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LATE CRETACEOUS FORAMINIFERIDS AND CALCAREOUS NANNOPLANKTON FROM THE WĘGLÓWKA MARLS (SUBSILESIAN UNIT, OUTER CARPATHIANS, POLAND)

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Abstract: The foraminiferal and nannoplankton assemblages analysed in the Węglówka Marls, Subsilesian Unit, indicate the Campanian–Maastrichtian age. These sediments were deposited on the outer shelf and the upper–mid part of the slope. Paleoecological analyses indicated a relationship between some morphotypes and their life strategies. Morphogroup analysis of the foraminiferids are indicative of paleobathymetrical changes in the studied part of the basin, based on the relationship between keeled/non keeled taxa as well as on the quantitative distribution of the several benthic genera. The foraminiferids and the calcareous nannoplankton assemblages indicate the Tethyan/Boreal affinity.

Key words: Late Cretaceous, Polish Flysch Carpathians, Węglówka Marls, paleoecology, paleobiogeography, bioprovinces, foraminiferids, calcareous nannoplankton.

Introduction

The first geological data from the Węglówka area were published by Uhlig in 1883. Subsequently, a summary of the historical investigations of the Węglówka Unit was outlined by Huss (1957). Hiltermann (1943), Czernikowski (1949), Huss (1957, 1966), Huss (in Mitura & Birecki 1966) and Geroch (in Bieda et al. 1963) were the first who described foraminiferids from the Węglówka Unit. The Węglówka Marls were stratigraphically evaluated as the Senonian-Paleocene sediments of the Subsilesian Unit by Bieda et al. (1963), Koszarski (1985) and Ślączka (1996) on their lithostratigraphical charts. In the meantime, Olszewska (1997, fig. 1) has indicated the stratigraphic position of the Węglówka Marls and Shales Formation from the Santonian to the top of the Bartonian.

An examination of the published micropaleontological data, which have been compiled up to date, taken together with new trends in micropaleontology, suggest that it is necessary to examine and to revise the micropaleontology of this significant stratigraphical horizon in the Carpathians. This is especially important, because the Subsilesian Unit occupies a significant position within the Outer Carpathian Basin and the Węglówka Marls form the main Late Cretaceous pelagic sequence of this unit. This unit is presumably continued by the Helveticum and Buntmergelserie in the Eastern Alps.

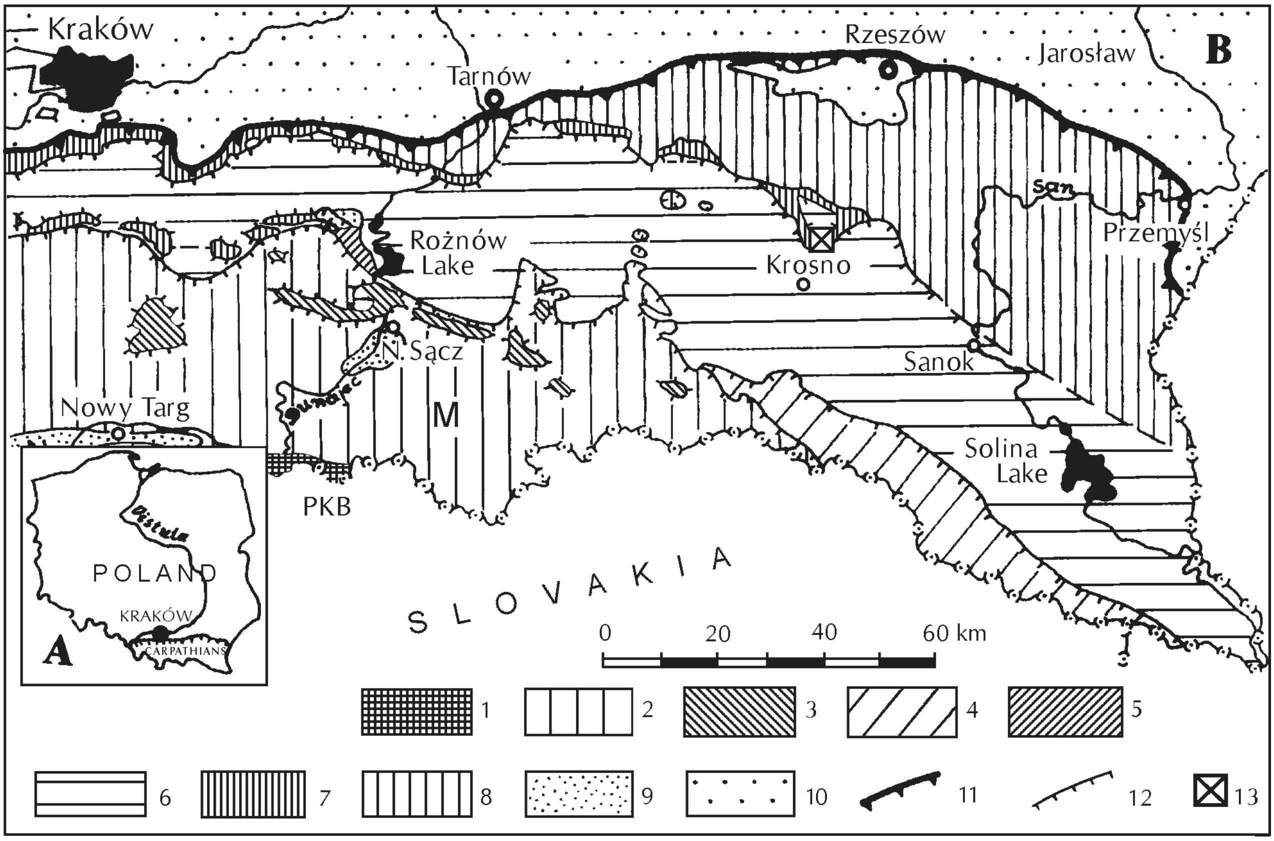
In the Carpathian Basin, autochthonous Late Cretaceous pelagic facies containing relatively rich planktonic foraminiferids, are rather uncommon within the dominant turbiditic sequences (Bieda et al. 1963). However, it is often difficult to differentiate between the autochthonous and allochthonous elements of the interturbidite pelagic sediments (see Winkler 1984; Winkler & Stuijvenberg 1982; Winkler in: Gasiński et al. 1997). Due to the general absence of planktonic foraminiferids, the Late Cretaceous sequences of the External Carpathians are stratigraphically dated mainly on the basis of deep-water agglutinated foraminiferids. Consequently, these Węglówka Marls, which are rich in planktonic foraminiferids can be used to establish the precise biostratigraphical position as well as the paleobiogeographical affinity.

The preliminary results presented concern the Late Cretaceous part of the Węglówka Marls, which are exclusively well exposed in Węglówka village, north of the town of Krosno (Fig. 1) and represents the only outcrop along the stream (Fig. 2B). Further studies, concerning the uppermost part of the Upper Cretaceous/Tertiary part of the Węglówka Marls will be carried out later, after a complete section have been exposed by cutting trenches.

Geological setting

In the area of Węglówka village, the Subsilesian Unit appears underlying the Silesian Nappe in a tectonic "semi-window" (Teisseyre 1947; Wdowiarz in: Książkiewicz 1968; Figs. 1, 2). It was formed by a secondary folded anticline, overthrust on the more external Skole Nappe.

