHY AND DISTRIBUTION

The outcrops of this horizon occur near Błażowa, SSE of Rzeszów (Fig. 2), The outcrop at Futoma has been first described by Jerzmańska & Jucha (1963). The possibility of occurrence of diatom-rich rocks in the outcrops at Brzezówka.

Borek Nowy and Hermanowa was suggested by J. Badak and B. Kawalec (personal communications). The lithostratigraphic succesion within the lower part of the Menilite Beds in this area includes the following lithologic units (from bottom to top, in brackets are given informal names used for these units in Kotlarczyk, 1985): 1) black shales (Jamna member), sometimes with intercalations of sandstones and conglomerates (Siedliska member), 2) cherts intercalated with black siliceous shales (Kotów member), 3) hard, partly silicified marls, light-coloured when weathered (Dynów member), 4) black shales with interbeds of ripple-laminated sandstones (Rudawka member), 5) light-coloured diatomites and diatomaceous shales with intercalations of cherts, sandstones and shales (Futoma member), 6) siliceous paper-shales with thin layers of cherts (Borek Nowy member). The more resistant chert and marl horizons are useful markers in the field.

The diatomite-bearing unit 5 is well individualized in the area about 10 km around Błażowa. Its thickness is more than ten metres in the centre of this area (Futoma, Borek Nowy) and decreases to a few metres at its periphery (Hermanowa, Brzezówka). Farther away from Błażowa, this unit quickly disapears, and only thin intercalactions (from a few to more than ten centimetres in thickness) of diatom-rich rocks (e.g. at Malawa) replace this unit in the sequence. These intercalations include the same diatom assemblage in all sections, and can be thus considered as one diatom horizon, named Futoma horizon. Probably to this horizon can also be included the thin intercalations of diatom-bearing shales found in Dobra, Rozpucie, Krościenko, Średnia and other localities (Kotlarczyk, 1982). Other areas where the Futoma horizon has been found are situated west and south of Przemyśl. The diatomites described from the vicinities of Dobromil (Gruzhiy & Ripun, 1970) also can be attributed to this horizon. The above data indicate that the Futoma horizon is widely distributed over an area of about 1.500 km^2.

Lithological sequences in the most important studied outcrops of the Futoma horizon are shown in Fig. 3 where the boundary of the lithological units 5 and 6 is accepted as datum. The Futoma horizon is best developed in Futoma and its type section is exposed in a field road running along a hill crest between Futoma and Ulanica (Fig. 4). The beds are dipping 10—30° towards SWW. The chert intercalation at the base of the Futoma horizon is situated about 13 m above the top of the Dynów marls. The Futoma horizon is about 13 m thick, of which the diatom-rich rocks, grouped in 3 complexes, occupy ca. 8 metres. The uppermost complex of diatom-rich rocks reveals features indicative of submarine slumping.

The thickness of the Futoma horizon is much lower in the investigated sections near Błażowa. In Borek Nowy in a slope east of the road to Rzeszów, some 800 m south of the post office, a sequence, 6 m thick, of the upper part of the Futoma horizon is exposed. A layer, 1.5 m thick, of diatomite mudflow, bearing granite granules and pebbles, occurs at the top of this sequence. The thickness of the Futoma horizon in Hermanowa is about 3.5 m, including about 2 metres of white, light diatomites. In Brzezówka (both escarpments of the field road to Borówki) the section of the Futoma horizon includes numerous thin — and some as thick

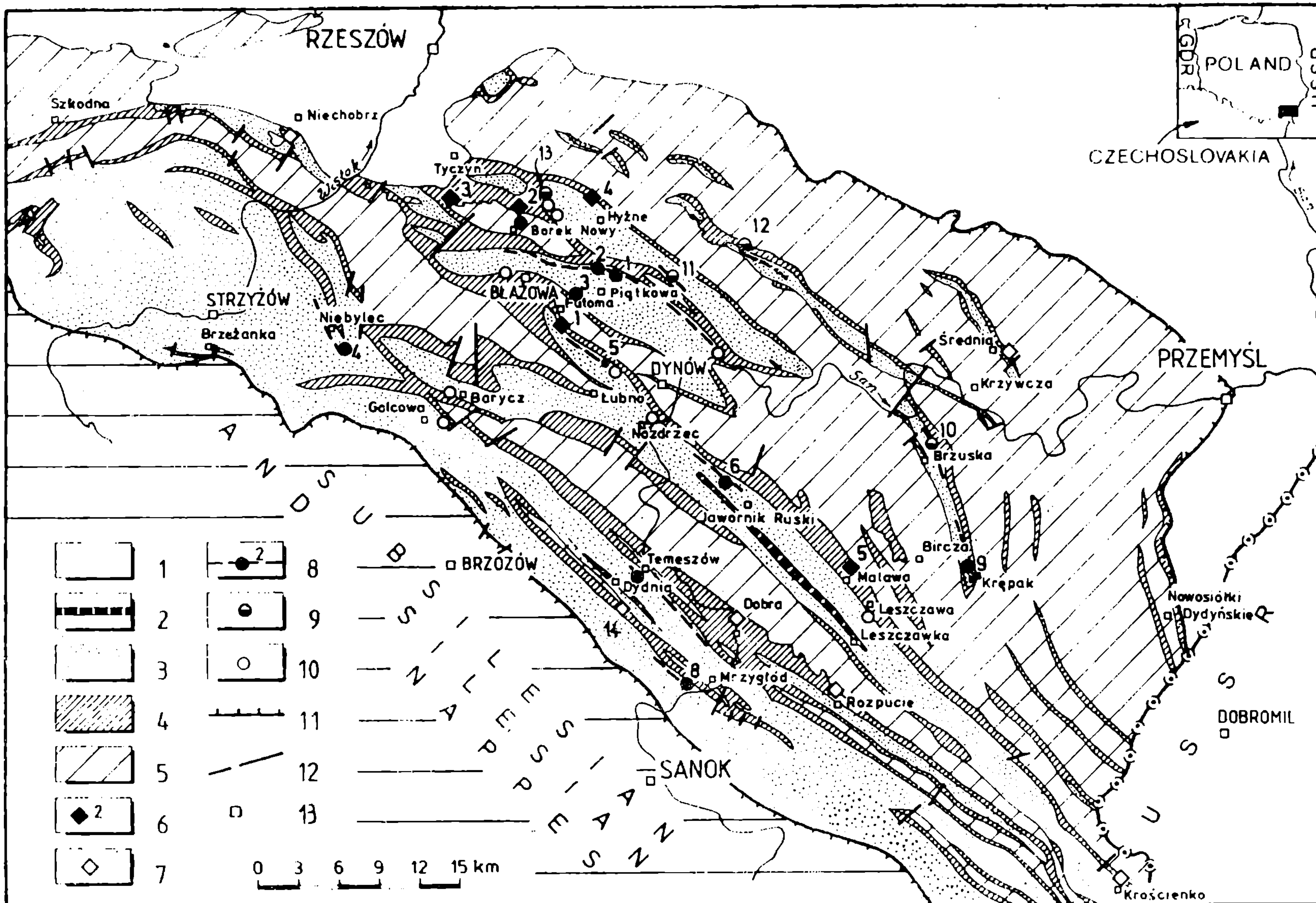

Fig. 2. Distribution of diatom horizons in Skole nappe of Polish Carpathians (after Kotlarczyk, 1982; updated). *1* — Miocene and Quaternary deposits of Carpathian foredeep; *2* — Leszczawka diatom horizon (includes tripoli shales from Brzeżanka near Strzyżów); *3* — Krosno Beds; *4* — Menilite Beds; *5* — strata older than Menilite Beds; *6* — investigated localities with Futoma horizon: (1) — Futoma (type section), (2) — Borek Nowy, (3) — Hermanowa, (4) — Brzezówka, (5) — Malawa; *7* — other localities with diatoms, probably representing Futoma horizon, not studied paleontologically: (14) — Końskie; *8* — investigated localities with Piątkowa horizon: (1) — Piątkowa I (type section), (2) — Piątkowa II, field road to bench mark 389 m, (3) — Błażowa-Łęg, (4) — Niebylec, (5) — Łubno, (6) — Dąbrówka Starzeńska, (7) — Temeszów, (8) — Jutna, (9) — Krępak; *9* — other localities with Piątkowa horizon, not studied paleontologically; (10) — Brzuska, (11) — Szklary, (12) — Widaczów, (13) — Przylasek, *10* — investigated section of Niebylec shaleş where diatoms were not found; *11* — major thrusts; *12* — major faults; *13* — towns and villages

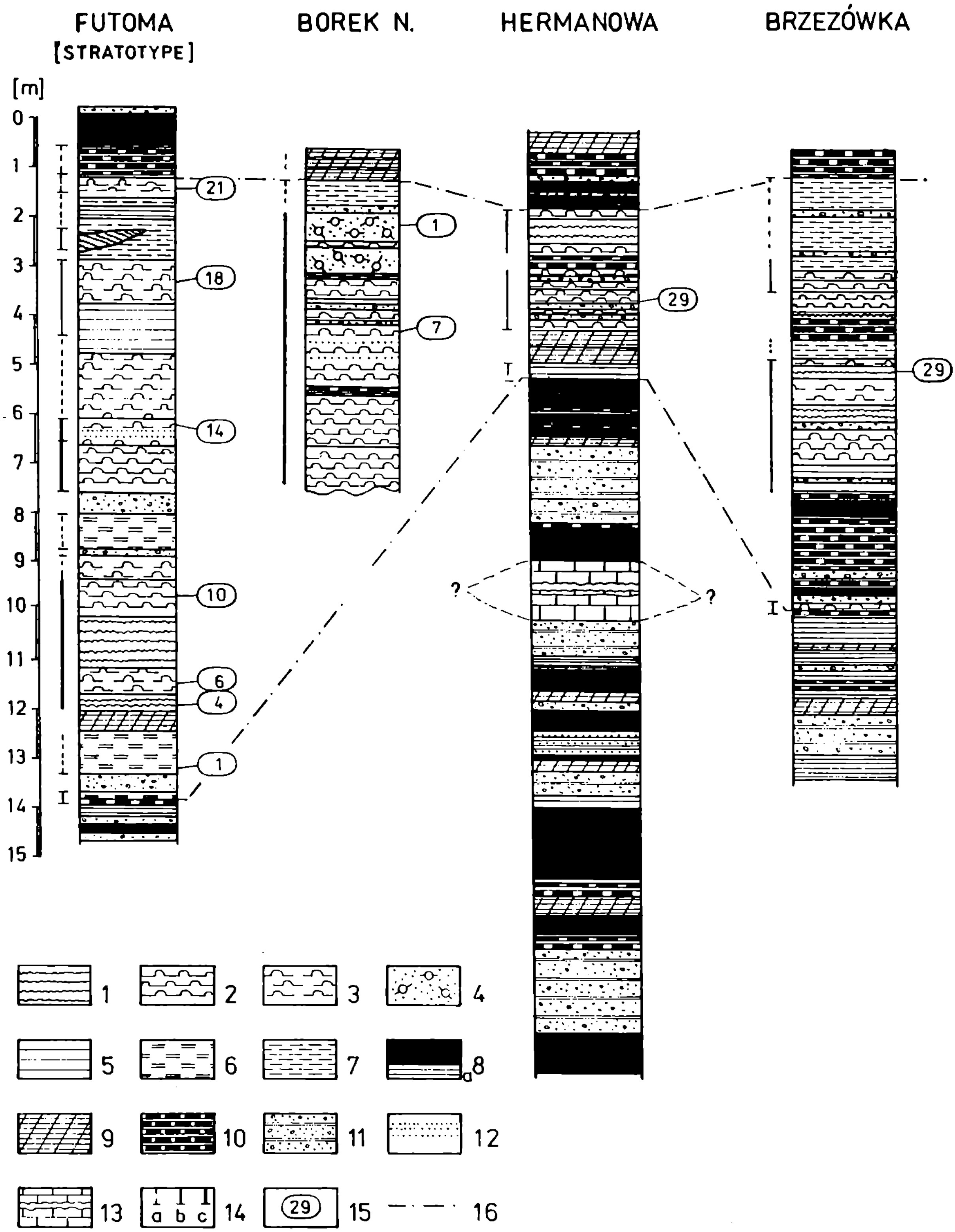

Fig. 3. Lithological columns of Futoma horizon. *1*–*7* — diatom-rich rocks: *1* — finely, wavy laminated, white shales; *2* — thickly laminated beige shales; *3* — platy, laminated light brown shales; *4* — diamictites; *5* — coarsely disintegrating, light brown shales; *6* — non-laminated, soft light brown shales; *7* — pale greenish-beige, sometimes indistinctly laminated shales; *8* — brown clayey-siliceous, hard shales (menilite shales), *a* — soft, brown or green shales; *9* — cherty shales; *10* — laminated and non-laminated beige cherts; *11* — light quartz sandstones; *12* — sandy laminae and ripples; *13* — olistholite of Dynów marl; *14* — frequency of diatoms: *a* — rare, *b* — frequent, *c* — abundant; *15* — locations and numbers of investigated samples; *16* — boundaries of Futoma horizon

as 1.5 m — intercalations of brown cherts with white laminae. The cherts and diatomaceous shales replace the diatomites in this section. The horizon is here 9 m thick, and 5.5 m of this are the diatom-rich rocks.

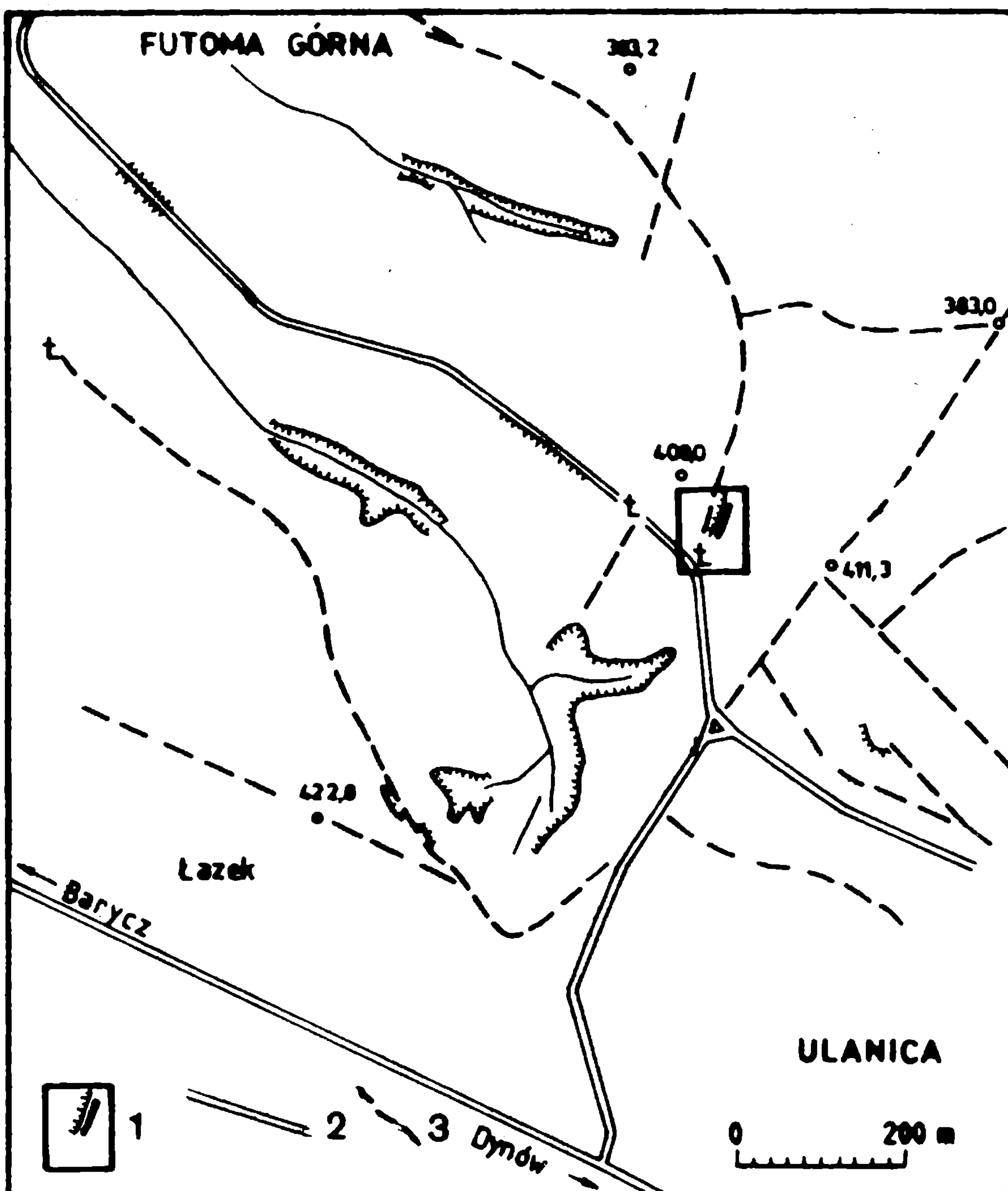

Fig. 4. Location of type section of Futoma horizon. *1* — type section; *2* — main roads; *3* — field roads

About 30 km SE of Błażowa, at Malawa (exposure near a chapel by the Bircza—Malawa road), the Futoma horizon is reduced to a few thin layers of porcellanite and white laminated diatom-rich shale. These rocks occur ca 3.5 m above the top of the Dynów marls (unit 3). In the same area, 8 km east, in the section of the Menilite Beds in Krępak near Korzeniec (Fig. 2), only a layer one centimetre thick was found, of white shale composed of diatomite micorclasts.

LITHOLOGY OF DIATOM-RICH ROCKS

The Futoma horizon is mainly composed of diatom-rich rocks and of rocks which originated by diagenetic transformation of original diatom-rich sediments: porcellanites, siliceous shales and cherts, also of siliceous-argillaceous shales with scarce diatoms, and of subordinate sandstones (Fig. 2). Characteristic features of this horizon are the total lack of calcium carbonate, and their colour, lighter than of the surrounding lithological units.

The weathered diatomites are cream-white, light to dark beige, sometimes greenish beige or light brown. They are light (ca. 1 g/cm^3), porous, brittle and smearing. Examinations of thin sections reveal that one lithological variety may include rocks with either more or less than 40% of diatoms in rock, so that macroscopical distinction of diatomites from diatomaceous shales is impossible. For this reason both types are considered together in the description of lithological varieties of the diatom-rich rocks in the Futoma horizon. Seven lithological varieties of diatom-rich rocks have been distinguished on the grounds of their macroscopic lithologic features:

1) finely laminated, white or beige, with slightly undulating laminae of submillimetric thickness, differing in their shade of colour, with good thin fossility;

2) thickly laminated, light and dark beige, with horizontal lamination (a lighter lamina, several millimetres thick occurs every few, rarely few tens of millimetres), splitting into plates;

3) indistinctly laminated, white and greenish beige, sometimes dark beige (each several millimetres occur poorly visible lighter laminae), with faint fissility, sometimes of scaly type;

4) non-laminated beige and light brown, light, porous, friable;

5) coarsely splitting brown or dark brown, with large content of clay minerals, non-laminated, heavier, more compact and more resistant than the former varieties, frequently with shell-like fracture;

6) platy, differing from the former only by its splitting into scale-like plates 1—3 cm thick, and by frequent laminae of fine quartz and glauconite sand;

7) layers of mudflows, beige, falling into blocks, rich in quartz sand and lithic fragments.

There are no regularities in the vertical sequence of these rock types.

SEDIMENTOLOGICAL OBSERVATIONS

The most conspicuous sedimentary feature in the Futoma horizon is the varve-like horizontal lamination of the diatom-rich rocks. The light laminae — white or light beige — are more constant in thickness than the dark laminae — beige or pale brown. In the finely and wavy laminated varieties of diatomites, the light laminae are thickner than the darker, while in the thickly laminated varieties they are much thinner. The light laminae are composed mainly of diatom frustules and their fragments, binded by opaline cement. The dark laminae, besides the diatom frustules include significant admixture of clay minerals, quartz and glauconite silt. Flakes of clay minerals parallel the laminae; also other terrigenous material is often accumulated in laminae or lenses (ripples of various size). Some diatomite laminae are thinning laterally; some are bent beneath ripples which sunk by loading, other are partly washed out, and some, sporadically, reveal ripple structure. Postdepositional interruptions of laminae are frequent. Evident grading was not observed in sandstones, siltstones or diatomites.

The described features of the very fine-grained sediments suggest their successive deposition from slow bottom currents. These currents temporarily moved the biogenous material accumulating at the bottom and occasionally supplied some terrigenous material, mainly quartz silt and fine sand. Permanent deposition could be limited to local depressions perched on the basin slope. In the remaining area, diatom frustules either did not accumulate at all or did only sporadically (e.g. Malawa); the sediment could be winnowed away (e.g. at Krępak near Korzeniec).

