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Nannoplankton stratigraphy of the Miocene deposits in Tarnobrzeg area (northeastern part of the Carpathian Foredeep)

The calcareous nannofossils of the Machów Formation (the *Pecten* Beds and Krakowiec Clays) from exposures at the sulphur mine Machów and from cores in northeastern part of the Carpathian Foredeep were studied using both light and electron microscopes. The stratigraphic position of the deposits which overlie the evaporite series is discussed. They seem to be younger than the NN 7 *Discoaster kugleri* Zone and they probably correspond to the NN 8 *Catinaster coalitus* and NN 9 *Discoaster hamatus* Zones of the standard nannoplankton zonation.

INTRODUCTION

This study presents the results of detailed investigations of calcareous nannofossils obtained from Miocene deposits which occur in the region of Tarnobrzeg. The aim of the work was to determine the age of clastic deposits which overlie the evaporite series using coccoliths and to discuss the possibility of stratigraphic correlation. Over seventy samples have been collected from cores, sulphur mine Machów and other outcrops for both foraminiferal and nannoplankton investigations. The foraminifera have been examined by J. Paruch-Kulczycka (Z. Krysiak *et al.*, 1993).

In the northern part of the Carpathian Foredeep the stratigraphical subdivision of the Miocene sequence which has been employed hitherto was based upon benthic foraminifera (E. Łuczowska, 1964). The nannoplankton zonation was established only for deposits accumulated before the evaporitic event. Investigations were concentrated westward of the current study area in the vicinities of Korytnica (E. Martini, 1977) and Chmielnik (J. Dudziak, A. Łaptaś, 1991).

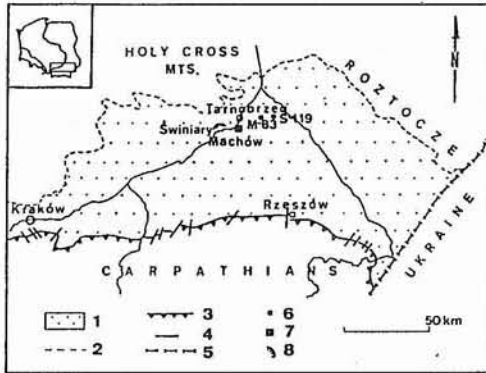


Fig. 1. Location of studied boreholes and outcrops in the Carpathian Foredeep

1 — Miocene of the Carpathian Foredeep, 2 — north extent of the Miocene deposits, 3 — Carpathian nappes overthrust, 4 — faults, 5 — boundary of state, 6 — borehole, 7 — sulphur mine, 8 — outcrop of Miocene deposits

Lokalizacja badanych otworów wiertniczych i odsłoneń w zapadlisku przedkarpackim

1 — miocen zapadliska przedkarpackiego, 2 — północny zasięg utworów miocenu, 3 — nasunięcie płaszczowin karpackich, 4 — uskoki, 5 — granica państwa, 6 — otwór wiertniczy, 7 — kopalnia siarki, 8 — odsłonięcie utworów miocenu

GEOLOGICAL SETTING AND LITHOSTRATIGRAPHY

The study area is located within the northeastern part of the Carpathian Foredeep where the Polish sulphur industry is concentrated (Fig. 1). The Carpathian Foredeep, a trough 320 km long and 80 km wide, is bordered to the south by external nappes of the Carpathians and to the north by the Holy Cross Mts. and Roztocze Hills. The geological development of the basin, filled by Miocene deposits, was closely connected with Late Alpine tectonic events. A more detailed account on the geological setting and the tectonic history of the area has been given by several authors (R. Ney *et al.*, 1974; M. Książkiewicz, 1972; J. Kotlarczyk, 1985; S. Kwiatkowski, 1985).

Thrusting of the Carpathian nappes resulted in migration of the basin northward. The transgression onto the southern slopes of the Holy Cross Mts. occurred during the Lower Badenian (E. Martini, 1977). The sedimentation started with organogenic (often *Lithothamnium* limestones) or detrital (clays and sands) deposits with marine fossils. To the south the deposition was more clayey. The thickness of these deposits, called the Baranów Beds, varies from 2 to 150 m (S. Pawłowski *et al.*, 1985). They are overlain by chemical deposits represented by sulphates (gypsum and anhydride, locally altered into sulphur-bearing limestones) and salts. They are assumed to be of Middle Badenian (Wielician) age (E. Łuczowska, 1978). After chemical sedimentation ended, a monotonous series of clays, siltstones, clayey marls, sands and sandstones were deposited. This sequence, called the Machów Formation (A. Garlicki, 1994), overlies transgressively the older strata. The lowest part of the formation developed as argillaceous marls with *Pecten* and *Spirialis* and is named the *Pecten* Beds. The thickness of the *Pecten* Beds reaches up to 50 m and their Upper Badenian (Kosovian) age has been deduced from microfaunal assemblages (E. Łuczowska, 1978). The *Pecten* Beds pass gradually upward into the thick complex of the Krakowiec Clays which are placed in the Lower Sarmatian. In the eastern part of the Carpathian Foredeep, the thickness of the Krakowiec Clays exceeds 2500 m. A younger age for the upper part of this sequence is suggested on the basis of calcareous nannofossils as well as consideration of the rate of deposition (J. Głazek, E. Gaździcka, *in press*).