The Subsilesian Unit represents a part of the Northern Carpathian depositional area, which was connected with a submarine swell developed during the Early Cretaceous period; that unit extends from Moravia in the West to the town of Lesko in the East. In the eastern part of the Northern Carpathians, the sedimentary basin of the Subsilesian swell was situated between the Silesian and Skole troughs and is characterized by the occurrence of varie-



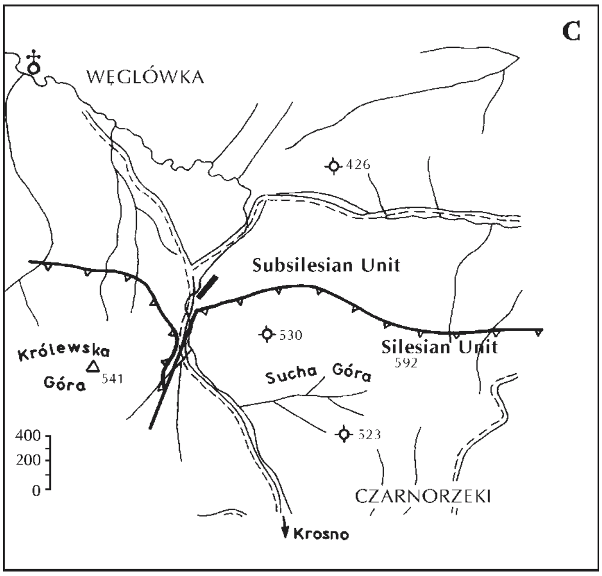


Fig. 1. A. Position of the Polish Carpathians. **B.** General geological sketch of the Northern Carpathians (Polish sector; after Cieszkowski 1992, simplified). 1 — Pieniny Klippen Belt (PKB); 2 — Magura Nappe; 3 — Grybów Unit; 4 — Dukla Unit; 5 — Michalczowa zone; 6 — Silesian Nappe; 7 — Subsilesian Nappe; 8 — Skole Nappe; 9 — Miocene deposits on the Carpathians; 10 — Carpathian Foredeep; 11 — Carpathian overthrust; 12 — main thrust-zones; 13 — Węglówka section. **C.** Localization of the Węglówka (after Jucha, Mitura & Swidzinski in Książkiewicz 1968, simplified).

gated pelagic sediments of Late Cretaceous, Paleocene and Eocene ages (Książkiewicz 1962).

The Early Cretaceous sediments of the Subsilesian Unit are very similar to the sediments of the Silesian trough and they are represented by black clayey shales with intercalations of turbidites.

In the area of Węglówka, the Subsilesian Unit starts with the Lower Cretaceous sequence, which comprise the following beds: black, clayey shales (Verovice Shales) with intercalations of thick to medium-bedded turbidites (Grodziszcze Sandstones) of Barremian–Aptian age; thick-bedded turbidites (Lower Lgota Beds) representing the early part of Albian; dark, spotted and greenish shales with medium and thin-bedded turbidites, mainly gaize facies (Gaize Beds) of Late Albian age.

The Upper Cretaceous sequence begins mainly with green shales with Radiolaria and radiolarites, followed by red clayey shales of Turonian age; these sediments are similar to the coeval sediments found in other parts of the Carpathian depositional area. Later on, the sediments of the North Carpathians became differentiated due to local uplifts**.** In the Węglówka area, the shales pass quickly upwards to red, pink, green and yellow homogenous marls (Węglówka Marls) of Santonian–Eocene age (after Olszewska 1997). In the adjacent Silesian and Skole basins thick siliciclastic turbidites prevailed. It is difficult to establish the total thickness of the Węglówka Marls because of its strong tectonic deformation, but they are in excess of 600 metres (Wdowiarz in Książkiewicz 1968). This marly sedimentation lasted for about 45 Ma, at a sedimentation rate of about 0.03 cm/a (30 cm/1000a).

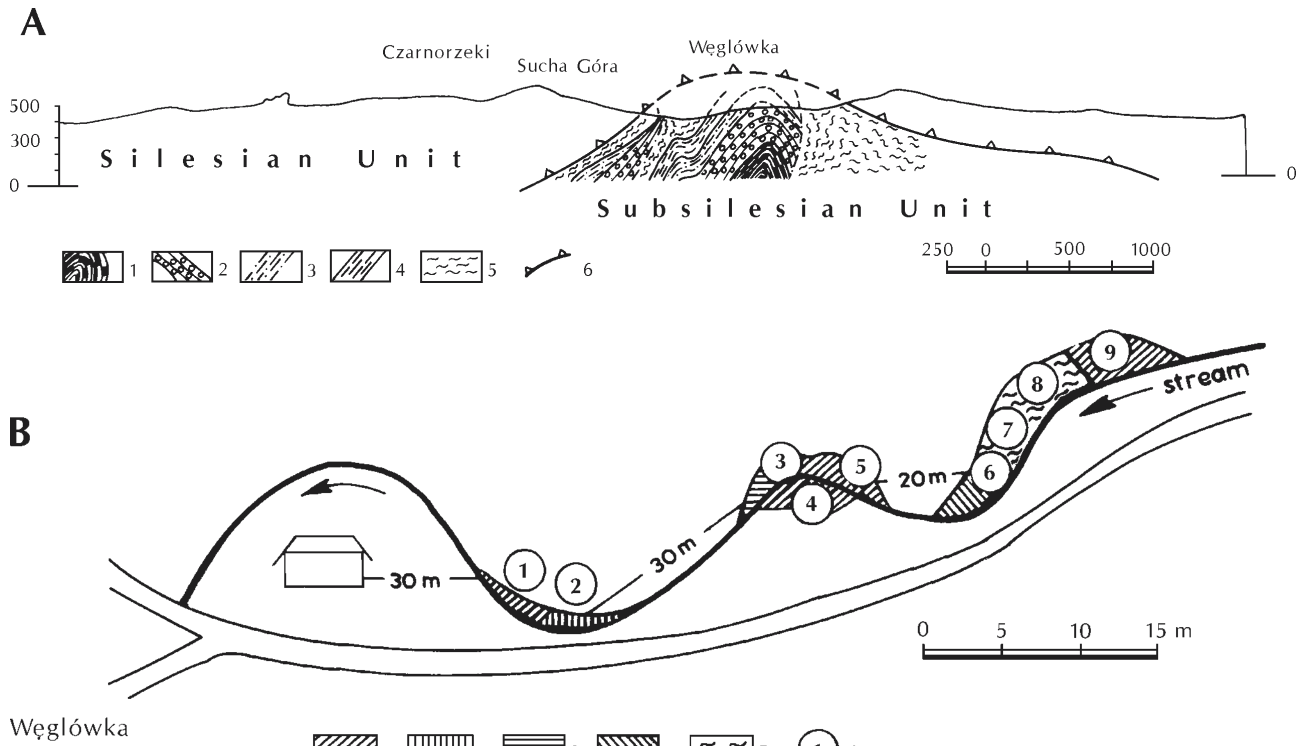


Fig. 2. A. Geological cross-section of the Węglówka area (after Jucha, Mitura & Świdziński, in Książkiewicz 1968, simplified). Subsilesian Unit: 1 — Verovice Shales; 2, 3 — Lgota Beds with gaizes; 4 — Variegated shales; 5 — Węglówka Marls; 6 — thrust-line of the Silesian Nappe. **B.** Lithology and samples location of the Węglówka Marls studied. 1 — red marlstones; 2 — green marlstones; 3 — pinkish-grey marlstones; 4 — brownish marlstones; 5 — whitish marlstones; 6 — samples location.

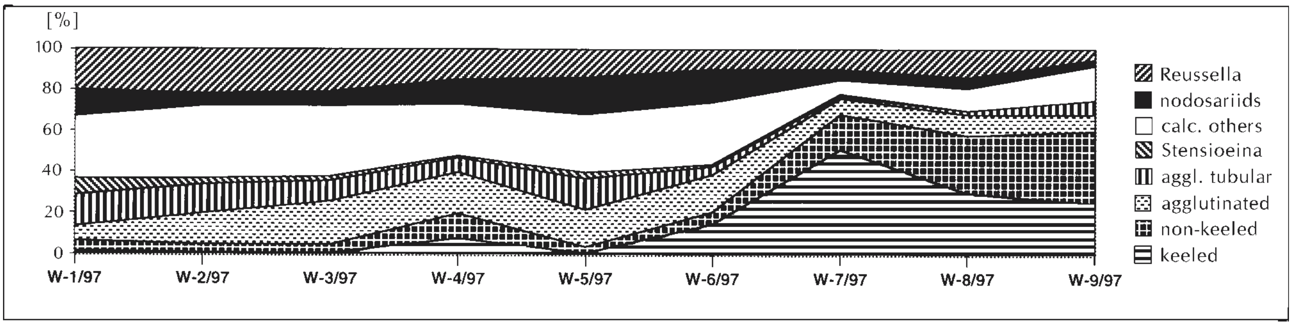


Fig. 3. Quantitative diagram of the studied foraminiferids. *Abbreviations:* calc. others — other calcareous benthic foraminiferids; aggl. tubular — agglutinated tubular foraminiferids (suspension feeders morphogroup).