Layers of mudflow deposits and submarine slumps occur in the higher part of the Futoma horizon.

FREQUENCY DISTRIBUTION OF DOMINANT TAXA IN STUDIED SAMPLES AND POSSIBILITIES FOR LOCAL STRATIGRAPHY

Individual dominant taxa occur with different frequency in the studied slides (min. 3 slides from each sample). A semiquantitative, 5-rank scale has been used to compare the frequency of their occurrence (Table 1).

Each of the four most numerous among the 30 dominant taxa (*Actinoptychus senarius* (Ehr.), *Chaetoceras compressus* Land., *Odontella cornuta* (J. Brun.) Schrader, *Paralia sulcata* (Ehr.) Cleve), occurs in each sample. The frequencies of some taxa (*Grammatophora* sp., *Pyxilla prolongata* Brun., *Rhizosolenia* sp., *Stephanopyxis turris* (Grer. et Arn.) Ralfs) oscillate in the section. Other dominant taxa appear or disappear in different parts of the section.

In the type section, the diatomite layers include the most diversified diatom assemblages, comprising usually about 20 dominant taxa (Table 1). In samples from diatomaceous shales, the numbers of taxa are much lower. Apart from the type section, the same diatom assemblage was found in all studied sections in the vicinity of Błażowa (Fig. 2), and only five taxa from this assemblage have been found in Malawa, 30 km to SE (Fig. 1).

Within the generally uniform composition of the diatom assemblage, some vertical changes have been ascertained. Comparisons of the composition of the diatom assemblages in the nearest investigated layers of the stratotype section indicate that similarities become greater upwards. This may suggest progressive stabilization of the biocenosis during its development. However, taking into account the most frequent (++++ and +++ in Table 1) taxa, we find greater differences both in the lower (between samples 4 and 6) and in the upper (between samples 14 and 18, 18 and 21) parts of the section. Combinatorical comparison of the layer groups (each to each) reveals greatest differences of the number of common taxa between the bottom and top layers, and between layer 21 and the middle part of the section.

Table 1

Frequency distribution of dominant taxa in investigated samples from Futoma (F), Hermanowa (H), Brzezówka (B), Borek Nowy (BN) and Malawa (M)

Name of taxon	Sample number											
	F1	F4	F6	F10	F14	F18	F21	H29	B29	BN1	BN7	M2
1. *Actinocyclus loczyi* Pant.	+	++	++	++	++	+		+	++		+	+
2. *Actinoptychus senarius* (Ehr.) Ehr.		+	+++	+++	++++	+++	+++	++	++	++	++	
3. *A. senarius* var. *tamanicus* (Jouse) Hajos			++							++		
4. *Cestodiscus intersectus* Brun		+	+	++	++	+	++	+	+	+	+	
5. *Chaetoceros compressus* Laud.		++	++	++	++++	+++	++	+++	+++	+	+	
6. *Ch. robustus* Makar.					+			+++	++			
7. *Chasea ornata* Hajos et Stradner		++	++	+					+	+		
8. *Coscinodiscus* cf. *subtilis* Ehr.		+	+	+	+	+	+	+	+	+	+	+
9. *Grammatophora* sp.		++			++		+	++	++			
10. *Hemiaulus* cf. *malleolus* Pant.		+	+	+	+++	++	++	++	++	++	+++	
11. *Hemiaulus sporalis* Streln.			++			++	++	+	+	++		
12. *Hyalodiscus scoticus* (Kütz.) Grun.						+	+		+	+		
13. *Melosira architecturalis* Brun			++				+	+	++			
14. *Melosira praeislandica* Jouse			++	++	++	++	+	++	++	++	++	+
15. *Odontella cornuta* (J. Brun) Schrader	+	+++	+++	+++	++	+++	+++	++	+++	++	+	
16. *O. fimbriata* (Grev.) Schrader		+++		++	+			+		+	+	
17. *Paralia sulcata* (Ehr.) Cleve	+	++++	+++	++++	++++	++++	++++	++++	++++	+++	+++	+
18. *Par. sulcata* var. *crenulata* (Grun.) Freng.		++	+		+			+			+	
19. *Pseudopodosira witti* (Schulz) Veksh.			+++	++	+++	++	++	+	++	+++	++	+
20. *Pyxilla prolongata* Brun		+++	+++		+	+++	+			++	+	

cd. table 1

Name of taxon	Sample number											
	F1	F4	F6	F10	F14	F18	F21	H29	B29	BN1	BN7	M2
21. *Rhaphoneis amphiceros* Ehr.		+	+		+	+	+			+	+	
22. *Rhizosolenia* sp., seta type of *Rh. setigera* Brigh.		+++	+	++++	++++	+	+++	++++	++++	++++	+++	
23. *Stephanopyxis turris* (Grev. et Arn.) Ralfs	+		++		+	+++		+	++			
24. *Sceptroneis grunowii* Anissim.				+	+	+	++	+++	++		+	
25. *Thalassiosira* cf. *baltica* (Grun.) Ost.	+	+++	++	++	++							
26. *Triceratium condecorum* Ehr.			+++	++	++	+	+	+	++	++	+	
27. *T. tesellatum* Grev.			++		++	++	+					
28. *Trochosira spinosa* Kitt.		++	++	++	+++	+++	++	++	+++		+	
29. *Xanthiopyxis oblonga* Ehr.		+	+		+				+	+		
30. *X. papillosus* Hajos							++	+				

+ few frustules in each slide; ++ 11–20 frustules in each slide; +++ few frustules in each surveyed traverse; ++++ 11–20 frustules in each surveyed traverse

The vertical differences in the composition of the diatom assemblages have been also used to verify the lithological correlation of the other sections with the stratotype. The greatest similarities, coupled with the smallest number of differences are found in the following couples of samples (for sample location see Fig. 3): BN7 — F14, H29 — F14, B29 — F18, H29 — BN7. These results generally agree with the lithological correlation.

Two sub-assemblages have been distinguished in the type section, characteristic for the lower and upper part, respectively.

For the lower part of the section characteristic are: *Chasea ornata*, *Actinoptychus senarius* var. *tamanicus*, *Paralia sulcata* var. *crenulata*, *Odontella fimbriata*, *Thalassiosira baltica* and *Xanthiopyxis oblonga*. The upper part of the section is characterized by *Chaetoceros robustus*, *Hyalodiscus scoticus*, *Sceptroneis grunowii* and *Xanthiopyxis papillosus*. However, in all other sections, few specimens of the taxa characteristic for the lower part of the horizon occurred in the upper part of the section (see Fig. 3 and Table 1).

ECOLOGY AND AGE OF THE DIATOM ASSEMBLAGE

The diatom assemblage in the Futoma horizon (Table 2) is indicative of neritic--sublittoral environment and it lacks oceanic pelagic taxa. Besides stenohaline ones there occur taxa which can live also in brackish water (*Hyalodiscus scoticus*, *Raphoneis amphiceros*, *Thalassiosira baltica*), one known from brackish and fresh water

Table 2

Environment and age of dominant taxa in Futoma horizon

Name of taxon	Environment: marine (M) brackish (B) fresh-water (F)	Biotope				Age						
		Neritic	Littoral	Planktonic	Epiphytic	Recent	Pleistocene	Miocene	Oligocene	Eocene	Paleocene	Cretaceous
1. *Actinocyclus loczyi* Pant.	M							+				
2. *Actinoptychus senarius* (Ehr.) Ehr.	M	+	+	+		+		+	+	+	+	
3. *A. senarius* var. *tamanicus* (Jouse) Hajos	M		+	+				+				
4. *Cestodiscus intersectus* Brun	M							+				
5. *Chaetoceros compressus* Laud.	M	+		+		+		+				
6. *Ch. robustus* Makar.	M	+				+		+				
7. *Chasea ornata* Hajos et Stradner	M								+	+		+
8. *Coscinodiscus* cf. *subtilis* Ehr.	MBF					+		+				

cd. table 2

Name of taxon	Environment: marine (M) brackish (B) fresh-water (F)	Biotope				Age						
		Neritic	Littoral	Planktonic	Epiphytic	Recent	Pleistocene	Miocene	Oligocene	Eocene	Paleocene	Cretaceous
9. *Grammatophora* sp.												
10. *Hemiaulus* cf. *malleolus* Pant.	M							+	+	+	+	
11. *Hemiaulus sporalis* Streln.	M											+
12. *Hyalodiscus scoticus* (Kütz). Grun.	MB	+	+	+		+		+	+	+	+	
13. *Melosira architecturalis* Brun	M								+	+		
14. *Melosira praeislandica* Jouse	F						+	+				
15. *Odontella cornuta* (J. Brun) Schrader	M							+				
16. *O. fimbriata* (Grev.) Schrader	M								+	+		
17. *Paralia sulcata* (Ehr.) Cleve	M	+	+			+	+	+	+	+	+	+
18. *Par. sulcara* var. *crenulata* (Grun.) Freng.	M		+						+	+	+	+
19. *Pseudopodosira wittii* (Schulz) Veksh.	M								+	+		+
20. *Pyxilla prolongata* Brun	M								+	+		
21. *Rhaphoneis amphiceros* Ehr.	MB		+			+		+	+	+		
22. *Rhizosolenia* sp., seta type of *Rh. setigera* Brigh.	M											
23. *Stephanopyxis turris* (Grev et Arn.) Ralfs	M	+	+	+		+		+	+	+	+	+
24. *Sceptroneis grunowii* Anissim.	M									+	+	+
25. *Thallassiosira* cf. *baltica* (Grun.) Ost.	MB			+		+						
26. *Triceratium condecorum* Ehr.	M	+					+	+	+	+		
27. *T. tesellatum* Grev.	M	+						+	+	+		
28. *Trochosira spinosa* Kitt.	M	+		+				+	+	+		
29. *Xanthiopyxis oblonga* Ehr.	M							+	+	+		
30. *X. papillosus* Hajos	M							+				

(*Coscinodiscus subtilis*) and one typically fresh water taxon (*Melosira praeislandica*).

The fishes found in the diatomites are exclusively neritic-sublittoral forms. This character of fossils suggests deposition in a shallow sea, possibly in vicinity of a river mouth, during the Early Oligocene stage of the general shallowing of the basin (cf. Kotlarczyk & Jerzmańska, 1976).

The diatom assemblage in the Futoma horizon is not indicative of precise age of its host deposits. Most taxa are long-ranging, usually known from the whole Tertiary. About one third of the taxa are not hitherto known from strata older than Neogene, while five taxa are considered not younger than Oligocene (Table 2).

Here, the upper limits of the stratigraphical extents of the Palaeogene taxa are considered more significant for the conclusions regarding the age. The lower limits of the stratigraphical ranges of the well studied Neogene taxa are frequently lowered with the increasing number of studies on the Palaeogene assemblages (e.g. the extent of *Thalassiosira baltica* and some other taxa must be extended downwards as a result of our study). The Palaeogene age of the diatom assemblage in the Futoma horizon is suggested by *Chasea ornata*, *Melosira architecturalis*, *Odontella fimbriata*, *Pseudopodosira wittii* and *Pyxilla prolongata*. The lack in this assemblage of the forms, which accompany *P. wittii* in the Upper Eocene deposits in nearby localities in Ukraine (*Triceratium barbadensis* and *Melosira oamurensis*), suggests the age not older than Early Oligocene.

The diatom assemblage in the Futoma horizon is a very distinctive one, not similar to any hitherto described Oligocene assemblage. Some similarities occur to the diatoms described from the deposits of the Norvegian Sea by Dzinoridze *et al.* (1976). These authors distinguished *Pyxilla prolongata* zone in the lowermost part of Oligocene. The nominal species of this zone occurs in relatively large numbers in all samples from the Futoma section. It should be noted however, that other authors place *Pyxilla prolongata* zone in the Upper Oligocene (McCollum, 1975; Gombos, 1976; Weaver & Gombos, 1981; Gombos & Ciesielski, 1983).

Other species common with the Norvegian Sea assemblage include *M. architecturalis* and *X. oblonga* (Dzinoridze *et al.*, 1976) as well as *Sceptroneis grunowii* and *Trochosira spinosa* (Schrader & Fenner, 1976). The assemblage from Futoma has three Palaeogene taxa in common with the Upper Eocene—Lower Oligocene assemblage of the SW Pacific Ocean (Hajos, 1976), one long-ranging taxon in common with the Upper Oligocene assemblage of Mangyshlak (Zhuze, 1978), and two long-ranging taxa in common with the Maikop Bedsof the Shibik area, considered as Lower Miocene (Sheshukova-Poretskaya & Gleser, 1962).

PIĄTKOWA HORIZON

LITHOSTRATIGRAPHY AND DISTRIBUTION

The Piątkowa horizon does not constitute a separate lithologic unit. It occurs within transitional strata between the Menilite Beds and the Krosno Beds, in their part traditionally named Niebylec shales. The Piątkowa horizon occurs in the part of the Niebylec shales which consists of alternations of grey marly shales and calcareous sandstones typical of the Krosno Beds, with subordinate layers of black and brown, rarely green, siliceous-argillaceous shales and rare intercalations of non-calcarous sandstones, both characteristic of the Menilite Beds. Characteristic for this strata are lenses of ferrugineous dolomite and layers of pyroclastic rocks, recognized as a marker horizon (tuff horizon IV of Sikora *et al.*, 1959).

There are several tens of brown shale layers in the studied sections near Błażowa and Niebylec (Figs 2 and 5) and all are diatomaceous shales. Towards S and SE the number of diatom-rich layers decreases and the diatom content diminishes. Individual diatom-rich layers have been found, and their diatoms studied, at localities Łubno, Dąbrówka Starzeńska, Jutna, Temeszów, Krępak (Fig. 1). Only in the last two sections the diatoms were numerous. Diatoms have been also found in the sections Szklary, Brzuska, Błażowa—Łęg II, Przylasek, Widaczów. In many investigated sections (Błażowa—Przedmieście, Błażowa—Wola, Borek Stary, Nieborów I and II, Dynów, Karolówka, Leszczawa, Golcowa I and II, Barycz) no diatoms at all were found at the position of the Piątkowa horizon.

The areal extent of the Piątkowa horizon is about 1.000 km^2. Its type area is situated near Błażowa and Niebylec. There the intercalations of diatomaceous shales may appear in the lower and middle parts of the Niebylec shales (Piątkowa) only in the middle part (Błażowa—Łęg), or throughout the whole thickness of the Niebylec shales (Niebylec). The vertical distance between the extreme diatom-rich layers varies from 21 to 90 metres, respectively, and the total thickness of the diatom-rich layers within the interval makes up 1 to 8 per cent of the interval thickness. Away of the type area, the diatom-rich layers appear either only in the lower part of the Niebylec shales (Krępak, Jutna, Temeszów) or in the middle and higher parts (Dąbrówka). Lithology of the diatom-rich layers, their vertical sequence, and the lithology of the accompanying rocks are highly variable laterally, even between closely spaced sections (see e.g. sections Piątkowa and Błażowa in Fig. 5).

The Piątkowa horizon has no fixed position in the lithological sequence. The diatom horizon itself is defined as the totality of the thin diatom-bearing layers which are intercalated within the Niebylec shales. Each diatom-bearing layer is of a limited areal extent, but their occurrence in the section is vertically restricted and represents a short time of diatom deposition.

There is no regularity in the mutual succession of the diatomaceous shales and the pyroclastic layers. The latter occur as well amidst the diatomaceous shales (Błażowa—Łęg, Piątkowa) as beneath them (Niebylec), or above them (Dąbrówka Starzeńska). Although there is no direct proof that all the tuff layers belong to tuff horizon IV, and their lithology is different in different localities, but their occurrence within the same lithological division suggests their isochroneity (Żgiet, 1963). This would corroborate the oppinion on the limited lateral extent and no fixed vertical position of the individual diatom-rich layers.

The Piątkowa horizon is best developed in the Piątkowa I section which is accepted as the horizon type section. The section is exposed in the escarpment of a hill-crest field road between Ulanica and Piątkowa, running from the bench mark 413.7 towards the road to Rzeszów (Figs 5, 6). The beds are overturned and dip at 75—80° to NE. The diatomaceous layers are grouped in two clusters separated by a vertical distance of 12 m. The lowermost diatom-rich layer is situated 11 metres above the top of the Menilite Beds. The individual diatom-rich layers are 5 to 42 cm

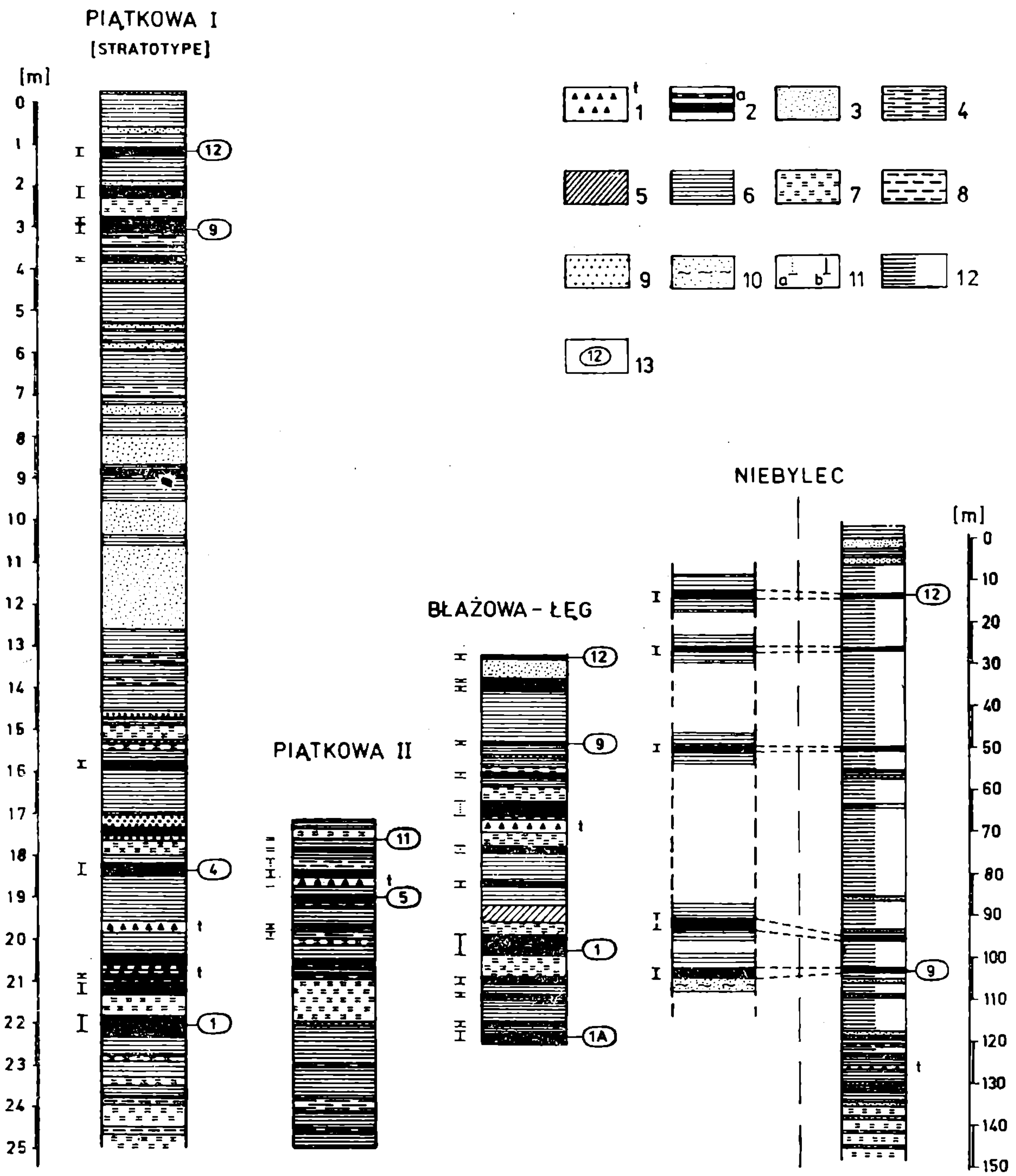

Fig. 5. Lithological columns of Piątkowa horizon. *1* — intercalations of pyroclastic rocks; *2* — diatomaceous shales, *a* — diagenetic chert; *3* — calcareous Krosno sandstones; *4* — ochre-yellow, porous, diatom-poor shales; *5* — ankerite lenses; *6* — grey marly Krosno shales; *7* — greenish clayey shales; *8* — brown clayey-siliceous shales (menilite shales); *9* — non-calcareous quartzous sandstones (Kliwa type); *10* — calcareous Krosno mudstones; *11* — frequency of diatoms: *a* — rare, *b* — frequent; *12* — hypothetical sequence of strata in Niebylec section (reconstruction); ovals with numbers locations and numbers of investigated samples