MATERIAL AND METHODS

Calcareous nannofossils were studied in a 200 m thick sequence of the Machów Formation from boreholes Jamnica M-83 and S-119 (Fig. 1). In both cores the base of the formation was accessible. Special attention was paid to the transition between the *Pecten* Beds and Krakowiec Clays; additionally, the 100 m thick section at the Machów mine was sampled in detail. Also, some samples from the Baranów Beds (from borehole Jamnica M-83 and the outcrop at Świniary) were studied to optimize the stratigraphic data.

The investigation of nannofossils was carried out using an *Olimpus BHS* light microscope. Centrifuge and smear slides were prepared following the standard techniques described by R. Taylor and G. Hamilton (1982). Selected samples were examined in the Scanning Electron Microscope *Philips XL 20*.

CALCAREOUS NANNOFOSSILS

The samples collected from the *Pecten* Beds produced an abundance of coccoliths while the samples from the Krakowiec Clays had lower yields. Preservation state of the specimens was variable. In the lower part of the formation they are better preserved than in the upper part where coccoliths are crushed and dissolved. The total diversity within assemblages is large but a great number of nannofossils were reworked from older deposits. The Upper Cretaceous and Eocene taxa dominated but in some levels there were coccoliths from the Paleocene, Oligocene and Middle Miocene. The taxonomic composition of assemblages and relative abundance data are presented in the Figures 2–4.

In the *Pecten* Beds the most abundant species are: *Calcidiscus leptoporus* (Murray et Blackman) (Pl. I, Figs. 6–8), *C. macintyreii* (Bukry et Bramlette) (Pl. I, Fig. 5), *Helicosphaera kamptneri* Hay et Mohler (Pl. II, Figs. 2–3), *Reticulofenestra pseudoumbilica* (Gartner) with concurrent small reticulofenestrids — *R. minutula/haqii* and *R. minuta* Roth (Pl. III, Fig. 7). Particularly notable is the occurrence of *Helicosphaera walbersdorfensis* Müller (Pl. II, Fig. 1), *H. sellii* Bukry et Bramlette and *Sphenolithus abies* Deflandre (Pl. II, Figs. 5–7). The other species are represented by small numbers; the discoasters are almost completely absent.

In the Krakowiec Clays the calcareous nannoplankton is less diverse. *Helicosphaera walbersdorfensis* Müller, *H. sellii* Bukry et Bramlette and *Sphenolithus abies* Deflandre disappear, *H. kamptneri* Hay et Mohler becomes rare. The assemblage of Miocene coccoliths is restricted to some placoliths: *Coccolithus pelagicus* (Wallich) (Pl. I, Figs. 1–4), *Umbilicosphaera jafarii* Müller, *Reticulofenestra pseudoumbilica* (Gartner) (Pl. III, Figs. 4–6) and *R. minutula/haqii*. The abundance of reworked specimens in the deposits is symptomatic. In the lower part of the Krakowiec Clays (so-called the *Syndesmya* Beds) *Braarudosphaera bigelowii* (Gran et Braarud) (Pl. III, Fig. 3) and the genus *Thoracosphaera* sp. (Pl. III, Fig. 8) increase in number.

The samples from the outcrop at Świniary yielded well preserved and diverse calcareous nannoplankton, similar to that from the *Pecten* Beds. Genus *Helicosphaera*, represented by *H. kamptneri* Hay et Mohler, *H. granulata* Bukry et Percival, *H. walbersdorfensis* Müller