The younger sequence comprises sediments which are similar to those of the adjoining Silesian and Skole troughs: thin-bedded turbidites (Hieroglyphic Beds) of the Middle and Late Eocene age, green shales and Globigerina Marls of the Late Eocene age, bituminous, brown shales with cherts (Menilite Beds) and turbidites (Krosno Beds) of the Oligocene age.

The Upper Cretaceous deposits are generally badly exposed and slightly longer sections are visible only in a few places. The best and longest outcrop exists along the stream running south of Węglówka village (Fig. 1). The marls visible in that stream belong to the southern limb of the Węglówka anticline which dips at an angle of 20–30° (Fig. 2A). However, neither the lower nor upper contacts are visible.

In the lower part of the profile, the marls are pinkish-red with weak fissility, interbedded with secondary green marls. The red marls have greenish spots, generally considered to be an effect of bioturbation; these are followed by pinkish-grey and red marlstones. In the upper part of the studied section, brownish, whitish and red marlstones appear (Fig. 2B).

Micropaleontological results

Foraminiferids

The composition of the foraminiferal assemblages from the studied samples are presented on Fig. 3 and characteristic taxa

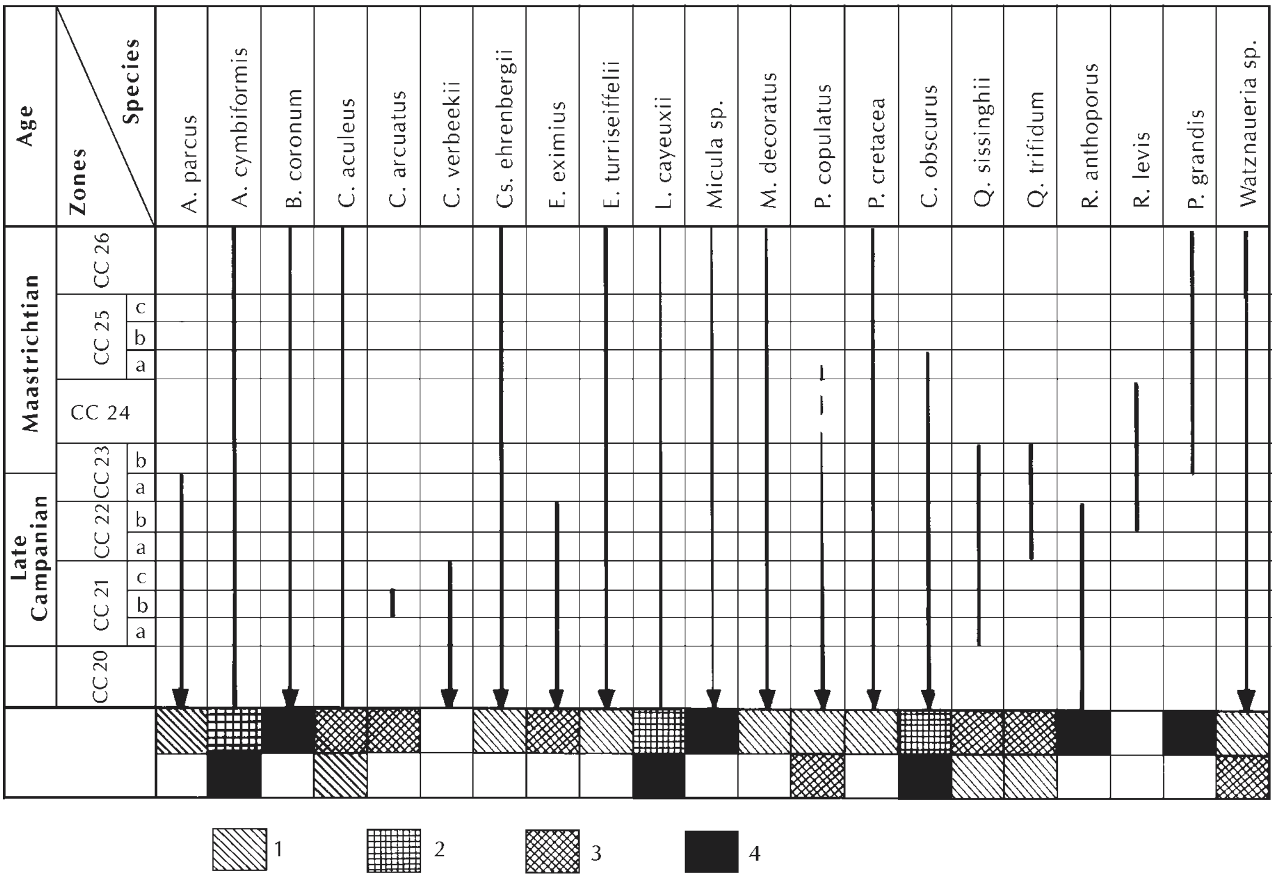


Fig. 4. Distribution of the stratigraphically significant calcareous nannofossils, with the standard nannofossils zones of Sissingh (1977) and Perch-Nielsen (1985). **1** — solution resistant taxa; **2** — marginal (shallow water) species; **3** — low and mid-latitude species; **4** — high-latitude species (after various authors).

are illustrated on Plates I–II. The identified foraminiferids are relatively well-preserved and are high diversified. The investigated assemblages are dated as being of Campanian–Early Maastrichtian age, mainly on the basis of the planktonic foraminiferids as well as selected benthic taxa (e.g. *Stensioeina* species).

Calcareous nannoplankton (see Appendix)

Watznaueria sp. and *Micula* sp. are the dominant genera in the studied samples. *Eiffellithus turriseiffelii*, *Cribrosphaerella ehrenbergii*, *Prediscosphaera cretacea*, *Microrhabdulus decoratus* and *Aspidolithus parcus* are also present. *Arkhangelskiella cymbiformis*, *Lucianorhabdus cayeuxii*, *Petrarhabdus copulatus*, *Quadrum sissinghii*, *Q. trifidum* and *Calculites obscurus* are relatively infrequent (1–10 specimens per sample). The studied nannoflora are relatively rich, well-preserved and, like the foraminiferids, highly diversified.

The important taxa are shown in Plates III–IV.

Biostratigraphy of the Upper Cretaceous sediments of the Węglówka Marls

The presence of planktonic foraminiferids, such as: *Globigerinelloides prairiehillensis* Pessagno, *Heterohelix striata* (Ehrenberg), *H. navarroensis* Loeblich, *Planoglobulina acervulinoides* (Egger), *Pseudotextularia elegans* (Rzehak), *Rosita fornicata* (Plummer), *Globotruncana arca* (Cushman), *Globotruncanita subspinosa* (Pessagno) as well as benthic *Stensioeina exsculpta* (Reuss) enable the studied samples to correlates with the interval of G. elevata?–G. gansseri zones *sensu* Caron (1985), Robaszynski & Caron (1995) i.e. Campanian–Maastrichtian. The samples Nos.W-1/97 to W-3/97 were dated to the Campanian and consequently, the foraminiferal assemblages belong to Caron's (1985) G. elevata? to G. calcarata zones. The samples Nos. W-4/97 to W-8/97 were compared with the Early Maastrichtian G. aegyptiaca Zone *sensu* Caron (1985), mainly on the basis of stratigraphic range of *G. prairiehillensis, H. navarroensis, G. subspinosa, R. fornicata*. These samples were compared with the revised chronostratigraphic position of zones by Robaszynski & Caron (1995), as being Late Campanian in age. In sample No. W-9/97, a few specimens were identified as *Abathomphalus* cf. *mayaroensis* (Bolli), which suggests the Late Maastrichtian.