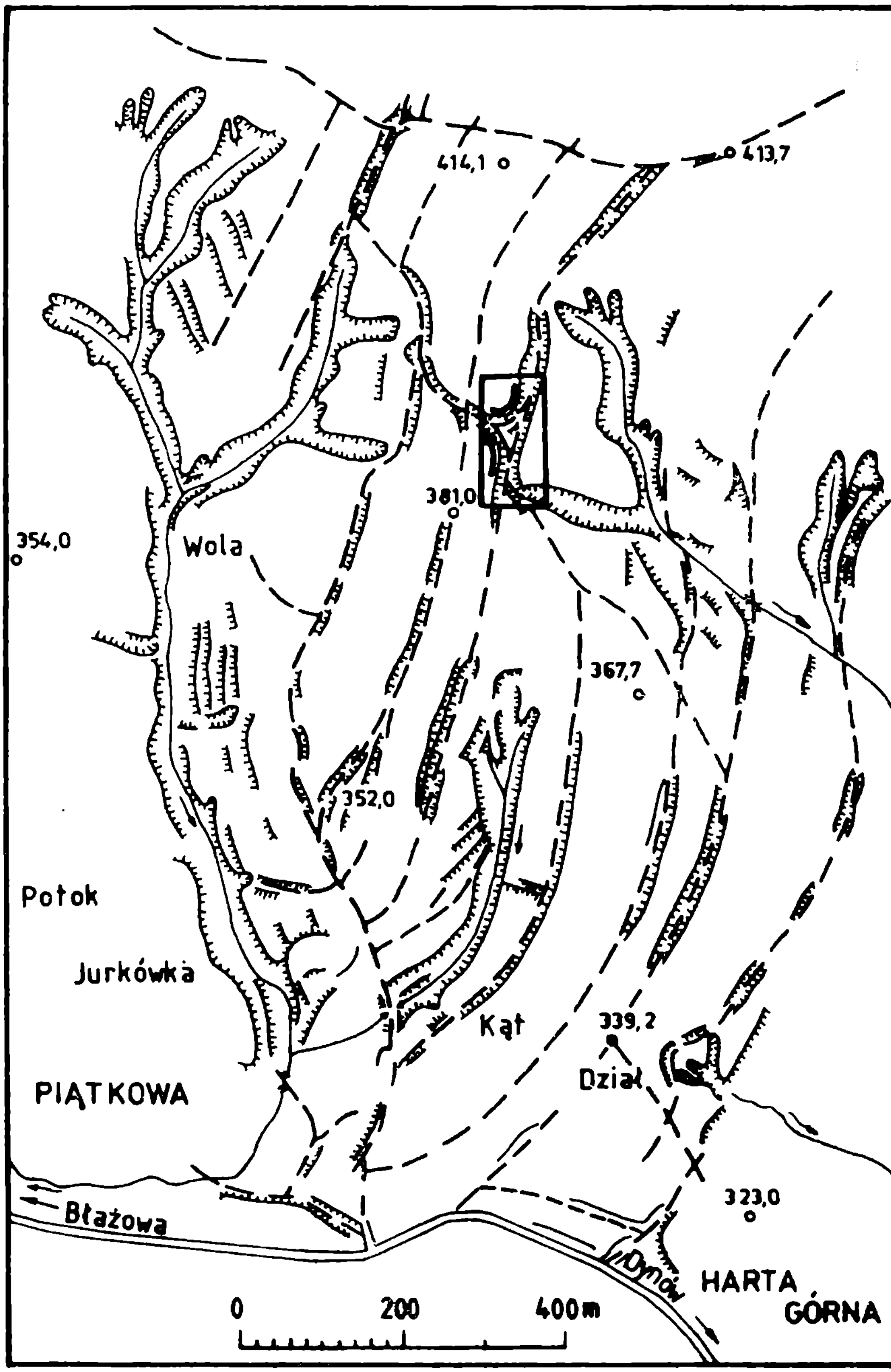

Fig. 6. Location of type section of Piątkowa horizon. Explanations as in Fig. 4

thick; their total thickness is about 2.5 m. The same outcrop zone of the Niebylec shales with diatom-rich intercalations was studied by Żgiet (1961, 1963) in prospection trenches. Natural exposures are scarce. Another section (Piątkowa II), including only the lower part of the Niebylec shales is exposed in the field road running from the altitude mark 389 m to Piątkowa village, some 1,600 m west of the stratotype. It includes four thin (3—11 cm) layers of diatom-rich shales, with total thickness of 35 cm (Fig. 5).

The lower part of the Piątkowa horizon is more completely exposed at Błażowa—Łęg locality, about 2 km away, in the opposite limb of a syncline. In the escarpment of the field road running from the store by the road to the bench mark 354 m, there are exposed 13 layers of diatom-rich rocks. They are up to 44 cm thick; their total thickness is about two metres.

At the periphery of the type area, in Niebylec, the number of the diatom-rich layers (see Fig. 5) is much lower (5—6), they are thinner (3—25 cm) and much more distant from one another (each 10 to 40 m). This section is now poorly exposed, south of the town, in a field road running to the hill 395. It was described earlier (Blaicher & Nowak, 1963; Nowak, 1979) but without mentioning the diatom-rich layers.

LITHOLOGY OF THE DIATOM-RICH ROCKS

The diatom-rich intercalations differ from the host rocks by their darker brown colour, dark beige with a violet shade when weathered, and higher porosity. These layers are well visible against the ash-grey or light-grey background of the marly and clayey shales.

Five lithological varieties have been distinguished on the grounds of lithological features of the weathered diatomaceous shales: (1) non-laminated, beige or brown, compact (the most frequent); (2) spotted and banded, beige-brown, with the spots and bands irregular, sometimes lenticular (up to 1 cm in size), sometimes very small (size of a comma); shales are brittle, friable and porous; (3) parallel laminated, brown, silty; white and beige laminae are up to 0.5 mm thick; (4) graded, brown or beige; (5) clayey, brown or black, coarsely disintegrating into blocks, sometimes indistinctly laminated, often slightly calcareous.

Diatom-poor shales found in the section of the Piątkowa horizon resemble macroscopically the last variety. Sometimes they are yellow-ochre in colour.

SEDIMENTOLOGICAL OBSERVATIONS

Intercalations of the diatomaceous shales are usually structureless. The spots, sometimes observed, are probably due to weathering and are porosity controlled. Only in one case, in the section Błażowa—Łęg, the pattern of the light spots seems to suggest that these may be feeding channels. Thicker layers of diatomaceous shales are distinctly graded, and sometimes display Bouma sequences. Some sequences are incomplete: DE, CD, BC; they occur in thinner layers. Macroscopically discernible sedimentary structures occur in 25—40% of diatomaceous shales. The described features indicate deposition by turbidity currents, as was suggested earlier by Żgiet (1963). Light-coloured, quartzous non-calcareous sandstone occurs at base of some diatom-rich layers. Its petrographical type, similar to that of the Kliwa sandstones, suggests the same provenance i.e. from the northern (external) margin of the Skole basin.

There are no regularities in the contacts of the diatomaceous shales with other rocks, including the pyroclastic layers.

Diagenetic silicification of the diatom-rich rocks was occasional, only at two localities (Niebylec, Błażowa Wola) individual thin layers of black cherts, adhering to black shale layers, have been found.

The Niebylec shales were laid down in a deep-sea environment, where biogenic and terrigeouns material was supplied by turbidity currents from the shallower zones of the basin.

FREQUENCY DISTRIBUTION OF DOMINANT TAXA IN STUDIED SAMPLES AND SECTIONS

The content of diatom frustules in the studied samples was variable and the amount of mineral contaminations was significant. For this reason all samples were subject to flotation before the preparation of slides. This resulted in fragmentation of delicate frustules, so that the semiquantitative analysis, similar to that done for the Futoma horizon, was not attempted. The information about the 31 dominant taxa is of different type than given in Table 1 for the Futoma horizon. Symbols in Table 3 denote the degree of confidence in the identification of the genera and species.

The preservation of diatom frustules in the diatomaceous shales was generally worse than in the diatom-rich rocks of the Futoma horizon, and in the shales with scarce diatoms it is poor or very poor. Some fragments found in the areas with the diatom horizon incompletely developed were determinable to the species, while in some sections (Łubno, Jutna, Temeszów and Niebylec) only genera could be determined.

The proportion of diatom-bearing layers to the total number of investigated black layers in individual sections was as follows: Łubno — 1:4, Dąbrowa Starzeńska — 2:8, Temeszów — 1:3, Jutna — 1:6, Krępak — 2:7, Brzuska — 2:11, Szklary — 1:3, Golcowa — 0:9, Bachórz — 0:5.

The diatom assemblage in the Piątkowa horizon is distinctive and uniform, both vertically and laterally (Table 3). Usually 18 to 27 taxa were found in individual layers of the diatomaceous shales after flotation; in individual layers of the siliceous-argillaceous diatom-poor shales, from one to eleven taxa were found.

ECOLOGY AND AGE OF DIATOMS IN PIĄTKOWA HORIZON

The diatom assemblage in the Piątkowa horizon is indicative of neritic-coastal, marine, normally saline environment (Table 4) but provides no indications on paleoclimate. The assemblage consists mainly of taxa with robust frustules. It represents thus not a complete thanatocoenose but only its heavier fraction, that of

Table 3

Frequency distribution of dominant taxa in investigated samples of Piątkowa horizon

Name of taxon / Locality	Piątkowa type section				Błażowa-Łęg				Piątkowa II		Niebylec		Dąbrówka	Jutna	Krępak	Łubno	Temeszów
Sample number	1	4	9	12	1A	1	9	12	5	11	9	12	7A	2	d	1	2
1. *Actinocyclus* aff. *cholnokyi* van Lan.		+	+	+	+	+	+	+	+	+	+						
2. *A. octonarius* Ehr.	+	+	+	+	+	+			+	+	+						+
3. *A. octonarius* var. *tenella* (Breb.) Hust.	+	+	+	+	+	+	+		+	+	+						
4. *A. octonarius* var. *sparsa* (Greg.) Hendey				+					+								
5. *Actinoptychus senarius* (Ehr.) Ehr.		+	+	+		+		+	+				?		+		
6. *A. thumii* (A.S.) Hanna			+	+	+			+	+	+	+						
7. *Biddulphia longispina* (Grun.) De Toni						+		+	+	+	+						
8. *Cocconeis praecellens* Pant.			+	+				+	+	+	+						
9. *C. vitrae* Brun	+		+	+		+	+			+							
10. *Coscinodiscus argus* Ehr.		+	+		+	+		+			+		}?		+}		?
11. *C. marginatus* Ehr.	+	+	+	+	+	+		+	+	+		?	?}	?	+}	?	?
12. *C. papillosus* Hajos	+			+	+		+			+	+		}		}		
13. *Cymatogonia amblyoceras* (Ehr.) Hanna		+	+	+	+	+		+	+	+	+						
14. *Diploneis nitescens* (Greg.) Cl.	+		+	+	+			+		+							
15. *D. szontaghii* (Pant.) Cl.		+		+	+		+		+								
16. *Grammatophora marina* (Lyngb.) Kütz.	+	+		+				+	+	+					+}		
17. *Hyalodiscus radiatus* (Meara) Grun.		+	+	+	+	+	+	+	+	+							
18. *Melosira clavigera* Grun.	+	+	+		+	+	+		+	+	+	+			+		
19. *M. omma* Cl.	+		+		+					+	+						
20. *Paralia sulcata* (Ehr.) Cl.	+		+	+	+	+	+	+	+	+	+	+	?		+		+
21. *P. sulcata* var. *biseriata* Grun.	+		+	+	+				+								
22. *Pseudopodosira wittii* (Schulz) Veksh.	+	+	+	+	+	+	+	+	+	+	+				+		+
23. *Pseudopodosira* sp.		+	+		+		+		+	+	+						
24. *Pleurosigma normanii* var. *marylandica* Grun.	+		+	+				+	+								
25. *Rhaphoneis gemmifera* Ehr.	+	+	+	+	+	+	+	+	+	+							

cd. table 3

Name of taxon	Locality: Piątkowa type section				Błażowa-Łęg				Piątkowa II		Niebylec		Dąbrówka	Jutna	Krępak	Łubno	Temeszów
Sample number	1	4	9	12	1A	1	9	12	5	11	9	12	7A	2	d	1	2
26. *Stephanopyxis corona* (Ehr.) Grun.		+	+	+	+		+	+	+	+	+}				+}	}	
27. *S. turris* (Grev. et Arnott) Ralfs	+	+	+	+	+	+		+	+	+	}	?			+}	?}	?
28. *S. turris* var. *arctica* Grun.		+		+	+	+		+	+		}		?		}	}	
29. *S. turris* var. *intermedia* Grun.	+				+	+		+	+	+	+}				+}	}	
30. *Thalassionema* aff. *obtusa* (Grun.) Andrews	+	+	+		+		+		+	+							
31. *Xanthiopyxis diaphana* Forti	+	+	+	+	+	+			+	+					+		

+ determination certain; ? determination uncertain, ornamentation may be accepted as typical for species; } determination uncertain even with respect to genus

Table 4

Environment and age of dominant taxa in Piątkowa horizon

Name of taxon	Environment: marine (M) brackish (B)	Biotope				Age						Climate
		Neritic	Littoral	Planktonic	Epiphytic	Recent	Miocene	Oligocene	Eocene	Paleocene	Cretaceous	
1. *Actinocyclus* aff. *cholnokyi* van Lan.	M	+	+			+	+					
2. *A. octonarius* Ehr.	MB		+	+		+		+	+			temperate warm
3. *A. octonarius* var. *sparsa* (Greg.) Hondey						+						
4. *A. octonarius* var. *tenella* (Breb.) Hust.	M	+	+	+		+	+	+				
5. *Actinoptychus senarius* (Ehr.) Ehr.	M	+	+	+		+	+	+	+	+		boreal
6. *A. thumii* (A.S.) Hanna	M						+	+				
7. *Biddulphia longispina* (Grun.) De Toni	M											
8. *Cocconeis praecellens* Pant.	M						+					
9. *C. vitrea* Brun	M		+			+	+	+				boreal
10. *Coscinodiscus argus* Ehr.												
11. *C. marginatus* Ehr.	M	+		+		+	+	+	+	+		boreal
12. *C. papillosus* Hajos	M					+	+					
13. *Cymatogonia amblyoceras* (Ehr.) Hanna	M						+					
14. *Diploneis nitescens*	M					+	+		+			tropical-subtropical
15. *D. szontaghii* (Pant.) Cl.	M						+					
16. *Grammatophora marina* (Lyngb.) Kütz.	M		+	+	+	+	+					boreal
17. *Hyalodiscus radiatus* (Meara) Grun.	M					+		+	+			boreal
18. *Melosira clavigera* Grun.	M			+			+	+	+			
19. *M. omma* Cl.	M						+					
20. *Paralia sulcata* (Ehr.) Cl.	M	+	+			+	+	+	+	+	+	
21. *P. sulcata* var. *biseriata* Grun.	M					+	+	+	+	+	+	
22. *Pseudopodosira wittii* (Schulz) Veksh.	M							+	+		+	
23. *Pseudopodosira* sp.												
24. *Pleurosigma normanii* var. *marylandica* Grun.	M					+	+					

cd. table 4

Name of taxon	Environment: marine (M) brackish (B)	Biotope				Age						Climate
		Neritic	Littoral	Planktonic	Epiphytic	Recent	Miocene	Oligocene	Eocene	Paleocene	Cretaceous	
25. *Rhaphoneis gemmifera* Ehr.	MB		+			+	+					
26. *Stephanopyxis turris* (Grev. et Arm.) Ralfs	M	+		+		+	+	+	+	+	+	
27. *S. turris* var. *arctica* Grun.	M		+					+	+			
28. *S. turris* var. *intermedia* Grun.	M	+					+	+	+	+	+	
29. *Thalassionema* aff. *obtusa* (Grun.) Andrews	M			+		+	+					
30. *Xanthiopyxis diaphana* Forti	M						+	+	+			

medium-sized frustules. This is due to sorting during their transportation by the turbidity currents. This transport mechanism explains also the neritic composition of the assemblage and its decreasing diversity to the south and south-west. The appearance of more numerous diatoms in the area of Krępak seems related to the deposition by an independent system of turbidity currents.

A slight lateral differentiation of the diatom assemblages appears between the peripherally situated sections and those in the type area. It consists in greater mutual similarity of the assemblages from the sections situated east of the meridian of Błażowa.

The diatom assemblage of the Piątkowa horizon is not precisely indicative of age. More than half taxa are long-ranging Palaeogene-Neogene forms; some of them range from Cretaceous till present (Table 4). A third part of the taxa are reported from Neogene, two only from strata older than Neogene (*Pseudopodosira wittii*, *Stephanopyxis turris* v. *arctica*) and some other taxa are reported from the Oligocene/Miocene boundary strata (e.g. *Actionoptychus senarius*, *Cocconeis vitrea*). Taking into account that lower limits of the stratigraphical ranges of many Neogene taxa are lowered with time (see p. 157), the taxa known in the literature as appearing only in Miocene are not conclusive for a Miocene age. The indications of Oligocene age are also inconclusive. The most justified appears the conclusion that the assemblage of the Piątkowa horizon dates from the Oligocene/Miocene boundary time, i.e. from the Eggerian. The data from other groups of fossils studied in the Niebylec shales are also inconclusive. According to Nowak (1979) and Nowak *et al.* (1985), planktonic foraminifers indicate an Early Miocene age, while Kotlarczyk (1985), basing on calcareous nannoplankton, dates these strata at the latest Oligocene. Conclusive paleontological data on the position of the Oligocene/Miocene boundary in the Skole unit sequence are still absent.

The assemblage from Piątkowa has no equivalents in the described assemblages from the uppermost Oligocene—lowermost Miocene. It has only ten taxa in common with the Eggerian assemblage from Wallern which includes more than one hundred taxa. Three of the common taxa have not been reported from the deposits older than Late Oligocene (Řehakova, 1975). There are four taxa common with the Upper Oligocene assemblage from Mangyshlak (Zhuze, 1978; and if the subspecies are excluded, there are seven common species) of which two have a narrow range (*Actinoptychus thumii* and *Raphoneis gemmifera*). Only three taxa are common with Lower Miocene assemblage from the Shibik area (Sheshukova-Poretskaya & Gleser, 1962), one of them unknown in strata older than Miocene (*Thallasionema obtusa*). These data corroborate our conclusion on the age of the Piątkowa horizon.

FINAL REMARKS

Both diatom-horizons are related to the facies of brown and black bituminous, argillaceous — siliceous shales, and both represent the same, neritic-sublittoral, type of biocoenosis. They are separated by the nearly whole thickness of Menilite Beds.

The separation is equivalent to the nearly whole duration of the Oligocene i.e. about 12.9 m.y. (cf. Berggren *et al.*, 1985). The analysis of about 30 dominant taxa from each horizon revealed that the assemblages differ significantly. Only three long-ranging and one Palaeogene (*Pseudopodosira wittii*) taxa are common for both horizons. The horizons can be easily identified, even in assemblages reduced to only a few taxa.

One of the reasons for the differences in the composition of the diatom assemblages in both horizons is the marked difference in age. Another reason are the different origins of diatom taphocoenoses in both horizons. The assemblage of the Futoma horizon is almost autochthonous, partly redistributed on the basin bottom. The diatoms of the Piątkowa horizon are allochthonous. The turbidity transport resulted in winnowing of the taxa with finer and lighter frustules. The difference between the two horizons consists also in the presence of few brackish and fresh-water taxa in the Futoma horizon.

A possibility for a more detailed biostratigraphic division of the Futoma horizon is suggested by its slow deposition during a long time (about 10 metres during one million years), accompanied by slight, but noticeable qualitative and quantitative changes in the composition of the assemblage. There is no vertical compositional variation in the Piątkowa horizon, probably due to the mixing by turbidity currents. The duration of the Piątkowa horizon deposition is tentatively estimated at 100—200 thousand years.

The appearance of the neritic-sublittoral assemblage of the Futoma horizon coincides with the shallowing of the depositional basin of Menilite Beds, registered in fish assemblage (IPM—2 zone of Kotlarczyk & Jerzmańska, 1976; Jerzmańska & Kotlarczyk, 1981).