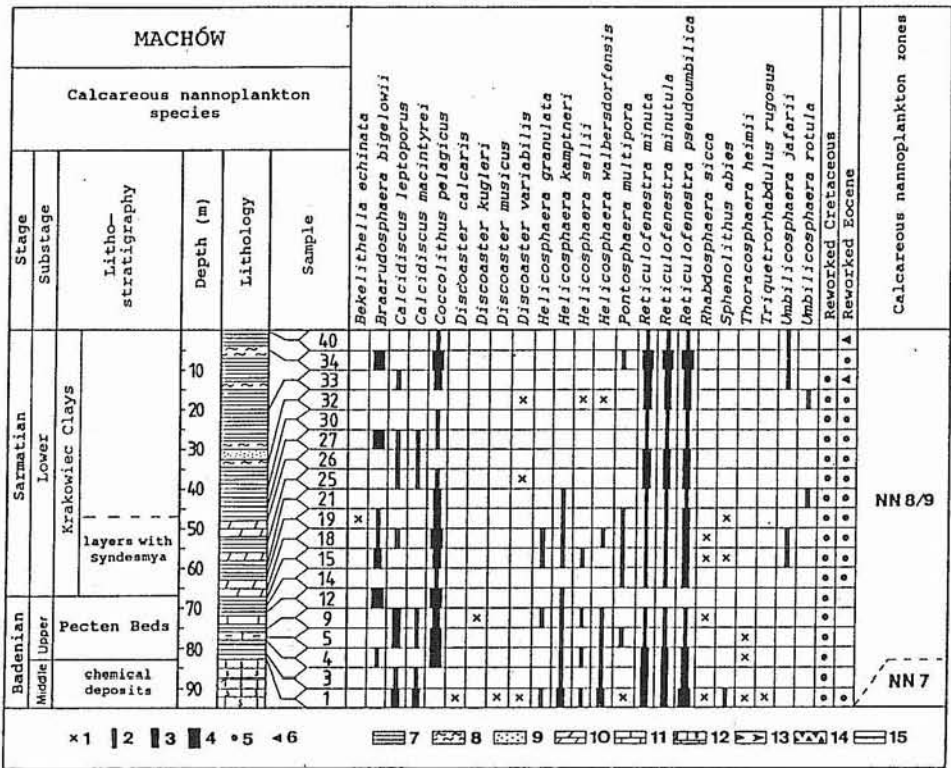


Fig. 2. Distribution of calcareous nannofossils in the section of sulphur mine Machów

Relative abundances: 1 — rare, 2 — few, 3 — common, 4 — abundant; 5 — revorked taxa; 6 — abundance of revorked taxa; 7 — clays; 8 — mudstones; 9 — sands, sandstones; 10 — marls; 11 — limestones; 12 — sulphur-bearing limestones; 13 — anhydrite; 14 — breccias; 15 — tuffs, tuffites

Nannoplankton wapienny w profilu kopalni siarki Machów

Taksony: 1 — rzadkie, 2 — obecne, 3 — liczne, 4 — obfite; 5 — kokkolity redeponowane; 6 — przewaga kokkolitów redeponowanych; 7 — iły; 8 — mułowce; 9 — piaski, piaskowce; 10 — margle, 11 — wapienie; 12 — wapienie osiarkowane; 13 — anhydryty; 14 — brekcja; 15 — tufy, tufity

and *H. philippinensis* Müller, is very common here. The helicolithids are accompanied by *Sphenolithus abies* Deflandre and *Rhabdosphaera sicca* Stradner (Pl. III, Fig. 2). *Bekelithella echinata* Bóna et Gal, known from the Pannonian of Hungary, is also observed here.

BIOSTRATIGRAPHY

The calcareous nannoplankton zonation of the Miocene is based on discoasters as zonal markers. A very low number of asteroliths in the studied samples makes age determination difficult. The single occurrence of *Discoaster kugleri* Martini et Bramlette and the presence