However, it should be noted, that most of the index taxa of the Late Cretaceous standard zones are absent in the studied assemblages: this is probably because of their bathymetric and/or paleobiogeographic preferences (cf. Hart & Bailey 1979; Caron & Homewood 1983; Hart & Ball 1986; Gasiński 1998). Affiliation to the "standard" zones is confirmed

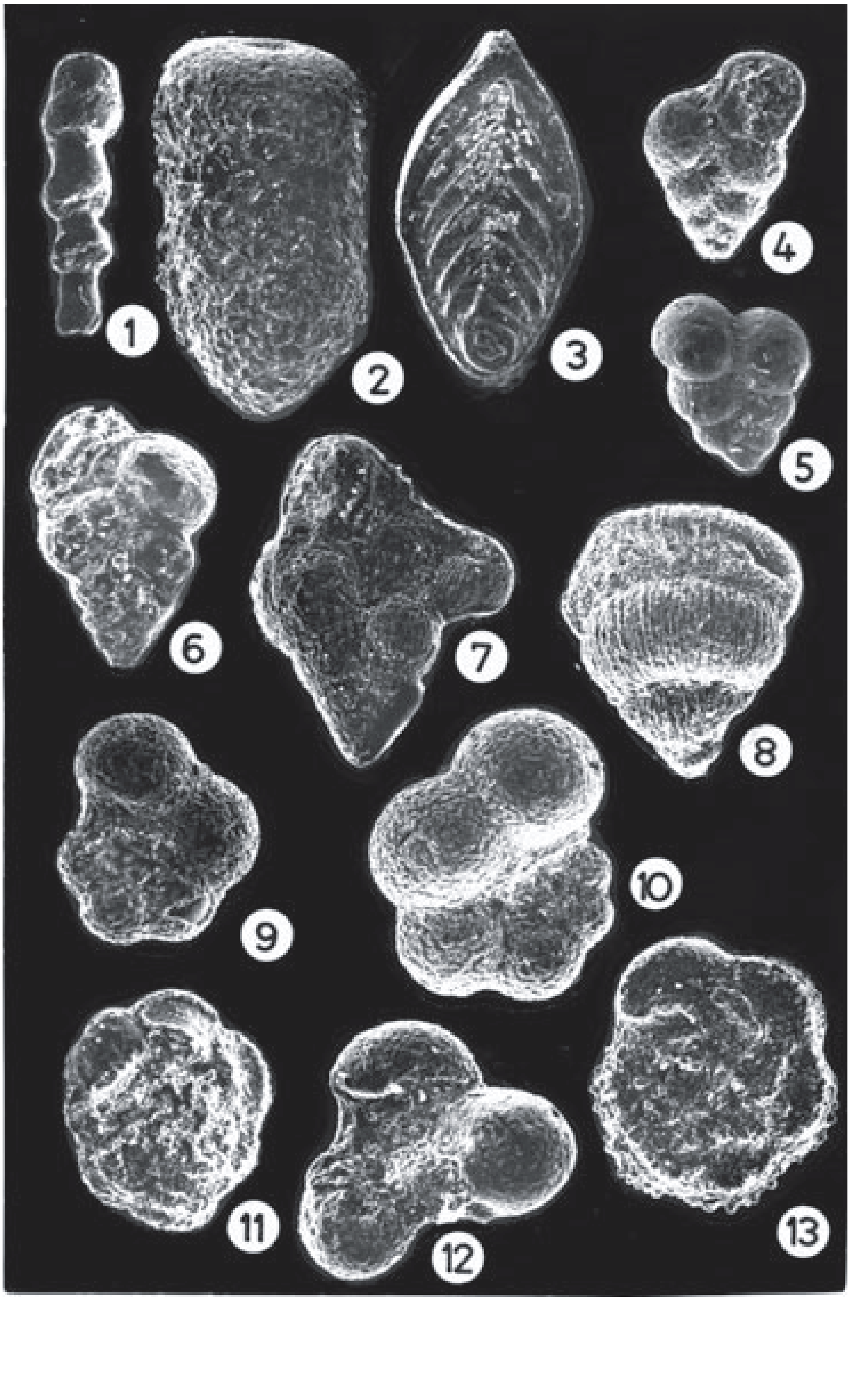


Plate I: Foraminiferids. **Fig. 1** — *Hormosina* cf. *excelsa* (Dylazanka), W-3; ×100. **Fig. 2** — *Goesella rugosa* (Hanzlikova), W-3, ×75. **Fig. 3** — *Neoflabellina numismalis* (Wedekind), W-2, ×75. **Figs. 4, 5** — *Heterohelix striata* (Ehrenberg), W-6; 4 — ×150; 5 — ×100. **Fig. 6** — *H. navarroensis* Loeblich, W-4, ×200. **Fig. 7** — *Planoglobulina acervulinoides* (Egger), W-9, ×200. **Fig. 8** — *Pseudotextularia elegans* (Rzehak), W-8, ×150. **Figs. 9, 10** — *Globigerinelloides prairiehillensis* Pessagno; 9 — W-4; 10 — W-6; ×200. **Figs. 11, 13** — *Globotruncana arca* (Cushman); 11 — W-4, ×150; 13 — W-8, ×100. **Fig. 12** — *Schackoina* cf. *tappanae* Montanaro-Gallitelli, W-8, ×350.