The patchy development of the Futoma horizon, with limited zones of maximum development separated by areas where the horizon is thin or absent, reflects lateral differences in the conditions of deposition in the basin. The investigated diatom--rich deposits were laid down in local depressions of the basin slope with a very small supply of sand, in a sea which was possibly shallowed; perphaps within the zone of fluvial influence reflected in the supply of the fresh-water taxa.

Similar areal restriction of the Piątkowa horizon and the limited lateral extents of individual layers, are in this case related to the limited areal extent of the turbidity currents which carried the diatoms from the neritic uzone to the deeper parts of the basin.

The diatom assemblages permitted approximate dating of both horizons, proving in this way that diatoms can be effectively used for stratigraphical purposes in the Carpathian flysch.

SYSTEMATIC DESCRIPTIONS

This chapter contains descriptions of selected most abundant diatoms from the Futoma and Piątkowa horizons.

Division: *Baccillariophyta*
Class: *Centricae*
Melosira architecturalis Brun, 1892 (in Schmidt *et al.*, 1874—continuing)
Pl. I: 1, 2

Description: Frustule flat. Valves flat, 30—48 μm in diameter. Margin of valve shows radial striae, 8—10 striae in 10 μm, extending up to the half of the valve diameter. Striae punctate. Puncta less distinct toward the valve margin, more sparse and less regularly distributed toward the centar.
Occurrence: Futoma horizon.

Melosira praeislandica Zhuze, 1952
Pl. I: 3, 4

Description: Frustule cylindrical, 7—12 μm in diameter, 9—18 μm in height, thick-walled, strongly silicified, oriented mostly in girdle view, arranged in long, thread-like colonies. Valves flat, covered with irregularly distributed puncta which become coarser near valve margin. Collumn short. Mantle short, shows elongate, slightly spiral rows of puncta, 10—11 rows in 10 μm, which are also arranged in transversal rows, 12—13 rows in 10 μm.
Occurrence: Futoma horizon.

Melosira clavigera Grunow, 1882 (in: Van Heurck, 1882)
Pl. VII: 7

Description: Frustule drum-shaped. Valves nearly flat, with a gradually arching central part. Diameter 55—83 μm. Ornamentation consists of radial, wedge-shaped striae, narrowing toward the center of valve. The outer part of striae differs from the inner one by the presence of an oval structure resembling alveolus. The edge of the valve is occupied by a band of fine, hexagonally distributed puncta, 18—20 puncta in 10 μm. Central area usually hyaline.
Occurrence: Piątkowa horizon.

Melosira omma Cleve, 1885
Pl. VII: 8

Description: Valves slightly convex, most strongly in the central part. Diameter 30—37 μm. Outer edge shows short striae, 10—12 in 10 μm. Center of valve occupied by thick, radial striae (probably hollows with thickened edges), narrowing markedly toward the center and showing broader, bluntly rounded ends; 5 striae in 10 μm. Central area usually small, probably due to small size of available specimens (smaller than indicated on the original illustrations).
Occurrence: Piątkowa horizon.

Paralia sulcata (Ehrenberg) Cleve, 1873
Pl. II: 1, 2, 4, 5

Description: Short cylindrical frustules found as single valves and fragments of filamentous colonies. Valve 8—20 μm in diameter. Edge of valve undulate. Marginal chambers small, 5 in 10 μm. Larger specimens show fine puncta in the front of the chambers. Center of valve shows either long, radial striae reaching nearly the center, or short radial striae which do not extend onto the hyaline central area, or concentrically distributed thickenings. Mantle covered with parallel punctate rows, 24 puncta in 10 μm, separated by narrower and broader hyaline bands.
Occurrence: Futoma and Piątkowa horizons.

Paralia sulcata (Ehrenberg) Cleve, 1873 var. *crenulata* (Grunow) Frenguelli 1924
Pl. II: 3

Description: Valves 15–20 μm in diameter, differing from the type specimens in having strongly undulating valve edge, which makes an impression that marginal chambers occur beyond the valve margin.

Occurrence: Futoma horizon.

Paralia sulcata (Ehrenberg) Cleve, 1873 var. *biseriata* Grunow, 1884
Pl. VIII: 6

Remarks: This species differs from the type specimens in having two concentrical rings of chambers on the valve margin, 6 chambers in 10 μm.

Occurrence: Piątkowa horizon.

Pseudopodosira witti (Schultz) Vekshina, 1961
Pl. I: 5–7

Description: In girdle view, frustule shows characteristic stepped valve face, so that it appears to consist of two flat discs superimposed one upon another. The smaller disc often reveals hollows-like variable ornamentation. Valves circular, 23–32 μm in diameter. A marked ring of delicate puncta, 20 in 10 μm, arranged in a hexagonal pattern, present at valve margin.

Occurrence: Futoma and Piątkowa horizons.

Pseudopodosira sp.
Pl. VIII: 1

Description: In girdle view, frustule in the shape of bi-convex lens. Valve 23–40 μm in diameter, consisting of two parts: a gradually domed peripheral part and a superimposed, highly domed central part. The latter extends 1/3 to 1/2 of the valve diameter. Central dome, 10–15 μm in diameter, free of ornamentation. Marginal part of valve covered by more or less regularly distributed thick protrusions. Outer edge bears fine spines, 8–10 in 10 μm, which are visible in the girdle view while in valve view they appear as puncta.

Comparison: In structure and ornamentation the valves under description correspond most closely to the genus *Pseudopodosira* Jouse. They also resemble to high extent the form described by Ehrenberg (1845) as *Hyalodiscus laevis*, whose outer margin is ornamented by puncta, which are seldom visible under light microscope.

Occurrence: Piątkowa horizon.

Coscinodiscus cf. *subtilis* Ehrenberg, 1843
Pl. II: 6, 7

Description: In girdle view, valve drum shaped, 30–69 μm in diameter, arching regularly nearly to the center which has a shallow, concentric depression or a convexity. Surface of valve covered with polygonal areolae which vary in size from 9–13 in 10 μm in the central part to 14–20 in 10 μm in the outer part. Areolae arranged in straight radial rows gathered in fasciae, 4 to a dozen or so on each valve. Some of the longest rows show in their innermost part a concentric rather than radial arrangement of the areolae. Marginal areolae fine, set apart from the valve face ornamentation. At the boundary between adjacent fasciae there occur marginal processes.

Comparisons: This taxon resembles *C. subtilis*, especially *C.* near *subtilis* (van Landingham, 1964). It is distinguished from the type specimens by the finer ornamentation and the presence of concentric convexities and large marginal processes.

Occurrence: Futoma horizon.

Coscinodiscus marginatus Ehrenberg, 1843
Pl. IX: 1

Description: Frustule in the shape of a cylinder. Valve circular, nearly flat, 30–140 μm in diameter. Marginal zone broad, markedly striated, 4–6 striae in 10 μm. Entire surface of valve covered with a net of areolae arranged in irregular, radial and concentric rows. Areolae of similar size over the entire valve, 1.5–3 areolae in 10 μm in the center, 3–4 at the margin. Depending on focus, the areolae circular or polygonal, with pronounced foramen or a net-like membrane which is either complete or preserved only near the areola margins. Central area and rosette missing.

Occurrence: Piątkowa horizon.

Coscinodiscus argus Ehrenberg, 1838
Pl. IX: 7

Description: Valve slightly convex, especially in its central part, 36–96 μm in diameter. Valve ornamentation not uniform. Central area of variable size and irregular shape; in some specimens it appears as a gap between central areolae. Central rosette missing. Areolae, arranged in radial rows, decrease in diameter to the distance of about 2/3 radius from the center, 3–4.5 areolae in 10 μm near center and about 6–7 near 2/3 radius. Tangential, spiral rows particularly well marked within area covered by larger areolae. The outer ring consists of 2 rows of fine areolae, 8–9 in 10 μm.

Occurrence: Piątkowa horizon.

Coscinodiscus papillosus Hajos, 1968
Pl. IX: 2

Description: Valve highly convex, 12–31 μm in diameter, covered with radially orientated rows of areolae. Rows of areolae do not extend to the valve center, where there is an irregular central area. Areolae of variable size, large in the center, 5–6 in 10 μm, becoming finer marginwards where they are arranged in striae, 10–13 striae in 10 μm.

Occurrence: Piątkowa horizon.

Cestodiscus intersectus Brun, 1891
Pl. II: 8

Description: Frustule bi-convex in girdle view. Valve gradually arching towards its center which is often depressed. Valve, 17–40 μm in diameter, covered with marked radial striae composed of rounded polygonal areolae. In valve center the striae are often shortened irregularly, and there occurs a small, irregular central area. Tangential arrangement of areolae poorly developed. Areolae large in the center, 10–12 in 10 μm, diminishing in size outwards to 18–20 in 10 μm. Between the fine marginal areolae there occur a few (4–12) processes.

Occurrence: Futoma horizon.

Actinocyclus loczyi Pantocsek, 1892
Pl. III: 10, 11

Description: Frustule drum-shaped in girdle view. Valve 55–81 μm in diameter, has a strong central convexity. Ornamentation consists of circular, large areolae, 10–12 in 10 μm. Larger specimens show a central areolar pore (Pl. III: 11). Areolae occur in straight radial rows arranged in fasciae. Central area of variable size, circular, with 2–3 areolae in the middle. Wide valve face margin composed of fine, radially distributed areolae, 15–17 in 10 μm. Between fasciae there occur marginal processes surrounded by radially arranged hyaline areas.

Occurrence: Futoma horizon.

Actinocyclus aff. *cholnokyi* van Landingham, 1967
Pl. VII: 11

Description: Valve flat, 21–64 μm in diameter, with short mantle. Margin of valve covered with small areolae, 10–12 in 10 μm, arranged hexagonally. Between areolae there occur processes spaced at distance of a dozen or so areolae. The remainder of valve covered with radial rows of areolae, 4—5 in 10 μm. Spiral rows are less distinctly marked than the radial ones. In valve center, areolae less densely packed. Central area small, irregular, usually having about 1—3 free areolae. Valve center sometimes slightly depressed.

Occurrence: Piątkowa horizon.

Actinocyclus octonarius Ehrenberg 1838
Pl. VII: 12

Description: Frustules drum-shaped in girdle view. Valve 29—82 μm in diameter, convex, with the highest convexity in the center. Valve covered with large, circular areolae arranged in straight radial rows occurring in fasciae. Each fascia bounded mostly by a marked, long hyaline rib. Central area circular, or variable size, having 2—3 free areolae in the center. Marginal zone covered with hexagonally arranged areolae, 18—23 in 10 μm.

Occurrence: Piątkowa horizon.

Actinocyclus octonarius Ehrenberg 1838 var. *tenella* (Brebisson) Hustedt 1929
Pl. VII: 9

Description: Frustule drum-shaped in girdle view, less silicified than the type specimens. Diameter 30—42 μm. Valve flat, divided into 4—6 sectors which are defined by distinct radial rows of areolae. Within the sectors, areolae arranged in tangential rows. Marginal part of valve very narrow, finely punctate. The margin radially striated, about 20 striae in 10 μm. Central area missing.

Occurrence: Piątkowa horizon.

Actinocyclus octonarius Ehrenberg, 1838 var. *sparsa* (Gregory) Hendey 1904
Pl. VII: 10

Description: Valve slightly convex, 20—36 μm in diameter, covered with fasciae of areola rows of variable size. Fasciae separated by rows of radially arranged areolae extending nearly from the center to the margin of the valve. Surface of fascia filled more or less completely by radial and tangential rows of areolae. These rows are normally less packed near the center of valve, and there, the fasciae are very distinct. Areolae rows separating fasciae do not extend to the center of valve. Central area circular, with 2—3 free areolae. Areolae of the same size over the entire valve, 5—6 in 10 μm, only at the valve margin, they are smaller, and arranged in striae, 14—17 striae in 10 μm. Pseudonodulus invisible.

Occurrence: Piątkowa horizon.

Thalassiosira cf. *baltica* (Grunow) Østenfeld 1901
Pl. II: 13, 14

Description: Frustule drum-shaped in girdle view. Valve slightly convex, 18—30 μm in diameter. Ornamentation consists of rounded-polygonal areolae. Margin of valve covered with tangential rows of areolae, convex towards the center of the valve. Radial pattern of areolation poorly developed. Valve center shows areolae assembled in a chequred pattern. Areolae finer at the margin, 21—26 in 10 μm, coarsening inwards to 14—18 in 10 μm. Margin of valve covered with numerous labiate processes characteristic of this genus. They appear as darker dots at smaller magnifications in the light microscope. Central labiate process not yet observed.

Comparisons: This taxon is distinctive from all known species of *Thalassiosira* in the ornamentation of valve center. The distribution of processes and the ornamentation of valve margin are somewhat also similar in *T. baltica* (Makarova, pers. comm.).

Occurrence: Futoma horizon.

Trochosira spinosa Kitton, 1871
Pl. III: 1—4

Description: Ellipsoidal frustules found either as single specimens or as bead on a in thread-like colonies. Valve circular or oval, 10—13 μm in diameter, covered with radial to slightly spiral rows of puncta, 28 in 10 μm. Center of valve shows a distinct ring of processes holding fast frustules in the colony. Margin of valve often reveals a centrifugal costa, beyond which there begins valve mantle. The latter shows the same ornamentation as the valve itself.

Occurrence: Futoma horizon.

Hyalodiscus radiatus (Meara) Grunow, 1880 (in Cleve et Grunow 1880).
Pl. VIII: 2

Description: In girdle view, frustule lens-shaped, 36—58 μm in diameter. Valve circular, slightly convex. Margin of valve rather narrow (especially in larger specimens), covered with radial rows of areolae, about 16 rows in 10 μm. Umbilicus relatively large, 20—36 μm in diameter, often irregularly punctate.

Remarks: Beside typical forms, numerous other valves were found, showing a more delicate ornamentation (17—18 rows in 10 μm) typical of *H. radiatus* var. *arctica* Grunow. Nevertheless, these valves are here assigned provisionally to *H. radiatus*, since they were encountered in fragments only.

Occurrence: Piątkowa horizon.

Hyalodiscus scoticus (Kützing) Grunow, 1879
Pl. III: 8, 9

Description: Frustule drum-shaped in girdle view. Valve hemispherical, 21—32 μm in diameter. Central part finely punctate to about half the width of the valve. Marginal zone covered with hexagonally arranged areolae, 24—28 or more in 10 μm. The boundary between central and marginal zones marked by an irregular line. Margin of valve denticulate. Marginal rim narrow, hyaline.

Occurrence: Futoma horizon.

Stephanopyxis turris (Greville et Arnott) Ralfs, 1861 (in Pritchard, 1861)
Pl. III: 5—7

Description: Frustule cylindrical (assemblages from Piątkowa horizon) or ellipsoidal (assemblages from Futoma horizon), in some cases composed of valves of different height. Valve 27—48 μm in diameter (Piątkowa horizon) or 50—80 μm (Futoma horizon), 12—38 μm in height (Piątkowa horizon) or 30—60 μm (Futoma horizon), varying in convexity and shape, bell like or with bulbous, inflated top. Valve and mantle covered with polygonal (mostly hexagonal) areolae, 2.5—5 in 10 μm (Piątkowa horizon) or 3—4 in 10 μm (Futoma horizon), often distributed hexagonally. At about half of the valve diameter, there occurs a ring of spines. Most are broken off and traces of spine bases can only observed.

Occurrence: Futoma and Piątkowa horizons.

Stephanopyxis turris (Greville et Arnott) Ralfs, 1861 (in Pritchard, 1861) var. *arctica* Grunow, 1884
Pl. VIII: 3

Description: Valve strongly convex, 32—40 μm in diameter. Entire valve surface covered with polygonal areolae which often reveal a perforated sieve membrane, 3—4 areolae in 10 μm.

Remarks: The present specimens are smaller than those described by Grunow; they also differ from the type specimens in having strongly deflected hyaline edge of the mantle.

Occurrence: Piątkowa horizon.

Stephanopyxis turris (Greville et Arnott) Ralfs 1861 (in Pritchard, 1861) var. *intermedia* Grunow, 1884
Pl. VIII: 4

Description: Valve 19–45 μm in diameter, more robust and having thicker walls between areolae than the type specimens. About 3–4 areolae in 10 μm. Mantle margin can be slightly deflected, hyaline (transparent) edge missing. No spines were observed.

Occurrence: Piątkowa horizon.

Stephanopyxis corona (Ehrenberg) Grunow, 1882 (in Van Heurck, 1882)
Pl. VIII: 5

Description: Frustule sphaerical, 28–68 μm in diameter. Valve circular, flat with low mantle. Valve covered with circular areolae arranged hexagonally in decussating rows so that tangential rows are more pronounced than radial ones, 3–5 areolae in 10 μm. Valve mantle shows the same areolation pattern. Two valves of a frustule differ in the ornamentation: one has distinct, large spines arranged in a dense ring occurring close to the valve margin (free ends of the spines branch off two- or three times), the other has the entire surface covered by randomly distributed spines of variable size.

Occurrence: Piątkowa horizon.

Actinoptychus senarius (Ehrenberg) Ehrenberg, 1843
Pl. IV: 1–5

Description: Frustule drum-shaped in girdle view. Valve 20–83 μm in diameter. Surface of valve divided into 6 sectors alternately depressed and elevated. Sectors covered with a net of polygonal (mostly hexagonal) lumina. This ornamentation much better marked on the elevated sectors, 3–6 lumina in 10 μm. Sectors are also covered by fine, radially arranged puncta, 16–24 puncta in 10 μm on the elevated sectors, 10–15 in 10 μm on the depressed sectors. Elevated sectors have labiate processes which occur in the middle of sector base (Piątkowa assemblages). Central area circular, smooth. Valve margin shows puncta having the same density distribution pattern as that on the depressed sectors.

Occurrence: Futoma and Piątkowa horizons.

Actinoptychus senarius (Ehrenberg) Ehrenberg var. *tamanicus* (Jouse) Hajos, 1968
Pl. IV: 6–7

Description: Frustule drum-shaped in girdle view, 26–42 μm in diameter. Valve as in nominate variety covered with a net of costae, 4–5 lumina in 10 μm, and with radially distributed puncta. About 20 puncta in 10 μm over the entire surface of the valve. Valve face with two elevated and two depressed sectors.

Remarks: This species is distinctive from typical valves of *A. senarius v. tamanicus* in poorer differentiation of two elevated and two depressed sectors.

Occurrence: Futoma horizon.

Actinoptychus thumii (A. S.) Hanna, 1932
Pl. VIII: 8

Description: Frustule in the shape of a bi-convex lens, 40–70 μm in diameter. Valve surface divided into 6 sectors of the same ornamentation, areolae fine 10 in 10 μm on the sectors and the valve face margin. Areolae in hexagonal pattern when in focus. Central portions of sectors with no ornamentation. Elevated sectors have one, centrally located labiate process surrounded by a hyaline area. Central area irregular, smooth.

Occurrence: Piątkowa horizon.

Cymatogonia amblyoceras (Ehrenberg) Hanna, 1932
Pl. X: 1

Description: Valve triangular, length of side 43—69 μm. Valve divided into sectors, 3 depressed and 3 elevated, devoid of processes. Valve covered with large, tightly packed polygonal areolae which are arranged in radial rows and secondarily in a roughly concentric pattern around the center. Central pore visible in the areolae. Center of valve shows a small, irregular central area.
Occurrence: Piątkowa horizon.

Xanthiopyxis diaphana Forti, 1913
Pl. X: 3

Description: Frustule flat, short. Valve elongate, linear, broadly elliptical, with rounded ends. Length 15—44.2 μm, width 5—15.5 μm. Valve covered with vague, irregularly distributed puncta. Margin of valve shows a transparent silica band, typical of this taxon.
Remarks: Smaller forms than those of the type material were also found in this assemblage.
Occurrence: Piątkowa horizon.

Xanthiopyxis oblonga Ehrenberg, 1844/1845
Pl. IV: 8, 9

Description: Valve elliptical-elongate, convex, with widely rounded apices. Length 20—22 μm, width 7.5—11.0 μm. Entire valve surface covered evenly with short or long, sharp-pointed spines. Center of valve often shows coarse, widely spaced puncta.
Occurrence: Futoma horizon.

Xanthiopyxis papillosus Hajos, 1968

Description: Valve elliptical-elongate, with widely rounded apices. Length 16—22 μm, width 14—16 μm. Valve covered with long, sharp-pointed spines, usually 2—4 spines in 10 μm.
Occurrence: Futoma horizon.

Chasea ornata Hajos et Stradner, 1975
Pl. V: 1, 2

Description: Valve elliptical, with blunt, widely rounded ends. Length 20—25 μm, width 16—17 μm. Center of valve has a small, marked dome. Valve surface covered with randomly scattered fine puncta. Margin of valve shows marked coarse puncta (spines?), about 2—8 in 10 μm.
Occurrence: Futoma horizon.