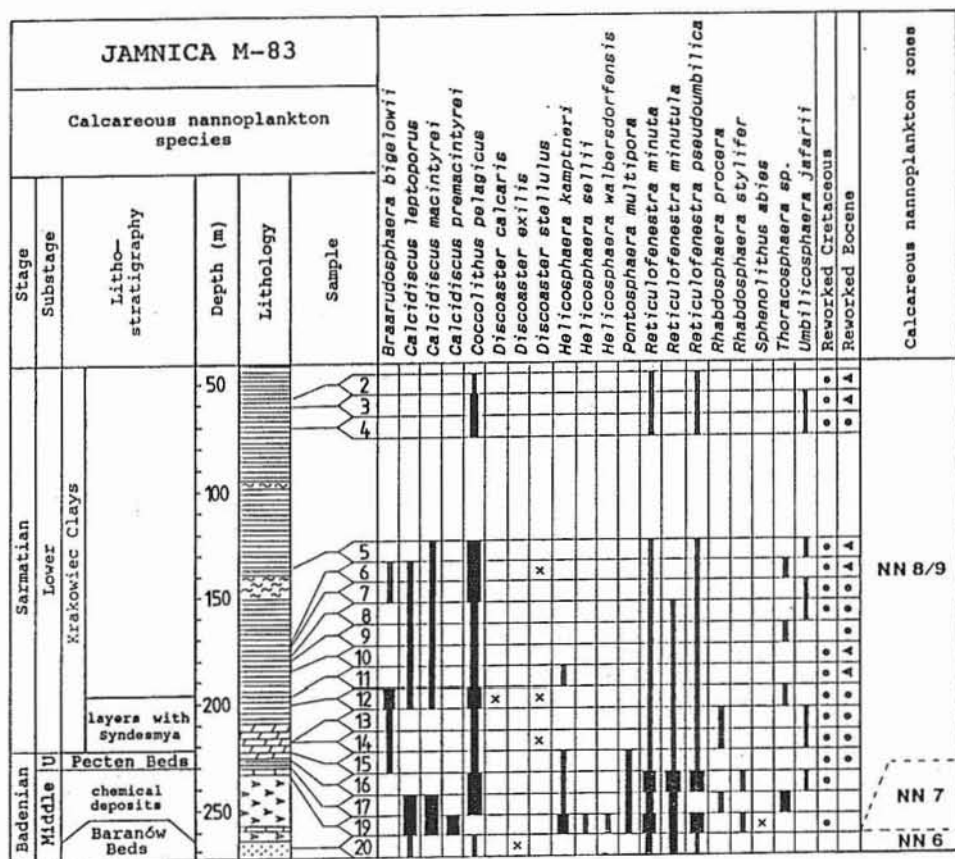


Fig. 3. Distribution of calcareous nannofossils in the core Jamnica M-83

Explanations see Fig. 2

Nannoplankton wapienny w profilu otworu Jamnica M-83

Objaśnienia jak na fig. 2

of several specimens of *D. calcaris* Gartner are considered, as well as the similarity of coccolith assemblages to the ones known from the Central Paratethys.

The presence of *Discoaster exilis* Martini et Bramlette in the Baranów Beds (core Jamnica M-83) and the absence of *Sphenolithus heteromorphus* Deflandre and *Discoaster kugleri* Martini et Bramlette indicates the NN6 *Discoaster exilis* Zone. *S. heteromorphus* Deflandre was found in the Lower Badenian deposits from the southern slopes of the Holy Cross Mts. (E. Martini, 1977; J. Dudziak, A. Łaptaś, 1991) and from the Roztocze region (D. Peryt, 1987), where coccolith Zone NN5 was established.

In the Machów Formation *Discoaster exilis* Martini et Bramlette is not observed. Instead, *D. calcaris* Gartner, which has its first occurrence in the NN8 Zone (K. Perch-Nielsen, 1985; E. Martini, C. Müller, 1986), appears. *D. kugleri* Martini et Bramlette, a zonal marker in the Middle Miocene is absent. The single specimen of this species in the *Pecten*

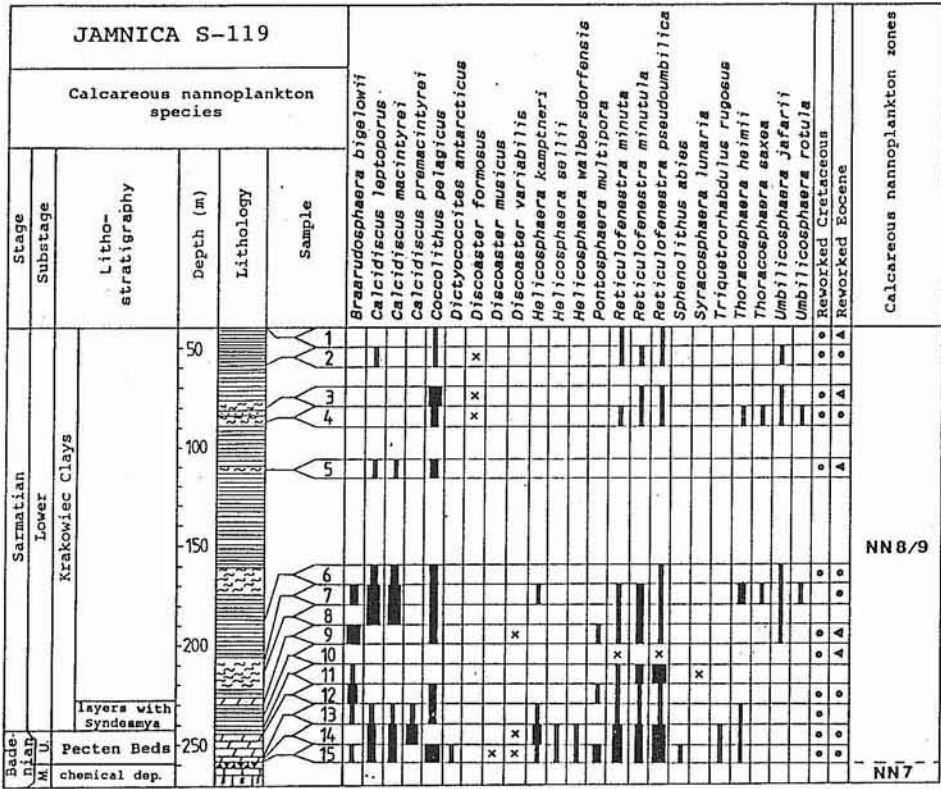


Fig. 4. Distribution of calcareous nannofossils in the core Jamnica S-119

Explanations see Fig. 2

Nannoplankton wapienny w profilu otworu Jamnica S-119

Objaśnienia jak na fig. 2

Beds at Machów suggests redeposition. All these data lead to the conclusion that in the Tarnobrzeg area the deposits overlying the evaporites are younger than the NN7 *Discoaster kugleri* Zone, and they could be assigned to the NN8 *Catinaster coalitus* or even NN9 *Discoaster hamatus* Zones.