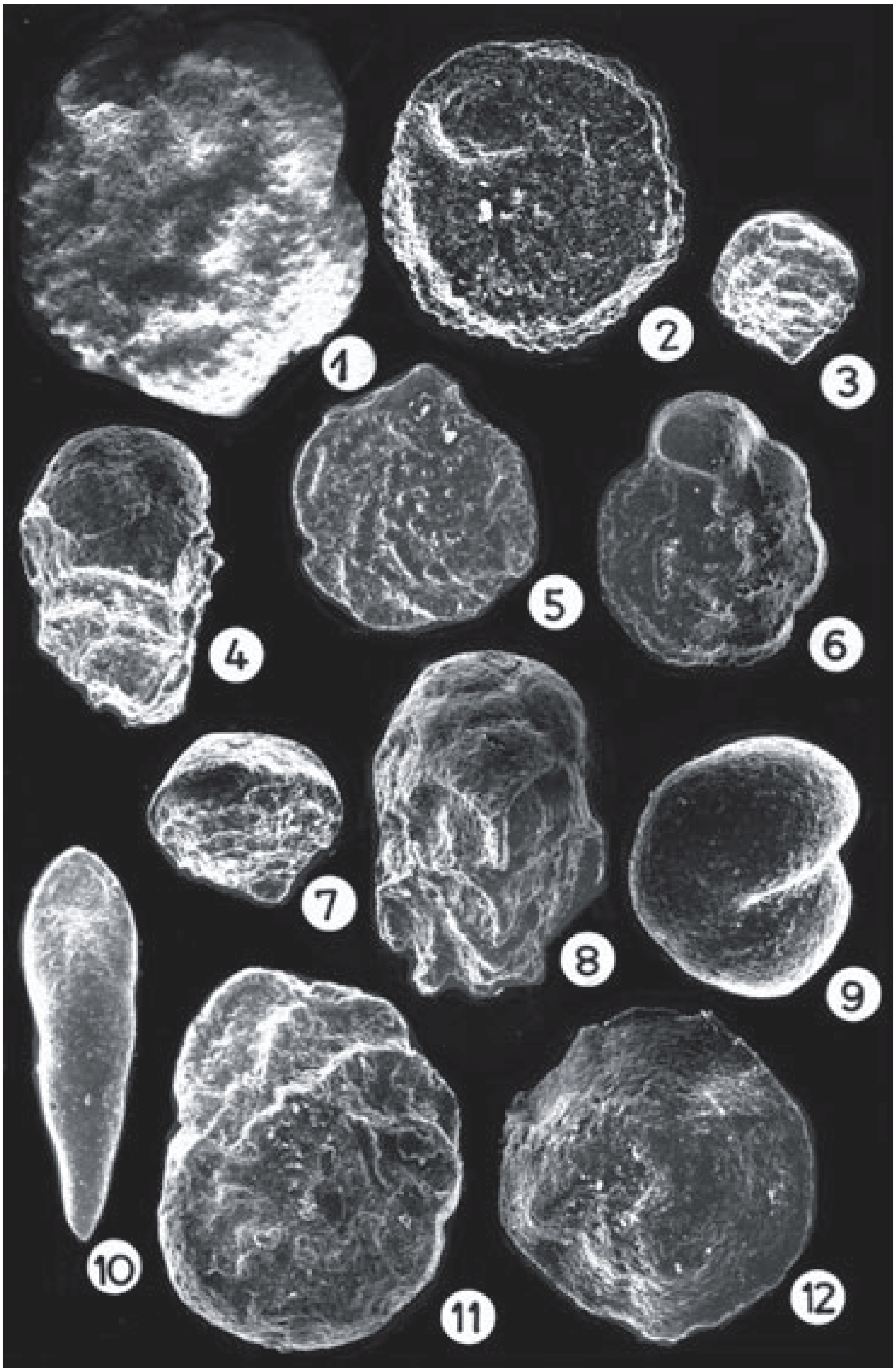


Plate II: Foraminiferids. **Fig. 1** — *Abathomphalus* cf. *mayaroensis* (Bolli), W-9, ×200. **Fig. 2** — *Rosita fornicata* (Plummer), W-7, ×150. **Figs. 3, 7** — *Aragonia velascoensis* (Cushman), W-3, ×150. **Figs. 4, 8** — *Reussella szajnochae* (Grzybowski), 4 — W-1; 8 — W-3; ×100. **Fig. 5** — *Globotruncanita subspinosa* (Pessagno), W-8, ×100. **Fig. 6** — *Globotruncana arca* (Cushman), W-8, ×100. **Fig. 9** — *Pullenia cretacea* Cushman, W-5, ×150. **Fig. 10** — *Pleurostomella subnodosa* Reuss, W-5, ×75. **Fig. 11** — *Stensioeina exsculpta* (Reuss), W-1, ×150. **Fig. 12** — *Globorotalites michelinianus* (d'Orbigny), W-5, ×150.

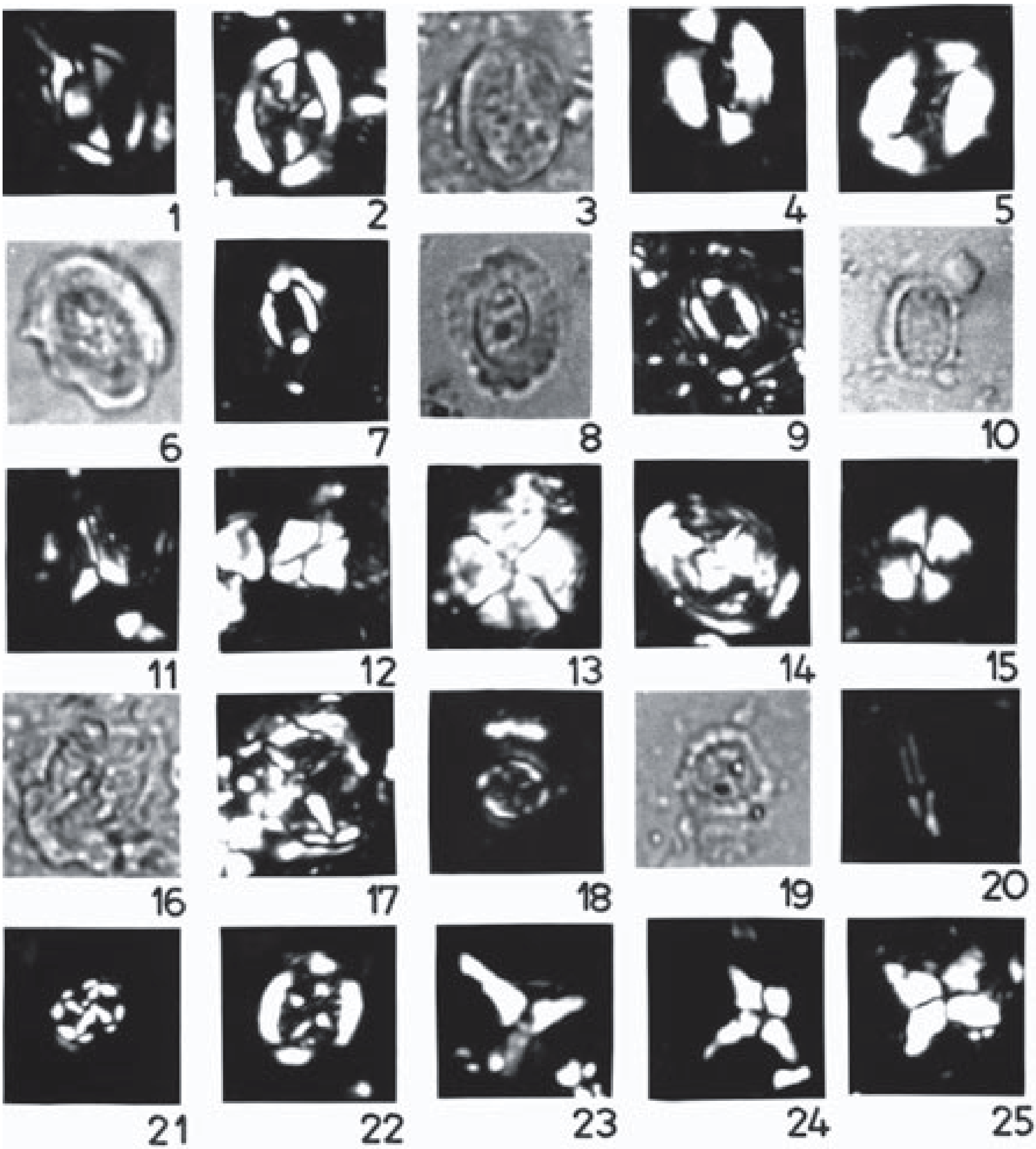


Plate III: Calcareous nannofossils. All specimens ×2400. **Figs. 1–3** — *Arkhangelskiella cymbiformis* Vekshina. **Figs. 4–6** — *Aspidolithus parcus* (Stradner) Noel. **Figs. 7, 8** — *Biscutum magnum* Wind & Wise. **Figs. 9, 10** — *Cribrosphaerella ehrenbergii* (Arkhangelsky) Deflandre. **Fig. 11** — *Ceratolithoides aculeus* (Stradner) Prins & Sissingh. **Fig. 12** — *Calculites obscurus* (Deflandre) Prins & Sissingh. **Fig. 13** — *Petrarhabdus copulatus* (Deflandre) Wind & Wise. **Fig. 14** — *Zeugrhabdotus pseudanthophorus* (Bramlette & Martini) Perch-Nielsen. **Fig. 15** — *Watznaueria barnesae* (Black & Barnes) Perch-Nielsen. **Figs. 16, 17** —*Prediscosphaera grandis* Perch-Nielsen. **Figs. 18–21** — *Prediscosphaera cretacea* (Arkhangelsky) Gartner. **Fig. 22** — *Stradneria crenulata* (Bramlette & Martini) Noel. **Fig. 23** — *Quadrum trifidum* (Stradner & Papp) Prins & Perch-Nielsen. **Figs. 24, 25** — *Quadrum sissinghii* Perch-Nielsen.

only by resolution of the stratigraphic range of recognized planktonic species.

Sissingh's (1977) zonation was applied to determine the age of the identified taxa. Samples Nos. W-1/97 to W-4/97 have been classified as a part of the CC 21 (Quadrum sissinghii) Zone *sensu* Sissingh (1977; nom. corr.—early Late Campanian), on the basis of the presence of *Q. sissinghii* and the lack of *Q. trifidum*, the scarcity of *A. cymbiformis, C. verbeekii*, and the abundance of *C. aculeus, R. anthoporus, E. eximius, E. turriseiffelii, C. ehrenbergii, P. cretacea* and *M. decoratus* (see Fig. 4).