Hemiaulus sporalis Strelnikova, 1974
Pl. V: 4

Description: Frustule lenticular in girdle view. Valve slightly convex, ovate, sometimes with slightly pointed ends. Length 24—100 μm, width 14—40 μm. Center of valve covered with rows of puncta arranged radially or randomly. Valve margin carries spines which sometimes form arcuate costae, 2—4 in 10 μm.
Occurrence: Futoma horizon.

Hemiaulus cf. *malleolus* Pantocsek, 1886
Pl. V: 5—7

Description: Frustule short-elliptical, 8—15 μm in diameter, with a high mantle (7—17 μm). Center of valve slightly downwarped or convex. Horns 24—33 μm in length, straight, slightly arcuate, or flexuous to irregularly curved. Horns terminated with single spines, in each specimen spines of the same length. Valve covered with randomly distributed areolae of variable size. Areolae show a vague radial pattern near the base of the horns. About 4–6 areolae in 10 μm on the valve, 6–8 in 10 μm on horns.

Remarks: The specimens observed in this assemblage are highly variable in the shape and the ornamentation pattern. They seem to show the closest affinity to *H. malleolus*, *H. curvatulus* and *H. pungens*. From *H. curvatulus* these specimens are distinctive in the larger size, subtler ornamentation and the inward location of the spines. From *H. pungens* they differ in the smaller size, the presence of straight horns, rapheless valve and the central location of the spines.

Occurrence: Futoma horizon.

Odontella cornuta (Brun) Schrader, 1976
Pl. VI: 5, 7

Description: Frustules large, seldom complete, observed only in girdle view. Valve elliptical, 57 μm long, with a high mantle (up to 27 μm) and several girdle bands. Center of valve flat. Apices show two short bow-shaped horns. Between the horns 4 setae, two long (longer than the horns) and 2 short (of the horn height). Setae most often straight, bow-shaped or rarely undulated. Fine, circular areolae, 14–18 in 10 μm, regularly distributed over the entire valve. Areolae arranged in straight parallel rows on the girdle bands and at the valve margin. Encountered fragments of valve show a radial areolation, while horns a spiral one.

Occurrence: Futoma horizon.

Odontella fimbriata (Greville) Schrader, 1976
Pl. VI: 6, 8

Description: Observed specimens were all in girdle view. Valve 15–17 μm in diameter, with a high mantle, about 20 μm in height. Width of girdle bands equals mantle height. Short horns (10–16 μm) deflected arcuately toward the valve center. Between horns on the valve there occur 2 setae, which are mostly bow-shaped, seldom nearly straight, markedly longer than the horns. Center of valve slightly concave. Fine, circular areolae, 14–16 in 10 μm, fill regularly valve face, margin, mantle and girdle bands. Areolae arranged in straight, parallel rows on valve margin and girdles, in slightly spiral rows on horns, and in radial rows on valve face. Transversal raphae lacking.

Occurrence: Futoma horizon.

Triceratium condecorum Ehrenberg, 1844/1845
Pl. VI: 1, 2

Description: Frustule flat. Valve triangular, sides straight, 38–50 μm long, apices bluntly rounded and finely punctate. The remainder of valve surface covered by polygonal areolae, 6–7 in 10 μm at valve margin and 5 in 10 μm near center. At valve margin areolae arranged in straight, short radial rows. Valve center usually domed, has less orderly distributed areolae showing a more concentric arrangement than that near the margin. Center of valve shows single fine puncta between areolae. Central area either vaguely marked or missing.

Occurrence: Futoma horizon.

Triceratium tesellatum Greville, 1861
Pl. VI: 3, 4

Description: Frustule flat. Valve triangular, has straight, sides 15–17 μm long, with sharp-pointed finely punctate apices. The remainder of valve covered with round, polygonal areolae, 9 in 10 μm, arranged radially at valve margin and concentrically near the center. Valve center domed, lacking central area.

Occurrence: Futoma horizon.

Chaetoceros compressus Lauder, 1864
Pl. V: 8—10

Description: This species was observed in the form of spores only. Setae belonging probably to specimens of this species were found occasionally. Spores provided with valves of different convexity, smooth, sometimes having 2—3 small spines located in the center of epivalve. The latter is normally more convex and has an edge of quite coarse granules at its margin. Spore 6—21 μm in height, 10—16 μm in width. Specimens larger than those originally described were also found.

Occurrence: Futoma horizon.

Chaetoceros robustus Makarova, 1962
Pl. V: 11—13

Description: This taxon was observed as spores only. Epivalve convex, covered with numerous spines. Some of them are markedly high. The margin of the valve has 1—2 rows of puncta which in some specimens are very fine. Hypovalve less convex, covered more or less regularly with spines. Valves 10—18 μm in diameter, 6—10 μm in height.

Occurrence: Futoma horizon.

Rhizosolenia sp., type of setae *Rh. setigera* Brightwell, 1858
Pl. VII: 1, 2

Description: This taxon is represented only by parts of valve faces and setae. Ornamentation of valve face extremely fine, 26—30 puncta in 10 μm. Setae sinuous, irregular or S-shaped, 43—59 μm long, having a central canal which widens markedly in the middle of the seta. Tip of seta in the form of a short solid spine.

Remarks: The setae observed in this assemblage are distinctive from the setae of known species of *Rhizosolenia* in having more curved shape and from *Rh. setigera* in being longer.

Occurrence: Futoma horizon.

Pyxilla prolongata Brun, 1893
Pl. VI: 9—11

Description: Frustule high-cylindrical. Valve with very high processes. Only fragments of valves were encountered. Processes 6—10 μm in diameter, up to 135 μm in length, covered with slightly rounded, polygonal areolae, 3 in 10 μm. Areolae arranged in linear and spiral rows, 4 in 10 μm. Terminal part of processes partly devoid of ornamentation, partly covered with small puncta arranged as densely as the areolae. Four hyaline spines of variable size are situated on tips of processes.

Occurrence: Futoma horizon.

Biddulphia longispina (Grunow) De Toni, 1894
Pl. VIII: 7

Description: This species occurs only as broken parts of valves. Valve apices in the form of horns, up to 30 μm high. Valve flat between the horns. Middle part of valve shows a hyaline keel bearing 6 spines higher than the horns. Spines have a central canal. The keel is thicker in places, forming costae, 6—8 in 10 μm. Valve covered with relatively coarse areolae, 12 in 10 μm.

Remarks: These fragments remind of the genus *Biddulphia*. No complete frustule of this diatom has been reported so far in the literature.

Occurrence: Piątkowa horizon.

Class: *Pennatae*

Sceptroneis grunowii Anissimova, 1949 (in Proshkina-Lavrenko, 1949—1950)
Pl. VI: 12, 13

Description: Valve lanceolate, gradually tapering, with capitate apices. Length 24—48 μm, width 5.0—5.9 μm. Transverse striae perpendicular, 9—10 striae in 10 μm, composed of coarse areolae, 2—5 in the stria. Axial area missing. Central area vague, extremely narrow.

Occurrence: Futoma horizon.

Rhaphoneis amphiceros Ehrenberg, 1844
Pl. VII: 3

Description: Valve broadly elliptical or lanceolate, with more or less extended, acute apices. Length 33—62 μm, width 15—18 μm. Transverse striae thick, 6—7 in 10 μm, having coarse areolae arranged in rows which are parallel to the valve margin. Axial area narrow lanceolate.

Occurrence: Futoma horizon.

Rhaphoneis gemmifera Ehrenberg, 1844
Pl. IX: 5

Description: Valve broadly lanceolate, with elongated, bluntly rounded apices. Length 35—60 μm, width 20—25 μm. Valve covered with coarse areolae, 4 in 10 μm, arranged in radial rows and sometimes in secondary longitudinal rows parallel to the valve margin. Axial area very narrow near the apices, gradually widenning into a lanceolate central area.

Remarks: The type specimens of this species have finer areolae.

Occurrence: Piątkowa horizon.

Thalassionema aff. *obtusa* (Grunow) Andrews, 1976
Pl. IX: 6

Description: Valve needle-shaped, gradually narrowing into rounded apices. Length of valve 40—87 μm, possibly larger, as complete valves were observed only exceptionally. Valve widest in middle part (4.5—6 μm). Valve margin shows thick, short striae, 9—10 in 10 μm.

Remarks: The specimens in this assemblage are distinctive from typical forms in being longer and always irregularly twisted (teratological?). Slightly bent valves were reported, but not figured, by Sheshukova-Poretskaya (1967). The observed specimens are strongly silicified and this feature makes them similar to *T. robusta* Shrader (1969) from which they differ in being longer and narrower.

Occurrence: Piątkowa horizon.

Grammatophora marina (Lyngbye) Kützing, 1844
Pl. X: 6

Description: Frustule rectangular in girdle view. Each girdle band bears one long, usually straight septa, sometimes the septa is slightly undulated near the apices. Valve elongate, nearly linear, 60—92 μm long, 7—16 μm wide. Apical parts bluntly rounded. Striae fine, 18—20 in 10 μm, puncta distributed hexagonally.

Occurrence: Piątkowa horizon.

Grammatophora sp.
Pl. VII: 4—6

Description: Valve elliptical-lanceolate, tapering gradually to sharp, elongated apices. Length 14—18 μm, width 3—7 μm. Transverse striae markedly punctate, 10—12 puncta in 10 μm. Axial area very narrow. Central area not differentiated. In girdle view, the septae show a central, drop-like termination.

Remarks: This taxon is similar in size to *Rhabdonema minutum* Kützing (1844), but the presence of two septae is sufficient for its assignement to the genus *Grammatophora*.
Occurrence: Futoma horizon.

Cocconeis praecellens Pantocsek, 1886
Pl. IX: 3

Description: Valve broadly elliptical, 47–56 μm long, 30–37 μm wide. Epivalve covered with transverse radial striae, 11–14 in 10 μm, disrupted by two or more, narrow, hyaline bands. Striated band at the middle valve bears globular thickenings arranged in longitudinal rows. Striated bands arranged parallel or in an undulatory fashion to the valve margin. The most central longitudinal band is in some specimens disrupted in the central area. Axial area broadly or narrowly lanceolate, or in the shape of an "8". Central area not differentiated. Hypovalve (preserved only on fragments) less silicified, showing similar though finer ornamentation, about 24 striae in 10 μm.
Occurrence: Piątkowa horizon.

Cocconeis vitrea Brun, 1891
Pl. IX: 4

Description: Frustule broadly elliptical, 43–78 μm long, 30–48 μm wide. Epivalve covered with transverse radial striae disrupted by wide, lanceolate, ornament-free areas. This results most often in the formation of four longitudinal bands of transverse striae, each band having in the center a longitudinal row of puncta, 11–12 puncta and striae in 10 μm. Axial area broadly lanceolate, passing gradually in to an undifferentiated central area. Ornamentation of hypovalve (preserved in fragments) shows that transverse striae are not disrupted with ornament-free sectors. Striae composed of a single row of fine puncta, 18 striae in 10 μm.
Occurrence: Piątkowa horizon.

Diploneis nitescens (Gregory) Cleve, 1894
Pl. X: 5

Description: Valve broadly elliptical, with gradually tapering apices. Length 42–109 μm, width 30–44 μm. Central nodule relatively large, ovate, having at its base wide processes, which taper rapidly towards the valve apices. Striae short (6–7 in 10 μm), show two alternate rows of puncta. The costae and striae extend to about half of the valve width. Remainder of valve occupied by very broad longitudinal canals, divided into longitudinal chambers of the same width as the striae, perforated with irregularly scattered puncta.
Occurrence: Piątkowa horizon.

Diploneis szontaghii (Pantocsek) Cleve, 1894
Pl. X: 4

Description: Valve elongate-elliptical, with wide, bluntly rounded apices. Length 39–50 μm, width 20–21 μm. Central nodule large, square. Axial area at the central area distinct and relatively wide. Canals narrow. Striae seem to consist of two large alveoli. Striae and costa equal in width 5–6 in 10 μm.
Occurrence: Piątkowa horizon.

Pleurosigma normanii Ralfs var. *marylandica* Grunow, 1880 (in: Cleve et Grunow, 1880)
Pl. X: 2

Description: This taxon was observed in the assemblage only as fragments of most robust central parts of valves. Length of the observed fragments up to 106 μm, width 20–41 μm. The shape of the raphae indicates that the valves may be slightly S-shaped. Axial area narrow. Central area small, circular. Valve covered with rows of circular, hexagonally arranged aroelae. Longitudinal and transverse rows of areolae show the same density, 15–16 rows in 10 μm. Transverse rows become more conspicuous close to the valve margin and the raphae, but their density remains unchanged.

Occurrence: Piątkowa horizon.

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REFERENCES

Andrews, G. W., 1976. Miocene marine diatoms from the Choptank Formation, Calvert County, Maryland. *U.S. Geol. Surv. Prof. Pap.*, 910: 1–24.

Barron, J. A., 1975. Marine diatom biostratigraphy of the Upper Miocene – Lower Pliocene strata of Southern California. *J. Paleont.*, 49: 619–632.

Berggren, W. A., Kent, D. V., Flynn, J. J. & Van Couvering, J. A., 1985. Cenozoic geochronology. *Geol. Soc. Am. Bull.*, 96: 1407–1418.

Blaicher, J. & Nowak, W., 1963. Mikrofauna otwornic łupkowej serii warstw krośnieńskich z Niebylca (południowa część jednostki skolskiej na S od Rzeszowa). (In Polish). *Kwart. Geol.*, 7: 711.

Brigtwell, T., 1858. Remarks on the genus *Rhizosolenia* of Ehrenberg. *Quarterly J. Microscop. Science*. 6: 93–95.

Brun, J., 1891. Diatomées espèces nouvelles marines, fossiles ou pélagiques. *Mem. Soc. Phys. Hist. Nat., Genève*. 31 (1): 1–47.

Brun, J., 1893. Notes sur quelques especes nouvelles (de Diatomées). *Le Diatomiste*, 1: 173–177.

Cleve, P. T., 1873. On diatoms from the Arctic Sea. *Bihang till Kongl. Svenska Vetensk.-Akad., Handlingar*, 1 (13): 1–28.

Cleve, P, T., 1885. On some fossil marine diatoms found in the Moravian "Tegel" from Augarten near Brünn. *J. Quekett Microscop. Club*, ser. 2, vol. 2: 165–177. London.

Cleve, P. T., 1894–1895. Synopsis of the naviculoid diatoms. *Kongl. Svenska Vetensk.-Akad., Handlingar*, 26–27; 1–194; 1–219.

Cleve, P. T. & Grunow, A., 1880. Beiträge zur Kenntnis der arktischen Diatomeen. *Kongl. Svenska Vetensk.-Akad., Handlingar*, 17 (2): 121 pp.

Dzinoridze, R. N., Jouse, A. P., Koroleva-Golikowa, G. S., Kozlova, G. K., Nagayeva, G. S., Petrushevskaya, M. G. & Strelnikova, N. J., 1976. Diatom and radiolarian Cenozoic stratigraphy, Norwegian Basin; DSDP Leg. 38. In: Talvani M., Udintzew G., *et al.*, *Initial Reps. DSDP*, 38: 289–427.

Ehrenberg, C. G., 1838. *Die Infusionsthierchen als vollkommende Organismen. Ein Blick in das tiefere organische Leben der Natur*. Leopold Voss, Leipzig. 548 pp.

Ehrenberg, C. G., 1843. Verbreitung und Einfluss des mikroskopischen Lebens in Süd- und Nord--Amerika. *Abh. Kön. Akad. Wiss.*, Jahr 1841. Berlin, Erster Teil, 291–443.

Ehrenberg, C. G., 1844. Mittheilung über zwei neue Lager von Gebirgsmassen aus Infusorien als Meeres-Absatz in Nord-Amerika und eine Vergleichung derselben mit den organischen Kreide-Gebilden in Europa und Afrika. *Ber. Bekann. geeign. Verh. preus. kön. Akad. Wiss.* Berlin, pp. 57–97.

Ehrenberg, C. G., 1844/1845. Untersuchungen über die kleinsten Lebensformen in Quellenlande des Euphrats und Araxes, so wie über eine an neuen Formen sehr reiche marine Tripelbildung von den Bermuda—Inseln vor. *Ber. Bekann. geeign. Verh. preus. kön. Akad. Wiss.* Berlin, 253—275.

Ehrenberg, C. G., 1845. Neue Untersuchungen über das kleinste Leben als geologisches Moment. Mit kurzer Charakteristik von 10 neuen Genera und 66 neuen Arten. *Ber. Bekann. geeign. Verh. könig. preus. Akad. Wiss.* Berlin. p. 53—88.

Filipescu, M. G. & Krestel, S., 1959. Studiul diatomeelor din oligocenul pîntetului de Văleni. *An. Univ. C. I. Parhon, Ser. Şt. Naturii Geol.-Geogr.*, 22: 171—182.

Forti, A., 1913. Contribuzioni diatomologiche. XIII. Diagnoses Diatomacearum quarumdam fossilium italicarum. *Atti reale Instit. Veneto Sci., Lettere Arti.*, 72 (2): 1535—1700. Venezia.

Frenguelli, J., 1923—1924. Resultados de la Primera Expedicion a Tierra del Fuego (1921). Diatomeas de Tierra del Fuego. *An. Soc. Cient. Argent.*, 96: 225—263 (1923); 97: 87—118, 231—266 (1924); 98: 5—63 (1924).

Gombos, A. M., 1976. Paleogene and Neogene diatoms from the Falkland Plateau and Malvinas outer basin; Leg. 36. In: *Initial Reps. DSDP*, 36: 575—689.

Gombos, A. M. jr. & Ciesielski, P. F., 1983. Late Eocene to Early Miocene diatoms from the Southwest Atlantic. *Initial Reps. DSDP*, 71: 583—634.

Greville, R. K., 1861. Descriptions of new and rare diatoms. *Transactions Microscop. Soc. London. 9* (new ser.): 39—45, 67—87.

Grunow, A., 1879. New species and varieties of *Diatomaceae* from the Caspian Sea. *J. Royal Microscop. Soc.*, 2: 677—691.

Grunow, A., 1884. Die Diatomeen von Franz Josefs-Land. *Denkschr. der Math.-Naturwiss. Classe: Kais. Akad. Wiss.*, pp. 53—112.

Gruzhiy, D. V. & Ripun, M. B., 1970. O dyatomitah v oligocenie skybovoy zony Karpat. *Dokl. Ak. Nauk SSSR*, 195: 163—165.

Hajos, M., 1968. Die Diatomeen der miözanen Ablagerungen des Matra Vorlandes. *Geolog. Hungarica, ser. Paleont.*, 37: 1—401.

Hajos, M., 1976. Upper Eocene and Lower Oligocene *Diatomaceae, Archaeomonadaceae* and *Silicoflagellatae* in southwestern Pacific sediments, Leg. 29. In: Hollister, C. D., Craddock, C., et al.: *Initial Reps. DSDP*, 35: 817—883.

Hajos, M. & Stradner, H., 1975. Late Cretaceous *Archaeomonadaceae, Diatomaceae* and *Silicoflagellatae* from the South Pacific Ocean, Leg. 29, Site 275. In: *Initial Reps. DSDP*, 29: 913—1009.

Hanna, G. D., 1932. The Diatoms of Sharktooth Hill, Kern County, California. *Proc. Calif. Acad. Sci. Ser. 4*, 20 (6): 161—263.

Hendey, N. I., 1937. The plankton diatoms of Southern Seas. *Discovery Reps.*, 16: 151—364.

Hendey, N. I,. 1904. An introductory account of the smaller algae of British coastal waters. Part V: *Bacillariophyceae* (diatoms). *Fisheries Investigations, Ser. IV*, HMSO, London, 317 pp.

Heurck, H., van, 1882. *Synopsis des Diatomèes de Belgique.* Atlas, p. 78—103. Ducaju et Cie., Anvers.

Hustedt, F., 1929. Die Kieselalgen Deutschland, Oesterreichs und der Schweiz. In: L. Rabenhorst, *Kryptogrammen Flora von Deutschland, Oesterreichs und der Schweiz.* 7 (3): 465—608. Akadem. Verlag, Leipzig.

Jerzmańska, A. & Jucha, S., 1963. L'affleurement de la faune de poissons dans les schistes de Jasło à Łubno près de Dynów (Karpates Polonaises). (In Polish, French summary). *Rocz. Pol. Tow. Geol.*, 33: 159—180.

Jerzmańska, A. & Kotlarczyk, J., 1981. Zmiany ewolucyjne ichtiofauny jako podstawa stratygrafii serii menilitowo-krośnieńskiej. (In Polish). *Zemni Plyn a Nafta*, 24 (1): 63—74.