FINAL REMARKS

In the Central Paratethys the Badenian stage is distinguished by the presence of rich, marine micro- and macrofaunas. In contrast, the Sarmatian deposits which overlie the Badenian rocks are impoverished in marine fossils. The Sarmatian calcareous nannofloras known from the Vienna and Pannonian Basins, are of low diversity. The floras are mainly restricted to a few species with high abundance: *Braarudosphaera bigelowii* (Gran et

Braarud), *Coccolithus pelagicus* (Wallich) and the reticulofenestrids. The discoasters and the sphenolithids, frequent in Badenian deposits, are absent (H. Stradner, R. Fuchs, 1979; A. Nagymarosy, 1985). The taxonomic composition of coccolith, as well as of the molluscan and foraminiferal assemblages, indicates the isolation of the basin from the world oceans and its reduced salinity (A. Nagymarosy, P. Müller, 1988). The Pannonian deposits in Hungary accumulated in brackish- or fresh-water environments. They yield only assemblages of endemic fossils which do not allow extrabasinal correlations (A. Nagymarosy, P. Müller, 1988). The lower boundary of the Sarmatian stage in the Central Paratethys is placed in the nannoplankton Zone NN7 and the upper boundary in the NN9 Zone, which is also the boundary between Middle and Upper Miocene (F. Steininger *et al.*, 1990).

In the study area, the Machów Formation lies transgressively on the evaporite series and it represents a single sedimentary sequence. The calcareous nannofossils from the *Pecten* Beds and Krakowiec Clays are comparable with the assemblages from the Sarmatian stage in the Vienna Basin, particularly from Walbersdorf (F. Rögl, C. Müller, 1976; H. Stradner, R. Fuchs, 1979), however, the presence of a few discoasters must be stated.

Moreover, in the top part of the Krakowiec Clays, from the vicinity of Stalowa Wola, *Discoaster bellus* Bukry et Percival, *D. brouveri* Tan Sin Hok, *D. intercalaris* Bukry and *D. neohamatus* Bukry and Bramlette were found (J. Głazek, E. Gaździcka, *in press*). They are considered indicative of the Upper Miocene NN9 – NN10 Zones. The taxonomic composition of the nannoplankton assemblages of the whole Machów Formation suggests its Upper Sarmatian and Lower Pannonian age.

The occurrence of calcareous nannofossils together with foraminifera and other micro- and macrofossils (e.g. dasycladacean algae — see J. Paruch-Kulczycka, 1994) indicates a marine environment with normal salinity. High abundance of the nannofossil genus *Helicosphaera* in the *Pecten* Beds and *Braarudosphaera bigelowii* (Gran et Braarud) and *Coccolithus pelagicus* (Wallich) in the lower part of the Krakowiec Clays suggests near-shore deposition. Also in the lower part of Krakowiec Clays, layers with abundant coccoliths are observed. They yield nearly monospecific assemblages consisting of *Reticulofenestra pseudoumbilica* (Gartner) (Pl. IV, Fig. 2) or *Umbilicosphaera jafarii* Müller without evidence of reworking. These layers may be considered pelagic sediments. The monospecific character of these assemblages resulted from extreme environmental conditions eliminating less tolerant species (A. Nagymarosy, 1983). The abundance of nutrients (compounds of nitrogen and phosphorus) was necessary for the blooms of nannoflora.

In the upper part of the Machów Formation the number of reworked nannofossils increased; this suggests intensive influx of terrigenous material into the basin. Upper Cretaceous and Middle Eocene coccoliths, derived from the northern coasts are predominant. The presence of recycled Badenian nannofossils is evidence of tectonic activity in the region during the Sarmatian.

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STRATYGRAFIA NANNOPLANKTONOWA UTWORÓW MIOCENU Z REJONU TARNOBRZEGA (PÓLNO-CNO-WSCHODNIA CZĘŚĆ ZAPADLIKA PRZEDKARPACKIEGO)