Samples Nos. W-5/97 to W-9/97 are correlated with CC 22 (Quadrum trifidum) Zone after Bukry & Bramlette 1970;

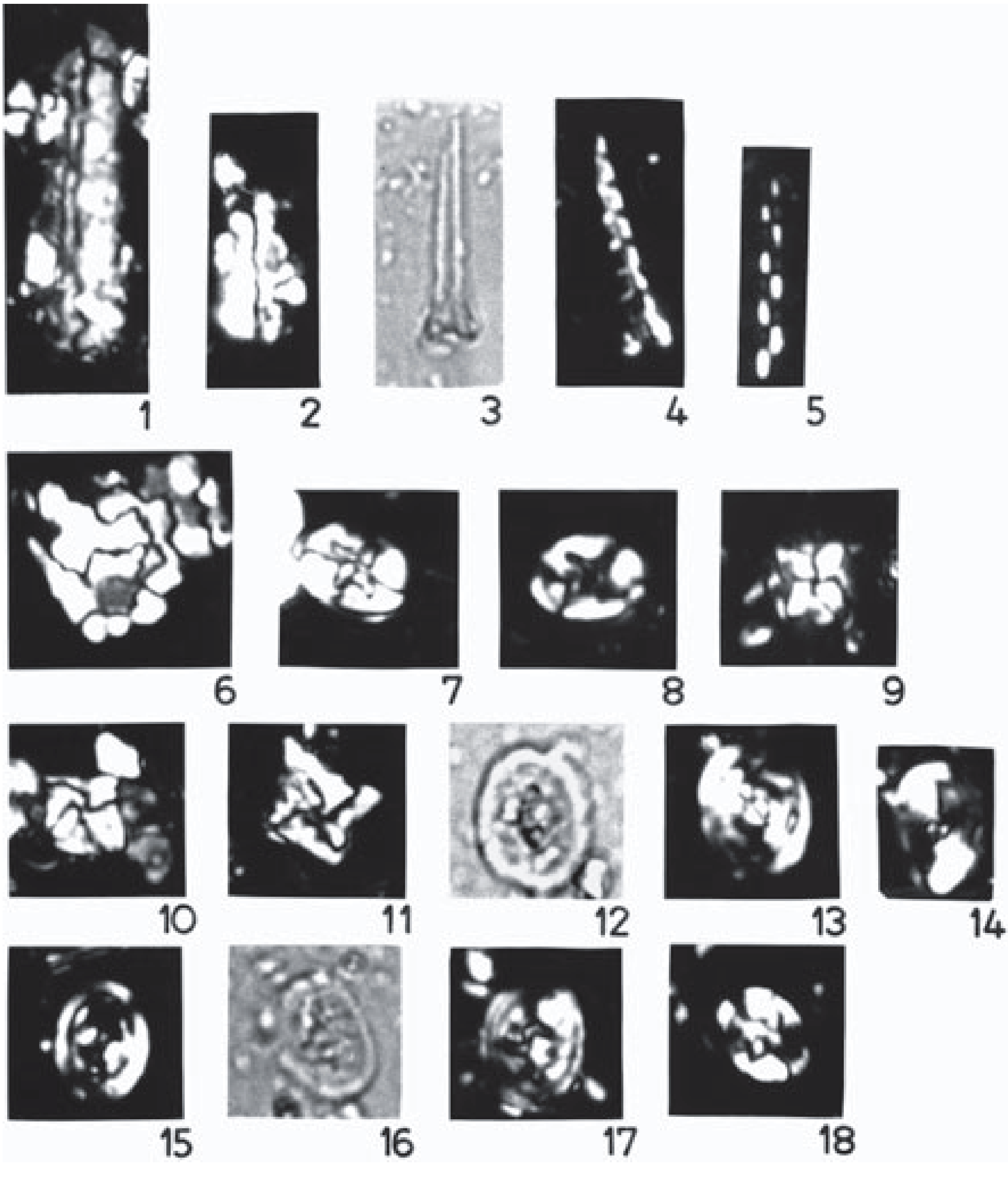


Plate IV: Calcareous nannofossils. All specimens ×2400. **Figs. 1, 2** — *Lucianorhabdus cayeuxii* Deflandre. **Figs. 3, 4, 7, 8** — *Eiffellithus turriseiffelii* (Deflandre & Fert) Reinhardt. **Fig. 5** — *Microrhabdulus decoratus* Deflandre. **Fig. 6** — *Thoracosphaera* sp. Kamptner. **Fig. 9** — *Micula decussata* Vekshina. **Figs. 10, 11** — *Micula swastica* Stradner & Steinmetz. **Figs. 12–15** — *Reinhardtites anthoporus* (Deflandre) Perch-Nielsen. **Figs. 16, 17** — *Reinhardtites levis* Prins & Sissingh. **Fig. 18** — *Eiffellithus* cf. *eximius* (Stover) Perch-Nielsen.

emended by Sissingh 1977; nom. corr.—early Late Campanian; the most diagnostic taxa are: *Q. trifidum* (first occurrence: the FO of this species indicates the base of the zone), *R. anthoporus, R. levis, A. parcus, P. cretacea, A. cymbiformis, P. copulatus, L. cayeuxii. B. coronum* and *M. decoratus*. Furthermore, in sample No. W-7/97, increases in *A. cymbiformis* and *R. levis* are obvious. In addition, rare specimens of *P. grandis* were identified, suggesting that this sample could be classified into CC 23 Zone: Tranolithus phacelosus Zone (mainly CC 23b, based on the FO of *P. grandis*), i.e. Early Maastrichtian (according to Sissingh 1977). However, *T. phacelosus* was not identified in the investigated samples (according to Doeven 1983; this species has its extinction before the last occurrence: LO of *Q. trifidum*). Furthermore, the absence of *E. eximius*, the last occurrence of which is correlated with the extinction of *R. anthoporus*, was observed.

The stratigraphic ranges and paleobiogeographical affinity of the significant nannofossil taxa are shown in Fig. 4.

Paleoecology and Paleobiogeography

An examination of the quantitative analysis of the studied samples from the Campanian to earliest Maastrichtian (Fig. 3) shows that during the studied timespan, the composition of foraminiferal assemblages show a following tendency towards the Campanian/Maastrichtian–earliest Maastrichtian (for samples W-7/97–W-9/97): keeled planktonic taxa (*Globotruncana, Globotruncanella, Rosita*) increased in reverse proportion to the non-keeled taxa (such as genera: *Globigerinelloides, Pseudotextularia, Planoglobulina, Heterohelix, Hedbergella*). It should be remembered that the relationship of keeled/non-keeled taxa is also diagnostic for paleobathymetry; i.e. keeled forms were found to be bathypelagic group and non-keeled taxa are epipelagic dwellers (cf. Sliter 1972, 1977; Sliter & Baker 1972; Gasiński 1997a, 1998). Therefore, domination of keeled taxa can be used as the main criterion among planktonic taxa, indicating the deep water character of the studied deposits.

A morphogroup analyses *sensu* Jones & Charnock (1985), Corliss & Chen (1988), Corliss & Fois (1990), Koutsoukos & Hart (1990), Nagy (1992), Gasiński et al. (1997) and Gasiński (1998) has indicated that suspension feeders (agglutinated foraminifers, *Rhabdammina*-type tubular taxa) also become more numerous as keeled taxa decrease; this is probably related to an increasing organic flux to the sea bottom, during the regression episode. In particular, the youngest sample studied (No. W-9/97) showed a decrease in the number of keeled taxa and an associated increase of the suspension feeders morphogroup.