Jouse, A. P., 1966. Diatomeen in sedimenten. *Arch. Hydrobiol.*, 4 (1—2): 1—32.

Kitton, F., 1870—1871. On diatomaceous deposits from Jutland. *J. Quekett Microscop. Club*, ser. 2, 99: 168—171. London.

Kotlarczyk, J., 1958. Preliminary results of investigations on Carpathian diatomites. (In Polish, English summary). *Prz. Geol.*, 6 (2): 67–72.

Kotlarczyk, J., 1966. Diatomite Horizon of the Krosno Beds in the Skole Nappe, Polish Carpathians (In Polish, English summary). *Studia Geol. Polon.*, 19: 129 pp.

Kotlarczyk, J., 1982. The role of diatoms in sedimentation and biostratigraphy of the Polish Flysch Carpathians. *Acta Geol. Acad. Sci. Hungaricae*, 25 (1–2): 9–21.

Kotlarczyk, J., 1985. An outline of the stratigraphy of marginal tectonic units of the Carpathian orogene in the Rzeszów–Przemyśl area; description of outcrops (stops) 12, 14, 29. In: Kotlarczyk, J. (ed.) – *Guide to excursion 4. Carpatho–Balkan Geological Association, XIII Congress, Cracow, Poland, 1985*. Geol. Inst., pp. 39–64; 103–107; 108–111; 145–148.

Kotlarczyk, J. & Jerzmańska, A., 1976. Biostratigraphy of Menilite Beds of Skole Unit from the Polish Carpathians. *Bull. Acad. Pol. Sci., ser. sci. Terre*, 24 (1): 55–61.

Kützing, J., 1844. *Die Kieselschaligen Bacillarien oder Diatomeen*. Nordhausen, 152 pp.; 1865 – 2 Auflage.

Landingham, S. L., van, 1964. Miocene non-marine diatoms from the Yakima Region in South Central Washington. *Beih. Nova Hedw.*, 14: 78 pp.

Landingham, S. L., van, 1967. Paleoecology and microfloristics of Miocene diatomites from the Otis Basin – Juntura Region of Horney and Malheur Counties, Oregon. *Beih. Nova Hedw.*, 26: 77 pp.

Lauder, H. S., 1864. Remarks on the marine *Diatomaceae* found at Hong Kong with descriptions of new species. *Trans. Microscop. Soc. London. N.S.*, 12: 75.

Makarova, I. V., 1962. Materialy k izucheniyu iskopayemykh spor vydov roda *Chaetoceros*. *Bot. Mater., Otd. Spor. Rast.*, 15: 41–57.

Makarova, I. V. & Kozyrenko, T. Ph., 1966. *Dyatomoviye vodorosly iz morskyh myotsenovyh otlozheniy juga evropeyskoy tchasty SSSR i ih znatcheniye dla stratigraphiy*. Izd. Nauka, Moskva. 69 pp.

Mandra, Y. T., Brigger, A. L. & Mandra, H., 1973. Chemical extraction techniques to free fossil Silicoflagellates from marine sedimentary rocks. *Proc. Calif. Acad. Sci., Ser.* 4, 39 (15): 273–284.

Mc Collum, D. W., 1975. Diatom Stratigraphy of the Southern Ocean. In: Hays, D. E., *et al.*, *Initial Reps. DSDP*, 28: 515–572.

Nowak, W., 1979. Niektóre jednostki lito- i biostratygraficzne i ich znaczenie dla korelacji najmłodszych utworów fliszu karpackiego. (In Polish). *Kwart. Geol.*, 23: 928–930.

Nowak, W., Geroch, S. & Gasiński, A., 1985. Oligocene/Miocene boundary in the Carpathians. In: *VIII Congress of the Regional Committee on Mediterranean Neogene Stratigraphy. 12–22 September, 1985, Budapest. Abstracts*. Hungarian Geol. Surv., pp. 427–429.

Østenfeld, C., 1901. Jagttagelser over Plankton–Diatomeen. *Nytt Magazin Naturvidensk.*, 39 (4): 287–302. Cristiania.

Pantocsek, J., 1886–1905. *Beiträge zur Kenntnis der Fossilen Bacillarien Ungarns*. Nagy Tapolcsany. Pozsony. Julian Platzko, I: 1–74 p., 1–30 pl., 1886; II: 1–123 p., 1–30 pl., 1889; III: 1–42 pl. 1892, 1–118 p., 1905.

Pritchard, A., 1861. *A history of Infusoria, living and fossil enlarged according to: "Die Infusioristhierdien" of C. G. Ehrenberg; containing colored engravings illustrative of all the genera and descriptions of all the species... 1842*. Ed. IV revised enlarged by J. T. Arlidge, W. Archev, J. Ralfs, W. C. Williamson and the author. Whittaker & Co., London, 968 pp.

Proshkina-Lavrenko, A. I., 1949–1950. *Dyatomoviy Analyz*. Kniga 2–3. *Opredelytel iskopayemyh i sovremennyh dyatomovyh vodorosley*. Izd. Geol. Lit. AN SSSR, Moskva, 398 pp.

Proshkina-Lavrenko, A. I., Gleser, S. I., Makarova, V. I., Sheshukova-Poretskaya, V. S. & Zhuze, A. P., 1974. *Dyatomoviye vodorosly SSSR, iskopayemiye i sovremyenniye*. T. 1. Izd. Nauka, Leningrad, 400 pp.

Řehakova, Z., 1975. Fossile Diatomen des Egerien. In: *Chronostratigraphie und Neostratotypen, Miozän OM Egerien*, Vyd. Slov. Akad. Vied., Bratislava.

Sawamura, K. & Yamaguchi, S., 1963. Subdivision of Miocene by fossil diatoms in the Tsubetsu area, East Hokkaido. *Bull. Geol. Surv. Japan*, 14 (10).

Schmidt, A., *et al.*, 1874-continuing. *Atlas der Diatomaceen-Kunde*. Heft 1—120, Tafeln 1—460. R. Reisland, Leipzig.

Schrader, H. J., 1969. Die Pennaten Diatomen aus dem Obereozän von Oamaru, Neuseeland. *Beih. Nova Hedw.*, 28: 124 pp.

Schrader, H. J. & Fenner, J., 1976. Norwegian Sea Cenozoic Diatom biostratigraphy and taxonomy. (Part I+II). In: Talwani, M., Udintsev, G. *et al.*, *Initial Reps. DSDP*, 38: 921—1099.

Sheshukova-Poretskaya, V. S., 1967. *Neogenovye morskye diatomoviye vodorosli Sakhalina i Kamchatki*. Izd. Leningr. Universit., Leningrad, pp. 1—432.

Sheshukova-Poretskaya, V. S. & Glezer, Z. I., 1962. Dyatomoviye vodorosly, silikophlagellaty i ebrideyi iz maykopskyh otlozheniy s r. Shibik. Uchen. *Zap. Lening. Gos. Univ., Ser. Biol. Nauk*, 49: 171—202.

Sikora, W., Wieser, T., Żytko, K. & Żgiet, J., 1959. Tuff horizons in the Menilite—Krosno Series of the Flysch Carpathians. *Bull. Acad. Polon. Sci., Ser. Sci. Geol. Geogr.*, 7 (7): 497—503.

Strelnikova, N. I., 1974. *Dyatomeyi pozdnovo myela (Zapadnaya Sibir)*. Izd. Nauka, Moskva, 144 pp.

Toni, J. B. de, 1891—1894. *Sylloge algarum omnium hucusque cognitarium*, vol. II, *Bacillarieae*; Typis Seminarii Patavii. Padova, 3 pts., 1556 pp.

Vekshina, V. N., 1961. Noviy rod o noviye vidy dyatomovyh iz melovyh y palieogenovyh otlozheniy Zapadno-Sibirskoy Nizmiennosty. *Trudy Sibir. Nau.-Issled. Inst. Geol., Geoph. i Miner. Siriya* 15: p. 89—93.

Weaver, F. M. & Gombos, A. M. jr., 1981. Southern high-latitude Diatom biostratigraphy. In: The Deep Sea Drilling Project: a decade of progress. *SEPM Spec. Publ.*, 32: 445—470.

Zhuze (Jouse), A. P., 1952. Noviye vidy dyatomovyh paleogenovo vozrasta. *Bot. Mat.*, 10: 81—103.

Zhuze (Jouse). A, P., 1978. Dyatomeyi i silikophlagellaty pozdnovo oligocena Juzhnovo Mangyshlaka. In: *Morskaya Mikropaleontologiya*. Izd. Nauka, Moscow. pp. 49—56.

Żgiet, J., 1961. Uwagi o występowaniu serii diatomitowej w warstwach krośnieńskich. (In Polish). *Kwart. Geol.*, 5: 996—997.

Żgiet, J., 1963. Spostrzeżenia nad sedymentacją wkładek diatomitów i tufów w Karpatach. (In Polish). *Kwart. Geol.*, 7: 714—715.

Streszczenie

DWA POZIOMY OKRZEMKOWE W OLIGOCENIE—DOLNYM MIOCENIE(?) POLSKICH KARPAT ZEWNĘTRZNYCH

Janusz Kotlarczyk & Irena Kaczmarska

Abstrakt: W serii menilitowo-krośnieńskiej jednostki skolskiej występują trzy poziomy ze skałami bogatymi w okrzemki. Dwa starsze — poziomy z Futomy i z Piątkowej — są najlepiej rozwinięte w okolicach Błażowej. Poziom z Futomy zbudowany jest głównie z laminowanych diatomitów i łupków diatomitowych ze śladami redepozycji przez prądy denne. Poziom z Piątkowej występuje w łupkach z Niebylca w postaci wielu cienkich wkładek turbidytowych bogatych w okrzemki, osadzonych w głębszej części basenu. Okrzemki obu poziomów pochodzą głównie ze środowiska nerytyczno-litoralnego. Wiek poziomów można odnieść na podstawie analizy okrzemek odpowiednio do wczesnego oligocenu oraz do pogranicza oligocenu i miocenu.

W płaszczowinie skolskiej polskich Karpat Zewnętrznych rozpoznano trzy poziomy z okrzemkami (Fig. 1, 2; Kotlarczyk, 1982, 1985). Dwa niższe, opisane w tej pracy, związane są z facją bitumicznych, ilasto-krzemionkowych łupków menilitowych. Poziom dolny — z Futomy — występuje w dolnej części warstw menilitowych, poziom wyższy — z Piątkowej — w serii przejściowej od warstw menilitowych do krośnieńskich. Oba poziomy są reprezentowane przez wiązki cienkich warstewek skał diatomitowych i łupków z okrzemkami, które rozprzestrzenione są odpowiednio na obszarze 1500 i 1000 km^2.

Poziom z Futomy występuje od kilku do kilkunastu metrów nad marglami dynowskimi i wykazuje lokalne zgrubienia m. in. w rejonach Błażowej i Przemyśla—Dobromila. W obszarze Błażowej sumaryczna miąższość poziomu waha się od kilku do kilkunastu metrów (Fig. 3), w tym na same skały diatomitowe przypada około 3/4 profilu. Cechą charakterystyczną skał diatomitowych poziomu z Futomy jest ich laminacja, głównie gruba płaskorównoległa, rzadziej drobna falista. Powstała ona najprawdopodobniej w wyniku sedymentacji różnobarwnych mułów okrzemkowych (zawierających zróżnicowaną domieszkę iłu i pyłu kwarcowego), przenoszonych prądami dennymi. Skały diatomitowe są w strefie wietrzenia jasne — beżowe lub białe, lekkie, porowate, mażące palce. Makroskopowo nie da się odróżnić typowych diatomitów, w których pancerzyki okrzemek i ich detrytus stanowią ponad 40% objętości skały, od łupków diatomitowych, w których ilość ich może spaść nawet do kilku procent na korzyść spoiwa opalowo-ilastego. Obok skał diatomitowych w ogniwie z Futomy występują jasnobrązowe łupki ilasto-krzemionkowe z okrzemkami (od paru procent w objętości skały), białe porcelanity, diagenetyczne rogowce, a także jasne piaskowce kwarcowe. Poza obszarami z dobrze wykształconym poziomem występują tylko łupki z okrzemkami, rzadziej łupki diatomitowe.

Opracowano metodę sporządzania preparatów dostosowaną do stopnia diagenezy diatomitów karpackich. Najdokładniej przebadano profil typowy (Futoma, Fig. 3, 4), zaś pojedynczymi próbami trzy dalsze profile w rejonie Błażowej (Borek Nowy, Hermanowa, Brzezówka) oraz jedno stanowisko (Malawa) spoza tego obszaru. W ocenie częstości występowania taksonów w próbie zastosowano klasyfikację rangową. Zespół taksonów dominujących, tj. występujących we wszystkich preparatach jest dość stabilny w czasie i w przestrzeni, choć pojawiają się nieznaczne różnice między skrajnymi warstewkami poziomu (Tabela 1). Zespół okrzemek reprezentuje środowisko nerytyczno-sublitoralne, pełnomorskie, z nieznaczną domieszką (3 taksony) gatunków brakicznych i słodkowodnych (Tabela 2). Niezłe zachowanie okryw taksonów nawet delikatnie wysyconych krzemionką przemawia przeciwko ich allochtoniczności, choć nie wyklucza przemieszczenia poziomego w obrębie obszaru depozycji. Nieco więcej niż połowa (17) dominujących taksonów znanych jest z młodszego paleogenu, z czego około 2/3 (10) sięga do neogenu, a około 1/3 nie przekracza górnej granicy oligocenu (6) bądź eocenu (1). Pozostałe znane są dopiero z osadów mioceńskich (9) lub współczesnych (1), ale wobec słabego rozpoznania zespołów oligoceńskich nie mogą przesądzać o wieku. Najpewniej zespół można datować na dolny oligocen. Najbardziej zbliżony doń jest zespół opisany przez Dzinoridze *et al.* (1976) z dolno(?)oligoceńskich osadów Morza Norweskiego (zona *Pyxilla prolongata*, umieszczana jednak przez niektórych autorów w górnym oligocenie). Pewne podobieństwo wykazuje nasz zespół do zespołu z górnoeoceńskich osadów Ukrainy, nie zawiera jednak typowych taksonów górnoeoceńskich.

Poziom z Piątkowej rozwinięty jest najpełniej również w rejonie Błażowej, a także koło Niebylca. Poszczególne warstewki brązowofioletowych łupków diatomitowych o grubości do 44 cm (i łącznej grubości około 2,6 m) tkwiące wśród szarych osadów ilasto-marglistych są bardziej od siebie oddalone niż w poziomie z Futomy, przy czym skrajne warstewki dzieli odległość od 22 m w Błażowej do 90 m w Niebylcu (Fig. 5). Poziom obejmuje zatem zmienną, niekiedy znaczną część łupków z Niebylca. Dalej ku E i SE liczba wkładek łupków diatomitowych zmniejsza się gwałtownie, a w końcu ich miejsce zajmują wkładki łupków brązowoczarnych z okrzemkami (Fig. 2). Wykształcenie wkładek diatomitowych, ich liczba, a także położenie względem IV horyzontu tufowego (Sikora *et al.*, 1959) zmienia się istotnie na obszarze występowania (Fig. 5, 6). Część warstewek łupków diatomitowych (25—40%) wykazuje struktury sedymentacyjne typowe dla turbidytów. Łupki diatomitowe są mało porowate, zbite i zailone. Przygotowanie preparatów wymagało wzbogacenia, przeto analiza półilościowa nie mogła być zastosowana.

Zespół okrzemek jest stabilny, nawet w przypadku zubożenia liczby taksonów do kilku (Tabela 3). Uformował się on wyłącznie z taksonów o grubych i większych okrywach, charakterystycznych dla strefy nerytyczno-sulitoralnej (Tabela 4). Okrywy drobniejsze i lżejsze zostały najwidoczniej przeniesione prądami zawiesinowymi dalej ku S i SE, poza rozpoznany obszar występowania poziomu. Określenie wieku zespołu natrafia na duże trudności. Oprócz form długowiecznych (14) i niezidentyfikowanych wiekowo (3), znaleziono 10 taksonów nie cytowanych dotychczas z osadów starszych od miocenu i 2 taksony nie sięgające powyżej górnej granicy oligocenu (Tabela 4). Zespół z Piątkowej ma 4 (lub 7, jeśli nie uwzględnić odmian) taksony wspólne z górnooligoceńskim zespołem Mangyszłaku (Jouse, 1978) i trzy taksony wspólne z dolnomioceńskim zespołem rejonu Szybik (Sheshukova-Poretskaya & Gleser, 1962), zaś z florą egerienu Waller (Řehakova, 1975) dziesięć elementów wspólnych. Podobnie niejednoznaczne datowania dają inne skamieniałości: nannoplankton — najwyższy oligocen (Kotlarczyk, 1985), plankton otwornicowy — najniższy miocen (Nowak *et al.*, 1985). Najprawdopodobniej zespół z Piątkowej reprezentuje wiek pogranicza oligocenu i miocenu.

Czas, jaki upłynął pomiędzy osadzeniem się obu zespołów (prawie cały oligocen), był wystarczający, aby doprowadzić do prawie zupełnego zróżnicowania zespołu okrzemek (wspólne są tylko 4 taksony długowieczne). Fakt ten, przy szerokim rozprzestrzenieniu poziomów, pozwala na wykorzystanie okrzemek w stratygrafii serii menilitowo-krośnieńskiej.

Quasi-autochtoniczny, płytkowodny zespół okrzemek z Futomy wskazuje na spłycenie zbiornika menilitowego. Spłycenie to było już wcześniej sygnalizowane na podstawie analizy zespołów ryb poziomu z Futomy i warstw sąsiadujących (Kotlarczyk & Jerzmańska, 1976) i prawdopodobnie łączy się z globalnym obniżeniem poziomu oceanów w oligocenie.

EXPLANATIONS OF PLATES

Descriptions of figures are followed by names of sections and sample numbers. All magnifications 1860×, unless otherwise stated.