Streszczenie

Zbadano nannoplankton wapienny z utworów miocenu w rejonie Tarnobrzega (kopalnia siarki Machów, otwory Jamnica M-83 i S-119, Świniary) (fig. 1). Badany materiał pochodził z warstw pektenowych tradycyjnie zaliczanych do badenu górnego oraz z dolnej części ilów krakowieckich uważanych za sarmat dolny. Pojedyncze próbki pobrano z warstw baranowskich występujących poniżej złoża siarki oraz z utworów ilastych z odsłonięcia w Świniarach. Zespoły nannoplanktonu wapiennego charakteryzują się małym zróżnicowaniem taksonomicznym przy dużej niekiedy frekwencji kokkolitów. W warstwach występujących powyżej osadów chemicznych w zespołach nannoplanktonu dominują: *Calcidiscus leptoporus* (Murray et Blackman), *C. macintyre* (Bukry et Bramlette), *Coccolithus pelagicus* (Wallich), *Reticulofenestrapseudoumbilica* (Gartner) wraz z drobnymi formami *R. minuta* Roth i *R. minutula/haqii* (tabl. I–III). W warstwach pektenowych charakterystyczna jest obecność rodzaju *Helicosphaera*, któremu towarzyszy *Sphenolithus abies* Deflandre. W ilach krakowieckich zróżnicowanie zespołu kokkolitów miocenijskich maleje, wzrasta natomiast liczba form redeponowanych ze starszych utworów, głównie kredowych i eoceńskich (fig. 2–4). Rodzaj *Discoaster*, ważny dla stratygrafii miocenu, w badanych utworach reprezentowany jest nielicznie. Skład taksonomiczny zespołów nannoplanktonu pozwala zaliczyć warstwy baranowskie do poziomu NN 6 *Discoaster exilis* standardowego podziału neogenu, natomiast osady formacji z Machowa (warstwy pektenowe i ily krakowieckie) reprezentują prawdopodobnie poziomy NN 8 *Catinaster coalitus* i NN 9 *Discoaster hamatus*. Sugeruje to sarmacki wiek formacji z Machowa, łącznie z warstwami pektenowymi. Skład taksonomiczny zespołów nannoplanktonu z warstw pektenowych i ilów krakowieckich jest podobny do sarmackich zespołów z Paratetydy Centralnej (basen wiedeński). Świadczy o morskim charakterze zbiornika, którego chemizm ulegał okresowym zmianom. Kopalnym zapisem tych zmian jest obecność w profilu ilów krakowieckich osadów zawierających monogatunkowe zespoły nannoplanktonu (tabl. IV, fig. 1, 2). Wzrost liczby kokkolitów redeponowanych w wyższej części profilu świadczy o intensywności dopływu materiału terygenicznego do zbiornika, a ich pochodzenie pozwala wnioskować, że północne otoczenie zbiornika stanowiło obszar alimentacyjny.

PLATE I

Figs. 1-4. *Coccolithus pelagicus* (Wallich)

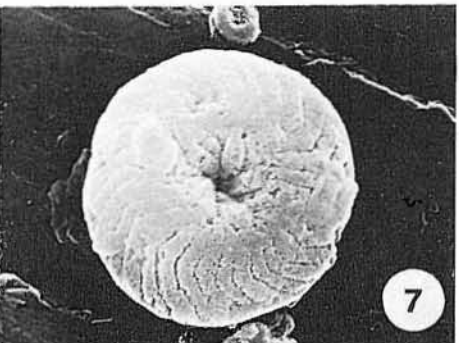
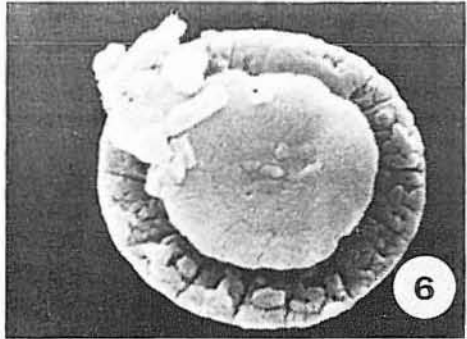
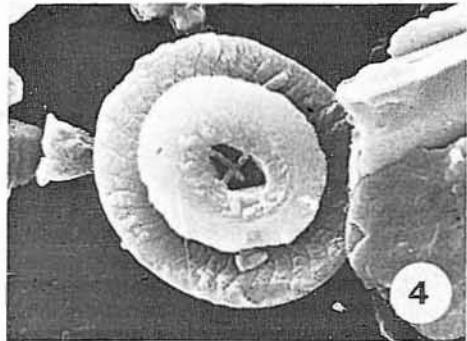
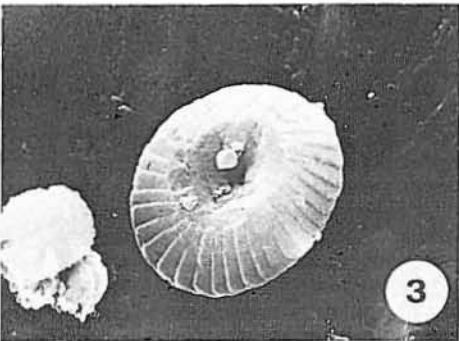
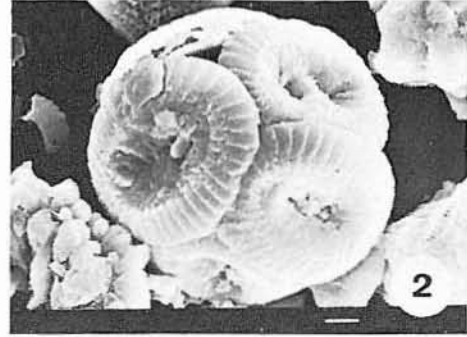
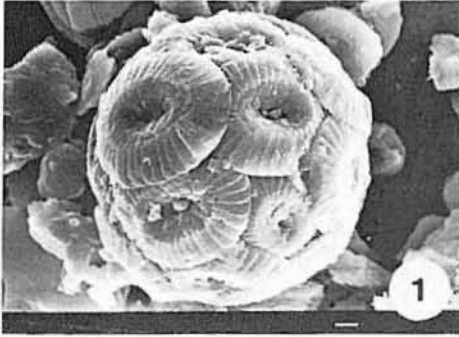
Machów mine, *Pecten* Beds (warstwy pektenowe): Fig. 1 — 3500 x, Fig. 2 — 4500 x; Jamnica S-119 borehole, Krakowiec Clays (iły krakowieckie): Fig. 3 — 4500 x, Fig. 4 — 7500 x