Nodosariids are relatively abundant in samples Nos. W-5/97 and W-6/97 (Early Maastrichtian); this abundance can be correlated with a rapid decrease in planktonic taxa (keeled and non-keeled forms; particularly in sample No. W-5/97); suspension feeders were relatively numerous in this sample and this can be interpreted as an indication of falling sea level which caused increasing organic flux on the sea bottom (cf. Corliss & Fois 1990; Gasiński 1998). These samples probably represent an environment which was located under a shallower water column, affected by eustatic and/or tectonic sea level changes. Towards the Maastrichtian samples, the decrease in the quantity of calcareous benthics is also obvious. Specimens of the genus *Reussella* (mainly *R. szajnochae*) were also relatively abundant in the Campanian assemblages (samples Nos. W-1/97 to W-3/97) and this genus gradually decreased towards the Maastrichtian. According to Kuhnt & Obert (1989) *Reussella szajnochae* (Grzybowski) is characteristic for the middle bathyal zone of the Morrocan Rif basin; this species was recognized in the Carpathian 'Velasco-type' assemblages, as being characteristic of the bathyal zone, in the part located above the CCD (Olszewska 1984, table II); Hart & Bailey (1979; fig. 3) have also confirmed its deep-water preferences. However, keeled planktonics are relatively scarce or even absent in samples Nos. W-5/97 and W-6/97. Specimens of *Stensioeina* are also relatively abundant in those samples, where specimens of genus *Reussella* are relatively common (Fig. 3).

Taking into consideration the above findings, the Campanian sediments were deposited in a deeper (uppermost–mid slope) environment, while the Maastrichtian ones indicate shallower conditions (outer shelf–uppermost slope). Another possible explanation is related to a local invasion of cold Boreal, less dense water masses carrying non-keeled taxa which, being dominant, do not indicate eustatic events (cf. Gasiński 1997a). The indicated mixed Tethyan-Boreal affinity of few species of calcareous nannoflora may have been caused by an invasion of epipelagic Boreal coccoliths, floating within the thin, cold surface waters. According to Olszewska (1997) red marls of the Węglówka type were deposited at the middle-lower bathyal depth.

The Tethyan affinity of the Węglówka Marls is confirmed by the foraminiferal assemblages. In contrary to the Andrychow klippes, having a "transitional" affinity (cf. Gasiński 1995, 1997b, 1998), the foraminiferal assemblages in the Węglówka Marls contain predominantly characteristic Tethyan species, e.g. very abundant *Reussella szajnochae* (Grzybowski), which is very scarce among the Andrychow assemblages (Fig. 3; cf. Gasiński 1998, fig. 13, table I). Geroch (in Geroch et al. 1967) described this species as being rather common in the Campanian marls of the Subsilesian Unit (see also: Liszkowa 1956, 1959, 1967; Książkiewicz 1975).

The majority of the identified calcareous nannoplankton species are resistant forms. Most of the taxa studied are well preserved and only some of them show signs of dissolution or of being overgrown with secondary calcite.

According to Perch-Nielsen (1979) and Thierstein (1976) *A. cymbiformis, L. cayeuxii, C. obscurus* preferred a hemipelagic environment.

It should be noted that among the studied assemblages, a very characteristic species, *P. copulatus* was identified; Deflandre (1959) noted this species in the Maastrichtian in France; however, this species has been mainly described from the Indian and Atlantic oceans, between 30°–40° S latitude. Nevertheless, the stratigraphic range of *P. copulatus* varies and its distribution appears to be limited to temperate and high latitude sites (cf. Wise 1983); its presence probably indicates influence on its niche by the Indian and South Atlantic oceans during the Campanian–Maastrichtian period. A similar suggestion has also been expressed by Švabenická (1995) from the Campanian of the Zdanice Unit; this is probably due to an imprecise determination of the paleobiogeographical range of this species. The calcareous nannoplankton assemblages of the Late Cretaceous part of the Węglówka Marls indicate a mixed Boreal-Tethyan affinity (see Fig. 4); some species are indicative of shallow (epicontinental seas and large shelf areas) water environments and these are mainly Boreal epipelagic nannoplankton taxa (see Fig. 4); their presence suggests possible activity of (wind-generated?) water surface currents; this fact supports the above opinion concerning the invasion of cold, Boreal surface waters into the Tethyan Realm.

Therefore, a consideration to be taken into account, is that this part of the Carpathian domain (see Geological setting) is located and/or influenced by the so-called "tension zone" (i.e. ecotone between the Boreal and Tethyan realms; see

Gasiński 1995, 1997a,b, 1998; Olszewska 1996); this influence is mainly expressed among the epipelagic nannoplankton associations (see Fig. 4).

Conclusions

— The Late Cretaceous part of the Węglówka Marls was dated as Campanian–Maastrichtian (within the G. elevata? to A. mayaroensis zones) on the basis of the planktonic foraminiferids and within the CC 21–CC 23b zones (Late Campanian–earliest Maastrichtian), on the basis of the calcareous nannoplankton;
— The foraminiferal assemblages have indicated that the deposits studied correspond to the upper–mid slope during the Campanian and to the outer shelf–uppermost slope environments at the begining of the Maastrichtian. Such bathymetric differences have been related to the invasion of cold, Boreal surface water;
— On the basis of the "morphotype" analysis, the foraminiferal assemblages indicate the fluctuation of the bathymetry which can be roughly correlated to global eustatic fluctuations.
— The foraminiferids document the Tethyan biogeoprovince, although the calcareous nannoplankton assemblages indicate a "tension zone" (Tethyan/Boreal) affinity.

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Appendix

(the list of nannofossil taxa, mentioned in the text)

Arkhangelskiella cymbiformis Vekshina (1959)
Aspidolithus parcus (Stradner 1963) Noel (1969)
Biscutum coronum Wind & Wise (1977)
Biscutum magnum Wind & Wise (1977)
Calculites obscurus (Deflandre 1959) Prins & Sissingh (1977)
Ceratolithoides aculeus (Stradner 1959) Prins & Sissingh (1977)
Ceratolithoides verbeekii Perch-Nielsen (1979a)
Cribrosphaerella ehrenbergii (Arkhangelsky 1912) Deflandre (1952)
Eiffellithus eximius (Stover 1966) Perch-Nielsen (1968)
Eiffellithus turriseiffelii (Deflandre & Fert 1954) Reinhardt (1965)
Lucianorhabdus cayeuxii Deflandre (1959)
Micula decussata Vekshina (1959)
Micula swastica Stradner & Steinmetz (1984)
Microrhabdulus decoratus Deflandre (1959)
Petrarhabdus copulatus (Deflandre 1959) Wind & Wise (1983)
Prediscosphaera cretacea (Arkhangelsky 1912) Gartner (1968)
Prediscosphaera grandis Perch-Nielsen (1979a)
Quadrum sissinghii Perch-Nielsen (1984b)
Quadrum trifidum (Stradner & Papp 1961) Prins & Perch-Nielsen (1977)
Reinhardtites anthoporus (Deflandre 1959) Perch-Nielsen (1968)
Reinhardtites levis Prins & Sissingh (1977)
Stradneria crenulata (Bramlette & Martini 1964) Noel (1970)
Watznaueria barnesae (Black & Barnes 1959) Perch-Nielsen (1960)
Zeugrhabdotus pseudanthophorus (Bramlette & Martini 1964) Perch-Nielsen (1984a)

References

Bieda F., Geroch S., Koszarski L., Książkiewicz M. & Zytko K., 1963: Stratigraphie des Karpates externes polonaises. *Biul. Inst. Geol.,* 181, 1–174.

Bukry D. & Bramlette M.N., 1970: Coccolith age determinations Leg 1, Deep Sea Drilling Project. *Init. Rep. Deep Sea Drilling Project,* 3, 589–611.

Caron M., 1985: Cretaceous planktonic foraminifera. In: Bolli H.M., Saunders J. & Perch-Nielsen K. (Eds.): *Plankton stratigraphy. Cambridge University Press*, Cambridge, 17–86.

Caron M. & Homewood P., 1983: Evolution of early planktic foraminifers. *Mar. Micropaleont.,* 7, 453–462.

Cieszkowski M., 1992: Michalczowa Zone — a new unit of the Fore-Magura Zone. West Carpathians, South Poland. *Zesz. Nauk. AGH*, *Geol.,* 18, 125 (in Polish, English summary).

Corliss B.H. & Chen C., 1988. Morphotype patterns of Norwegian Sea deep-sea benthic foraminifera and ecological implications. *Geology,* 16, 716–719.