Plate I

1, 2 — *Melosira architecturalis*, one specimen, different focus; Futoma, 6
3, 4 — *Melosira praeislandica*; Futoma, 10
5, 6, 8 — *Pseudopodosira witti*, one specimen, different focus; Futoma, 6
7 — *Pseudopodosira witti*; Futoma, 6

Plate II

1, 2 — *Paralia sulcata*; Futoma, 4
3 — *Paralia sulcata* var. *crenulata*; Futoma, 4
4 — *Paralia sulcata*, fragment of colony; Futoma, 4, 4300×
5 — *Paralia sulcata*, outer surface of valve; Futoma, 4, 4000×
6, 7 — *Coscinodiscus* cf. *subtilis*; Futoma, 6
8, 9 — *Cestodiscus intersectus*, one specimen, different focus; Futoma, 21
10, 11, 12 — *Cestodiscus intersectus*; Borek Nowy, 1
13, 14 — *Thalassiosira* cf. *baltica*, one specimen, different focus; Futoma, 4

Plate III

1 — *Trochosira spinosa*; Futoma, 10
2, 3 — *Trochosira spinosa*; Futoma, 14
4 — *Trochosira spinosa*, outer part of valve; Futoma, 4, 7600×
5, 6 — *Stephanopyxis turris*, one specimen, different focus; Brzezówka, 29, 750×
7 — *Stephanopyxis turris*; Futoma, 18, 750×
8 — *Hyalodiscus scoticus*; Futoma, 18
9 — *Hyalodiscus scoticus*; Futoma, 21
10 — *Actinocyclus loczyi*; Brzezówka, 29, 750×
11 — *Actinocyclus loczyi*, center of areolae shows pores; Futoma, 4

Plate IV

1 — *Actinoptychus senarius*, outer surface of vale; Futoma, 4, 3000×
2 — *A. senarius*, net of external costae on elevated sector of valve; Futoma, 4, 5400×
3, 4, 5 — *Actinoptychus senarius*, one specimen, different focus; Futoma, 10
6, 7 — *Actinoptychus senarius* var. *tamanicus*, one specimen, different focus; Borek Nowy, 1
8, 9 — *Xanthiopyxis oblonga*, onc specimen, different focus; Futoma, 14

Plate V

1, 2 — *Chasea ornata*, one specimen, different focus; Futoma, 10
3 — *Hemiaulus* cf. *malleolus*, internal surface of valve; Futoma, 4, 2800×
4 — *Hamiaulus sporalis*; Hermanowa, 29
5 — *Hemiaulus* cf. *malleolus*; Futoma, 8
6, 7 — *Hemiaulus malleolus*; Borek Nowy, 7
8, 10 — *Chaetoceros compressus*, one specimen, different focus; Futoma, 14
9 — *Chaetoceros compressus*; Futoma, 14
11, 12 — *Chaetocerus robustus*, one specimen, different focus; Hermanowa, 29
13 — *Chaetoceros robustus*; Brzezówka, 29

Plate VI

1, 2 — *Triceratium condecorum*; Futoma, 14, 750×
3, 4 — *Triceratium tesellatum*, one specimen, different focus; Futoma, 18
5 — *Odontella cornuta*; Futoma, 6
6 — *Odontella fimbriata*; Futoma, 4
7 — *Odontella cornuta*; Futoma, 10, 750×
8 — *Odontella fimbriata*; Futoma, 4, 750×
9 — *Pyxilla prolongata*; Futoma, 18
10 — *Pyxilla prolongata*; Futoma, 4, 750×
11 — *Pyxilla prolongata*; Futoma, 4
12 — *Sceptroneis grunowii*; Futoma, 14
13 — *Sceptroneis grunowii*; Futoma, 10, 750×

Plate VII

1, 2 — *Rhizosolenia* sp., seta type *Rh. setigera*; Futoma, 4
3 — *Rhaphoneis amphiceros*; Futoma, 6
4, 5, 6 — *Grammatophora* sp.; Futoma, 4
7 — *Melosira clavigera*; Piątkowa I, 4, 1000×
8 — *Melosira omma*; Piątkowa I, 1, 2500×
9 — *Actinocyclus octonarius* var. *tenella*; Piątkowa I, 12, 750×
10 — *Actinocyclus octonarius* var. *sparsa*; Piątkowa I, 12, 750×
11 — *Actinocyclus* aff. *cholnokyi*; Błażowa—Łęg, 1, 1500×
12 — *Actinocyclus octonarius*; Futoma, 4, 1500×

Plate VIII

1 — *Pseudopodosira* sp.; Piątkowa II, 5, 2500×
2 — *Hyalodiscus radiatus*; Piątkowa I, 1, 750×
3 — *Stephanopyxis turris* var. *arctica*; Piątkowa I, 12, 750×
4 — *Stephanopyxis turris* var. *intermedia*; Błażowa—Łęg, 1A, 750×
5 — *Stephanopyxis corona*; Piątkowa I, 12, 750×
6 — *Paralia sulcata* var. *biseriata*; Piątkowa I, 12
7 — *Biddulphia longispina*; Piątkowa II, 5, 1500×
8 — *Actinoptychus thumii*; Piątkowa I, 9, 750×

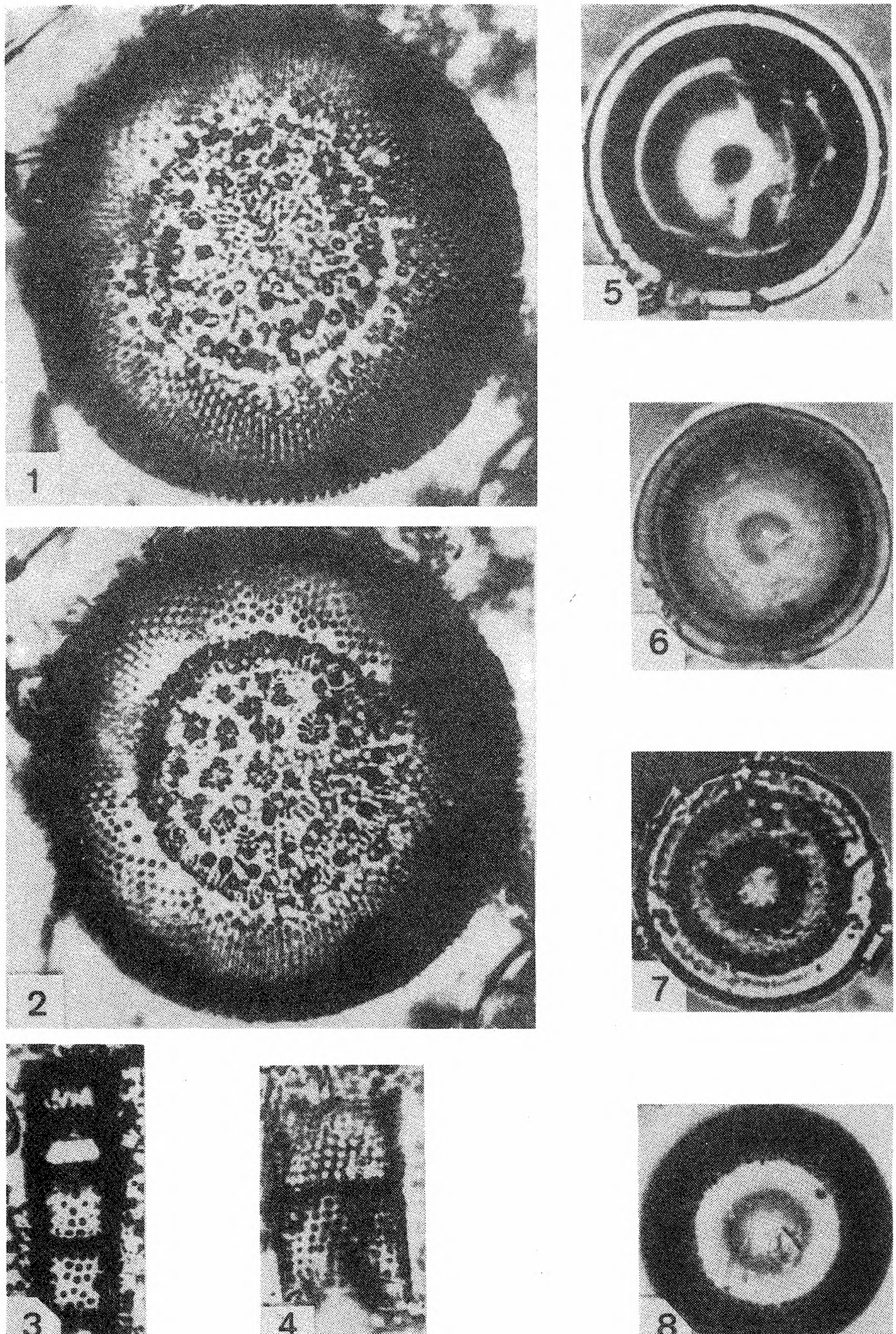
Plate IX

1 — *Coscinodiscus marginatus*; Piątkowa I, 4, 1500×
2 — *Coscinodiscus papillosus*; Piątkowa II, 11, 1500×
3 — *Cocconeis praecellens*; Piątkowa I, 9, 750×

4 — *Cocconeis vitrea*; Piątkowa I, 1, 750×
5 — *Rhaphoneis gemmifera*; Błażowa—Łęg, 1A, 1000×
6 — *Thalassionema* aff. *obtusa*; Piątkowa II, 9, 1100×
7 — *Coscinodiscus argus*; Błażowa—Łęg, 1, 1500×