Fig. 5. *Calcidiscus macintyre* (Bukry et Bramlette)

Machów mine, *Pecten* Beds (warstwy pektenowe), 4500 x

Figs. 6-8. *Calcidiscus leptoporus* (Murray et Blackman)

Jamnica S-119 borehole, Krakowiec Clays (iły krakowieckie): Fig. 6 — 9000 x, Fig. 7 — 6000 x, Fig. 8 — 8500 x



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PLATE II

Fig. 1. *Helicosphaera walbersdorfensis* Müller
4500 x

Figs. 2, 3. *Helicosphaera kampfneri* Hay et Mohler

Fig. 2 — 4500 x, Fig. 3 — 7000 x

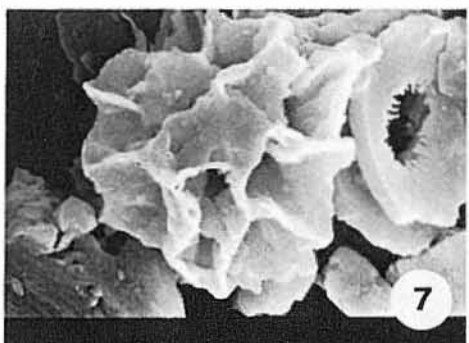
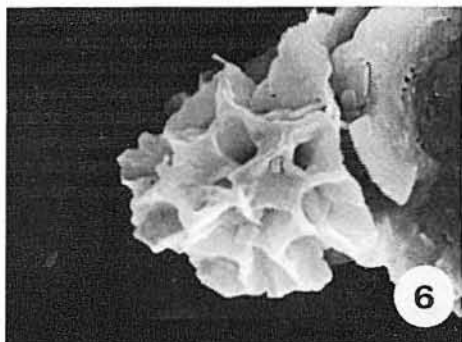
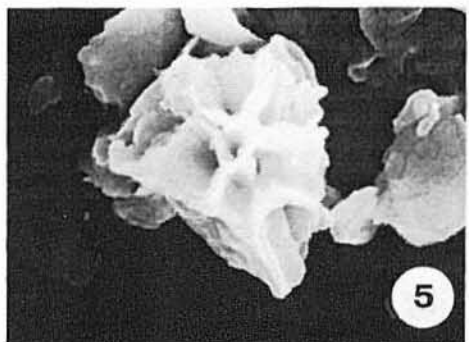
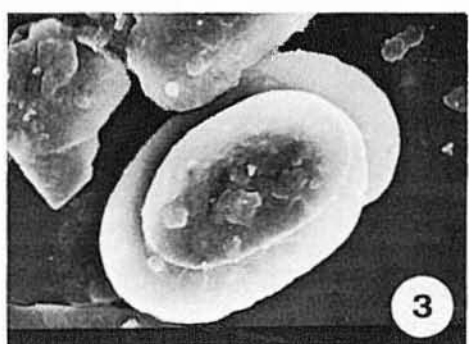
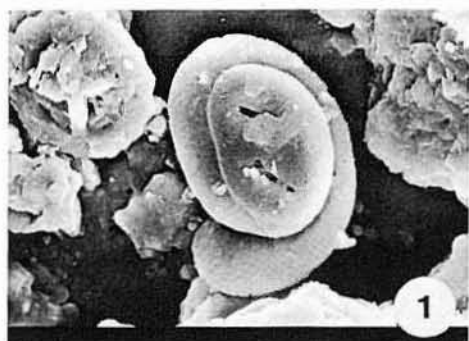
Fig. 4. *Helicosphaera granulata* Bukry et Percival
4500 x

Figs. 5-7. *Sphenolithus abies* Deflandre
9000 x

Fig. 8. *Discoaster stellulus* Gartner
4500 x

All specimens from *Pecten* Beds, Machów mine

Wszystkie okazy pochodzą z warstw pektenowych z kopalni Machów



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PLATE III

Fig. 1. *Holodiscus macroporus* (Deflandre)

15 000 x

Fig. 2. *Rhabdosphaera sicca* Stradner

7000 x

Fig. 3. *Braarudosphaera bigelowii* (Gran et Braarud)

2500 x

Figs. 4–6. *Reticulofenestra pseudoumbilica* (Gartner)

Fig. 4 — 6000 x, Fig. 5 — 4500 x, Fig. 6 — 8000 x

Fig. 7. *Reticulofenestra minuta* Roth

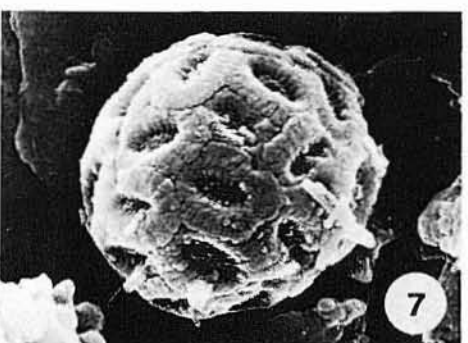
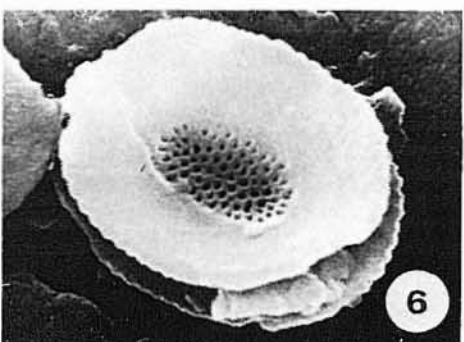
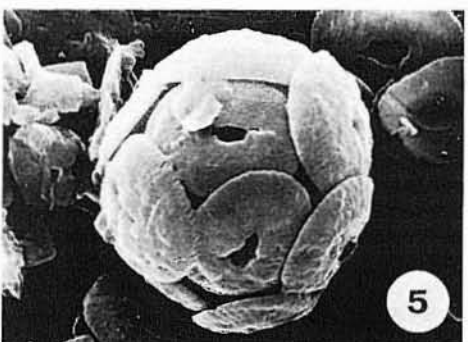
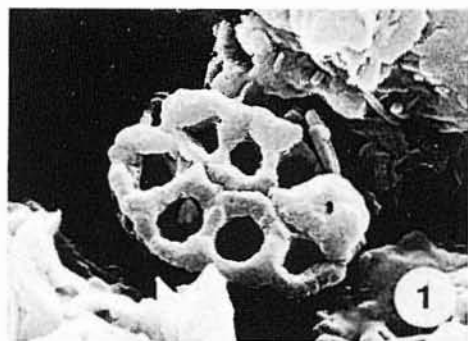
9000 x

Fig. 8. *Thoracosphaera* sp.

2000 x

All specimens from Krakowiec Clays, Jamnica S-119 borehole

Wszystkie okazy pochodzą z ilów krakowieckich z otworu wiertniczego Jamnica S-119



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PLATE IV

Fig. 1. Monospecific thanatocenosis of *Umbilicosphaera rotula* (Kamptner)

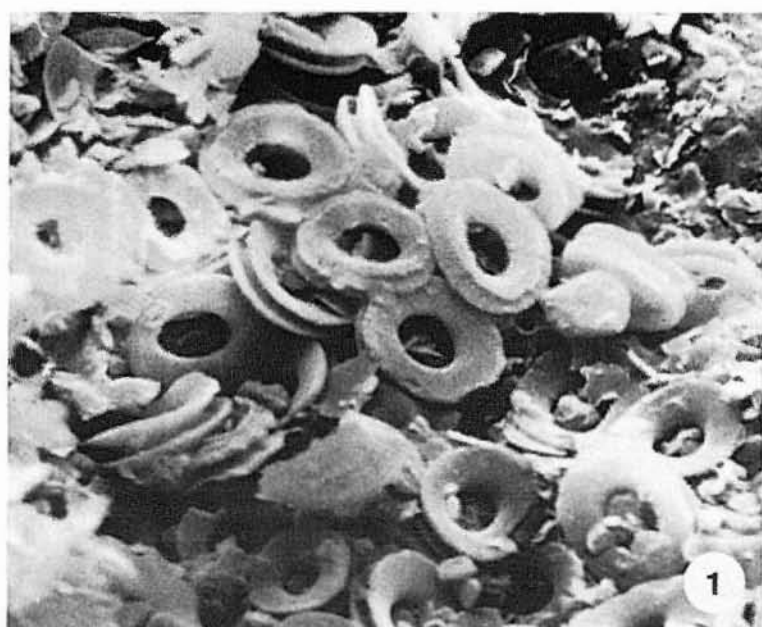
Krakowiec Clays, Machów, 4500 x (Fot. courtesy of R. Kaczyński)

Monogatunkowa thanatocenoza z ilów krakowieckich z kopalni Machów (fot. udostępnione przez R. Kaczyńskiego)

Fig. 2. Monospecific thanatocenosis of *Reticulofenestra pseudoumbilica* (Gartner)

Krakowiec Clays, Jamnica S-119 borehole, 2500 x

Monogatunkowa thanatocenoza z ilów krakowieckich z otworu wiertniczego Jamnica S-119



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