Plate X

1 — *Cymatogonia amblyoceras*; Piątkowa II, 11, 1000×
2 — *Pleurosigma normanii* var. *marylandica*; Błażowa—Łęg, 12, 750×
3 — *Xanthiopyxis diaphana*; Błażowa—Łęg, 1, 2500×
4 — *Diploneis szontaghii*; Piątkowa I, 12, 750×
5 — *Diploneis nitescens*; Piątkowa I, 1, 750×
6 — *Grammatophora marina*; Piątkowa II, 5, 750×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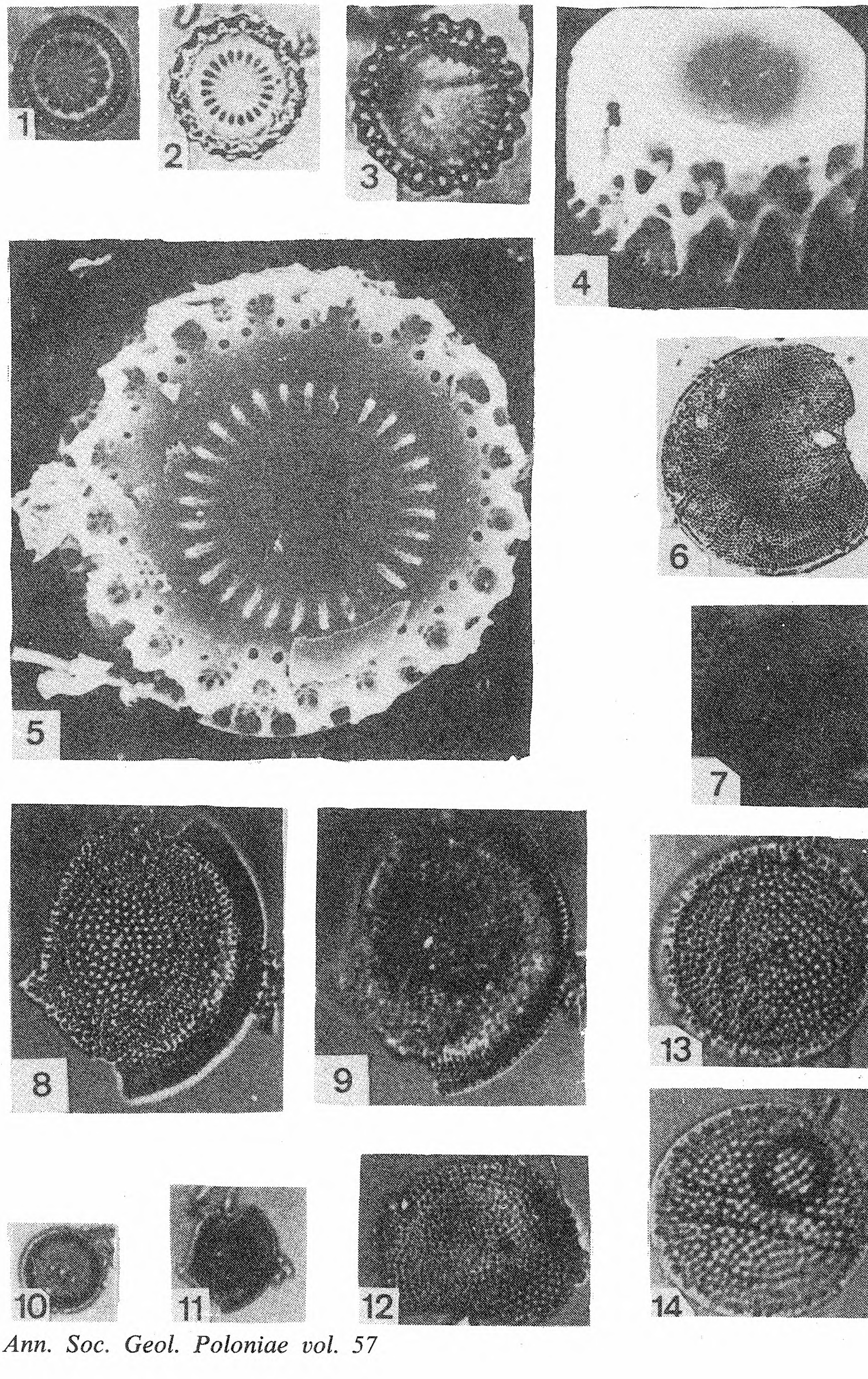
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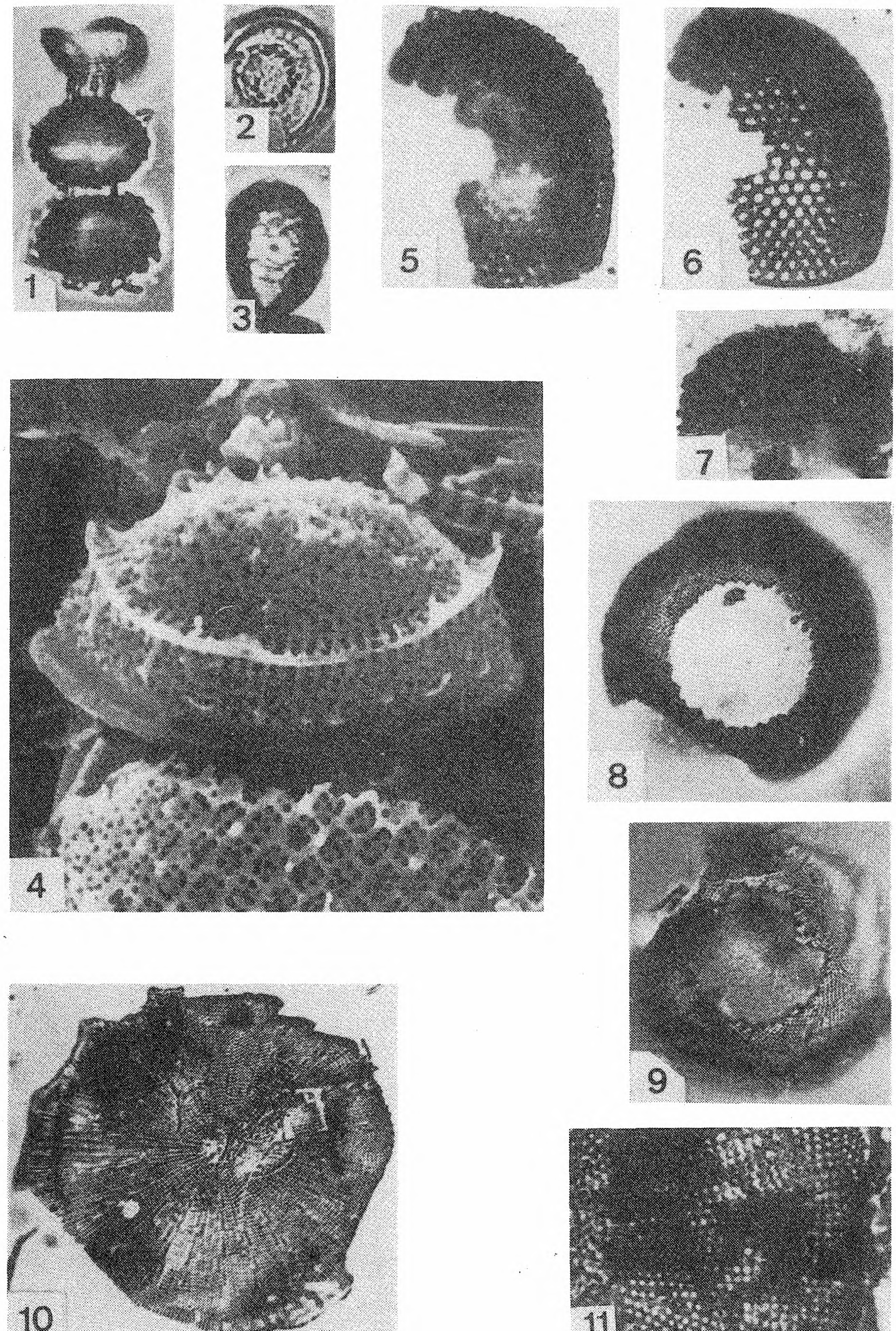
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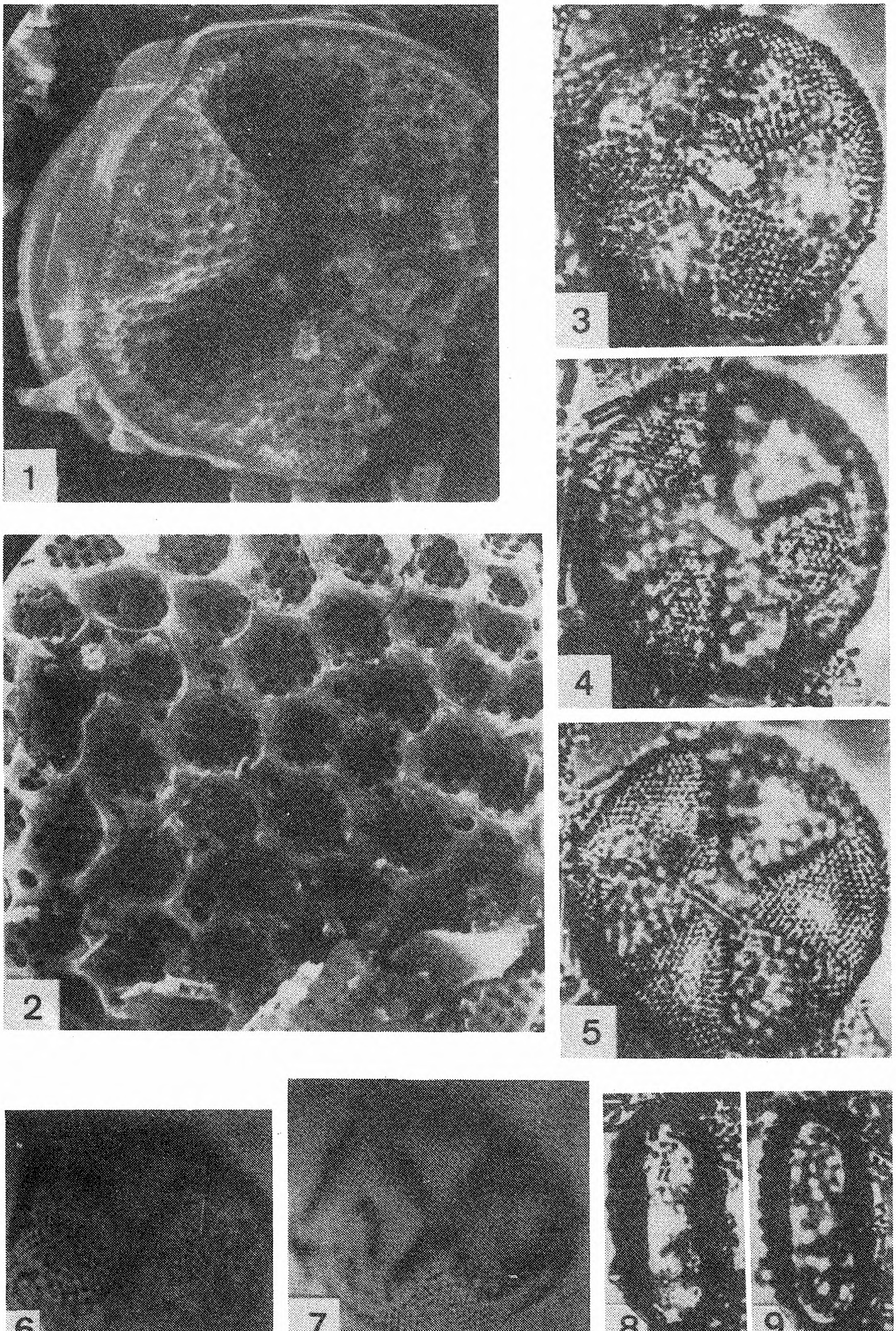
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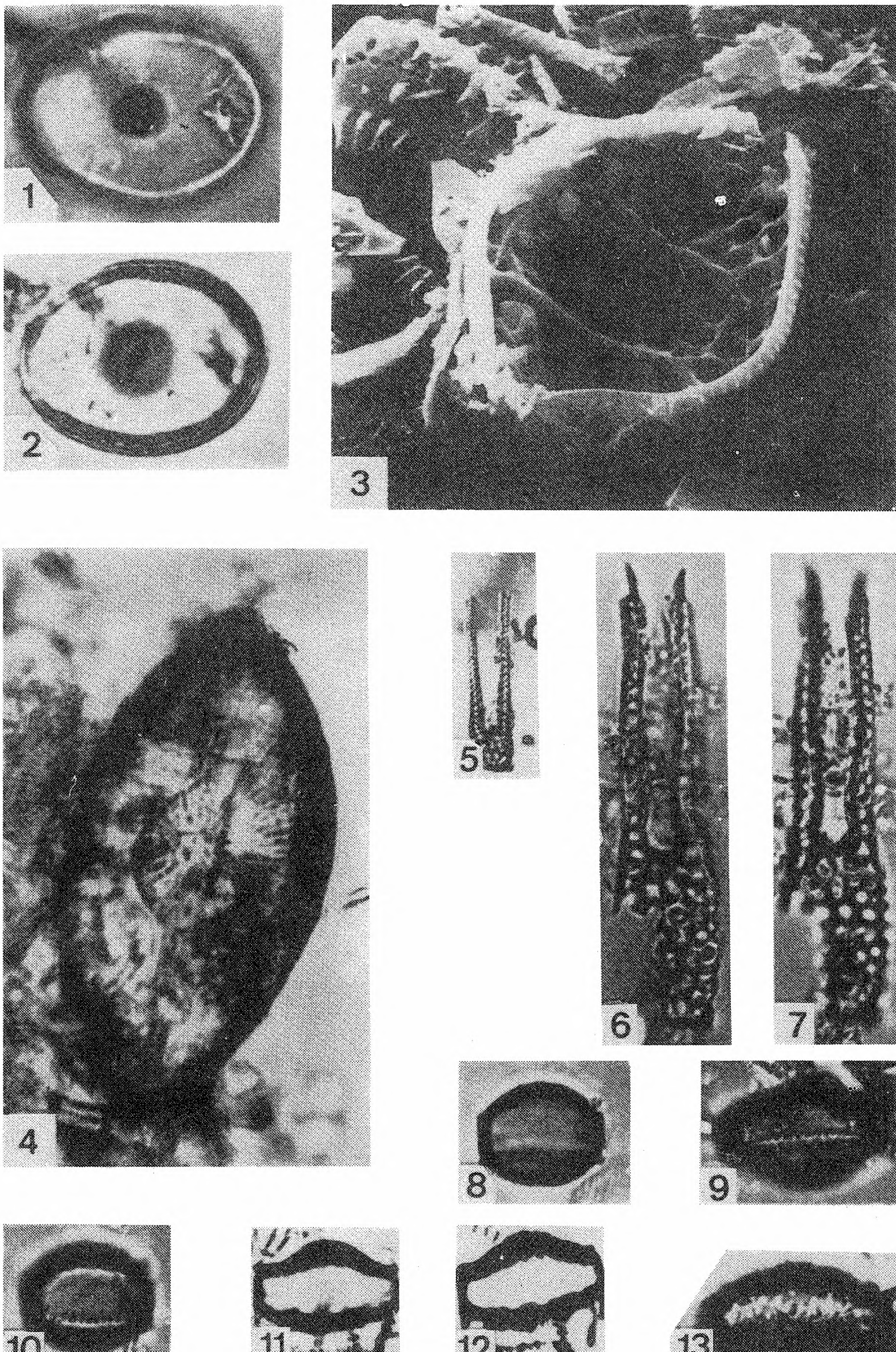
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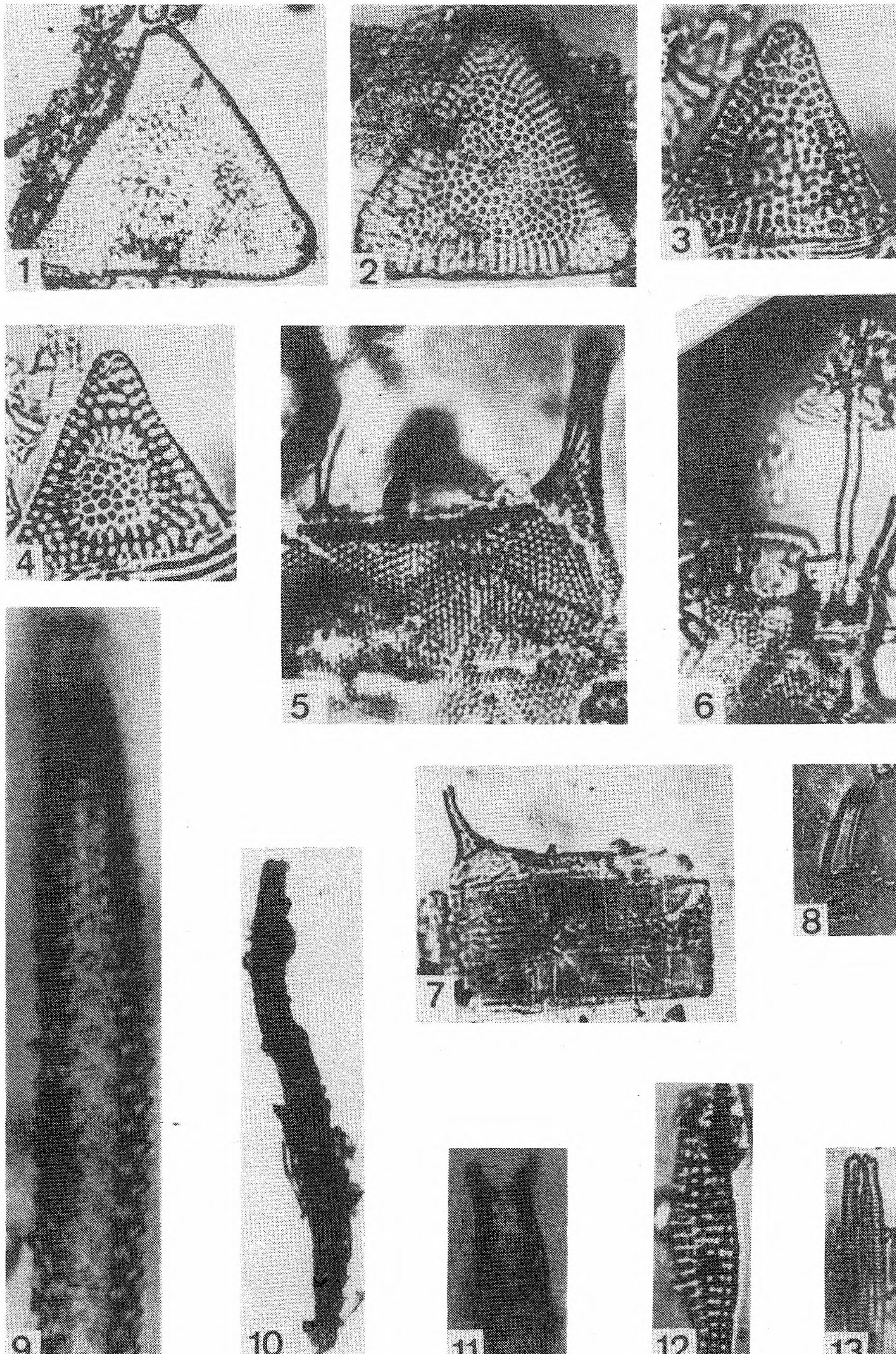
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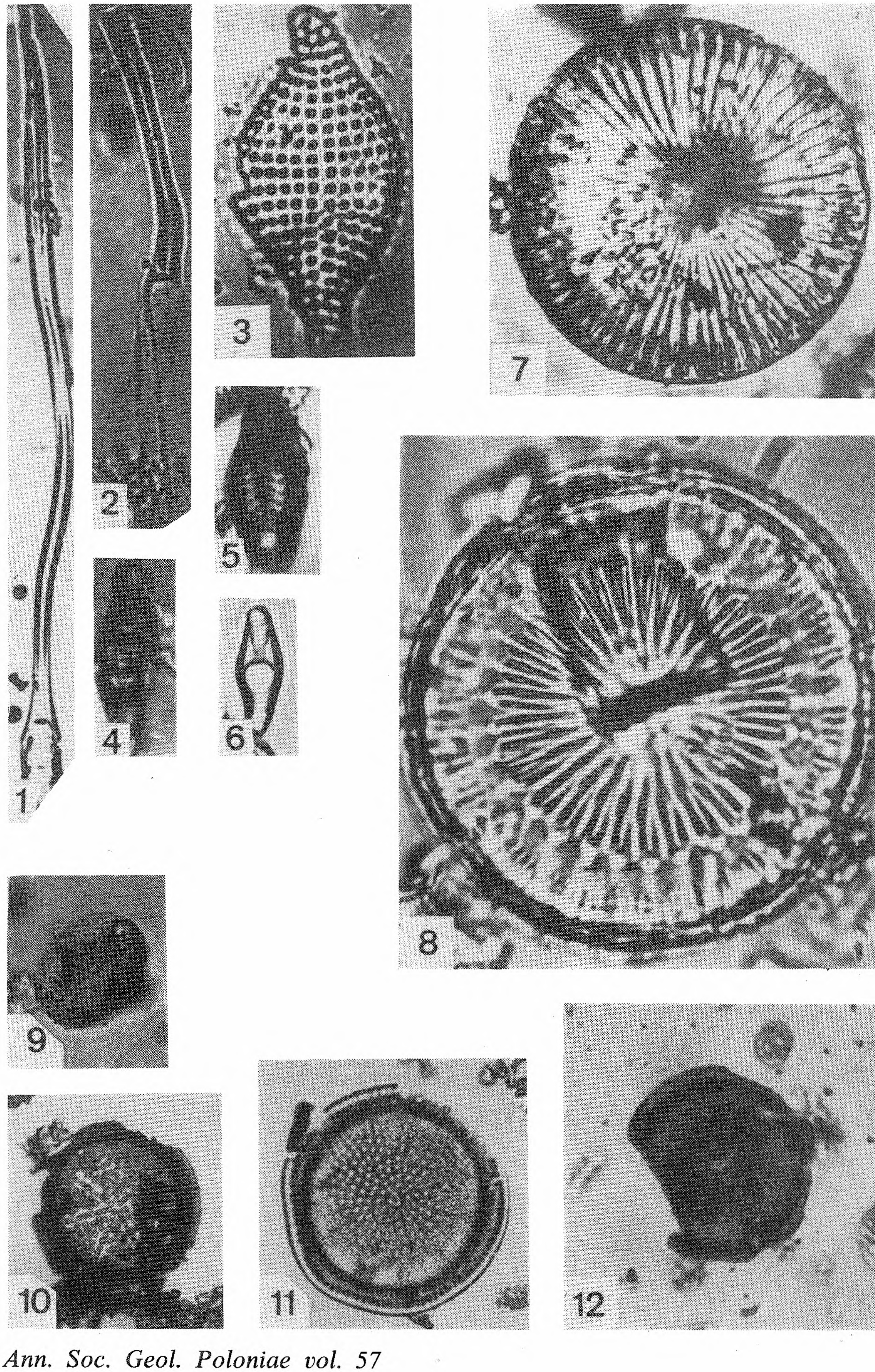
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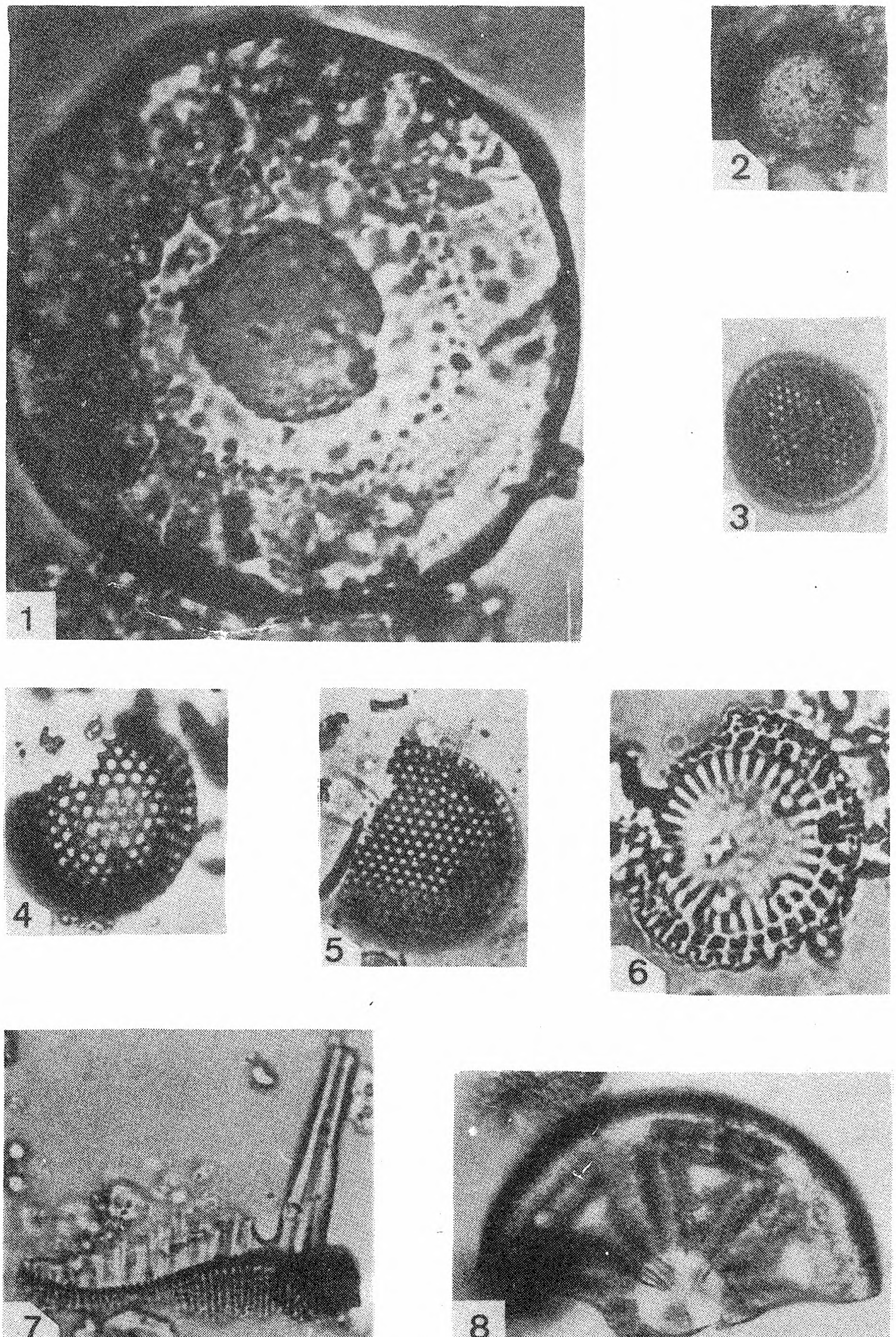
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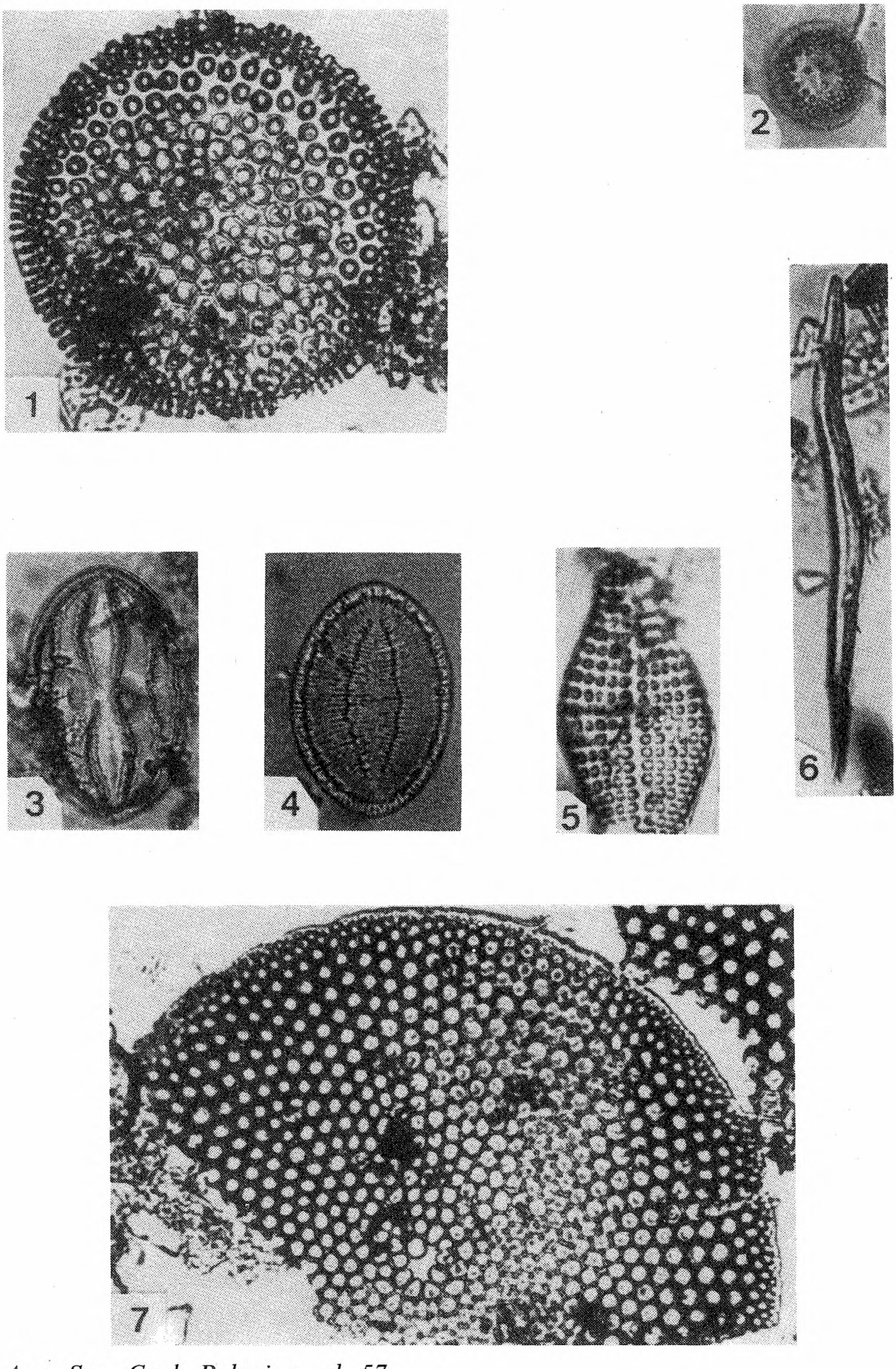
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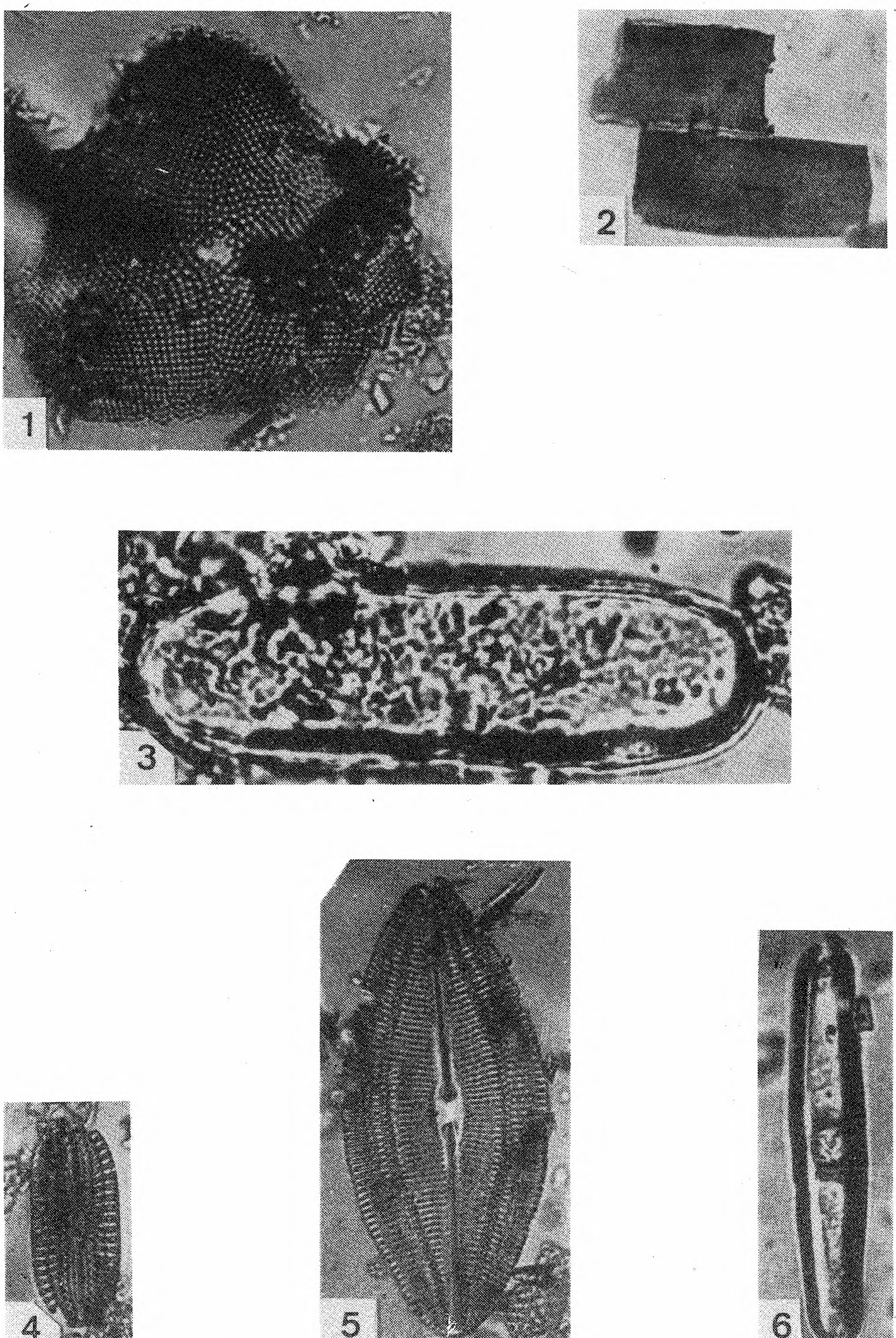
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