Corliss B.H. & Fois E., 1990: Morphotype Analysis of Deep-Sea Benthic Foraminifera from the Northwest Gulf of Mexico. *Palaios*, 5, 589–605.

Czernikowski J., 1949: The Age of the Godula Beds and the Węglówka Marls, *Nafta* V, 5–6 (in Polish).

Deflandre G., 1959: Sue les nannofossiles calcaires et leur systematique. *Rev. Micropaléont.,* 2, 127–152.

Doeven P.H., 1983: Cretaceous nannofossils. Stratigraphy and paleoecology of the Canadian Atlantic Margin. *Bull. Geol. Surv. Canada*, 356, 1–70.

Gasiński M.A., 1995: Campanian-Maastrichtian foraminiferal assemblages from the Andrychow Klippens (Polish Carpathians)-Boreal visitors to the Tethyan realm?. *Ann. Assembly IGCP 362*, Maastricht, 1995, 36.

Gasiński M.A., 1997a: Tehyan-Boreal connection: influence on the evolution of mid-Cretaceous planktonic foraminiferids. *Cretaceous Research,* 18, 505–514.

Gasiński M.A., 1997b: Late Cretaceous foraminiferal migrants to the Carpathians: an example from the Andrychow Klippen Zone. *Miner. slovaca,* 29, 254–255.

Gasiński M.A., 1998: Campanian-Maastrichtian palaeoecology and palaeobiogeography of the Andrychow klippes, Carpathians, Poland. *Jagiellonian Univeristy, Transactions–Monographies,* Kraków, 333, 104.

Gasiński M.A., Slaczka A. & Winkler W., 1997: Tectono-sedimentary evolution of the Upper Prealpine nappe (Switzerland and France): nappe formation by Late Cretaceous-Paleogene accretion. *Geodinamica Acta*, 10, 4, 137–157.

Geroch S., Jednorowska A., Książkiewicz M. & Liszkowa J., 1967: Stratigraphy based upon microfauna in the Western Polish Carpathians. *Biul. Inst. Geol.,* 11, 186–282.

Hart M.B. & Bailey H.W., 1979: The distribution of planktonic Foraminiferida in the mid-Cretaceous of NW Europe. In: Wiedmann J.E. (Ed.): *Aspekte der Kreide Europas. Schweizerbart'sche Verlagsbuchhandlung*, Stuttgart International Union of Geological series, A, 6, 527–542.

Hart M.B. & Ball K.C., 1986: Late Cretaceous anoxic events, sea-level changes and the evolution of the planktonic foraminifera. In: Summerhayes C.P. & Shackleton N.J. (Eds.): *North Atlantic Palaeoceanography. Geol. Soc. Spec. Publ.*, 21, 67–78.

Hiltermann H., 1943: Zur Stratigraphie und Mikrofossilfuhrung der Mittelkarpathen. Ö*l u. Kohle*, 39**.**

Huss F., 1957: Stratigraphy of the Węglówka Unit in the light of its microfauna. *Acta Geol. Pol.,* 7, 29–69 (in Polish, English summary).

Huss F., 1966: Agglutinated Foraminifera of the oil-bearing Węglówka Unit (Subsilesian Unit). *Polska Akademia Nauk, Komisja Nauk Geologicznych, Prace Geol.,* 34, 7–71 (in Polish).

Jones R.W. & Charnock, 1985: "Morphogroups" of agglutinated foraminifera. Their life position and feeding habits and potential applicability in (paleo)ecological studies. *Rev. Paleobiol.,* 4, 311–320.

Koszarski L. (Ed.), 1985: Geology of the Middle Carpathians and the Carpathian Foredeep, Guide to excursion 3. *Carpatho-Balkan Association XIII Congress. Krakow. Poland 1985*, 254.

Koutsoukos E.A.M. & Hart M.B., 1990: Cretaceous foraminiferal morphogroup distribution patterns, palaeocommunities and trophic structures: a case study from the Sergipe Basin, Brazil. *Transactions Royal Soc. Edinburgh: Earth Sci.,* 81, 221–246.

Książkiewicz M. (Ed.), 1962: Geological Atlas of Poland. Stratigraphic and Facial Problems. Fasc.13. Instytut Geologiczny.

Książkiewicz M. (Ed.), 1968: Geology of the Polish Flysch Carpathians. Guide to Excursion No. C44, International Geological Congress, XXIII. session, Prague, 1968, (Ed.): *Geological Institute, Poland*, 73.

Książkiewicz M., 1975: Bathymetry of the Carpathian Flysch Basin. *Acta Geol. Pol.,* 25, 309–367.

Kuhnt W. & Obert D., 1989: Two Transversals throught the Cretaceous North African Continental Margin: The Tellian Units of the Western Rif (Morocco) and of the Babors (Algeria). In: Wiedmann J. (Ed.): *Cretaceous of the Western Tethys. Proceedings 3rd International Cretaceous Symposium*, *Tuebingen, 1987. E. Schweizerbart'sche Verlagsbuchhandlung*, Stuttgart, 27–89.

Liszkowa J., 1956: Microfauna of the Subsilesian Unit. *Przegl. Geol.,* 10, 463–469 (in Polish).

Liszkowa J., 1959: Microfuana from beds with exotics at Bachowice. *Biul. Inst. Geol.,* 131, 39–110.

Liszkowa J., 1967: Microfauna of the Upper Cretaceous marls in the Sub-Silesian series of the Wadowice region (Western Carpathians). *Biul. Inst. Geol.,* 211, 341–351.

Mitura F. & Birecki T. (Eds.), 1966: Geological structure of the Carpathians between Korczyna and Domaradz. *Prace Inst. Naft., " Slask" Ed.,* Katowice, *52* (in Polish, English summary).

Nagy J., 1992: Environmental significance of foraminiferal morphogroups in Jurassic North Sea deltas. *Palaeogeogr. Palaeoclimat. Palaeoecol.,* 95, 111–134.

Olszewska B., 1984: A paleoecological interpretation of the Cretaceous and Paleogene foraminifers of the Polish Outer Carpathians. *Biul. Inst. Geol.,* 346, 7–62 (in Polish, English summary.

Olszewska B., 1996: Differences and similarities between the epicontinental and oceanic fossil assemblages of the Upper Cretaceous foraminifers of southern Poland in relation to their fossil environments. In: *Zagadnienia geologii Niecki Nidzianskiej, Prace Inst. Geogr. WSP w Kielcach*, 1, 197–213 (in Polish, English summary).

Olszewska B., 1997: Foraminiferal biostratigraphy of the Polish Outer Carpathians: a record of basin geohistory. *Ann. Soc. Geol. Pol.*, 67, 325–337.

Perch-Nielsen K., 1979: Calcareous Nannofossils from the Cretaceous between the North Sea and the Mediterranean. *Aspekte der Kreide Europas. IUGS Series A,* 6, 223–272.

Perch-Nielsen K., 1985: Mesozoic calcareous nannofossils. In: Bolli H.M., Saunders J.B. & Perch-Nielsen K. (Eds.): *Plankton stratigraphy*, *Cambridge University Press*, 329–426.

Robaszynski F. & Caron M., 1995: Foraminiferes planctoniques du Crétacé: commentaire de la zonation Europe-Méditerranée. *Bull. Soc. Géol. France,* 6, 681–692.

Sissingh W., 1977: Biostratigraphy of Cretaceous nannoplankton with appendix by Prins B. & Sissingh W. *Geol. en Mijnb*., 56, 37–65.

Slaczka A., 1996: Oil and gas in the Northern Carpathians. In Oil and Gas in Alpidic Thrustbelts and Basins of Central and Eastern Europe. *EAGE Special Publ*., 5, 187–195.

Sliter W.V., 1972: Upper Cretaceous planktonic foraminiferal zoogeography and ecology-eastern Pacific margin. *Paleogeogr. Paleoclimat. Paleoecol.,* 12, 15–31.

Sliter W.V., 1977: Cretaceous foraminifers from the Southwestern Atlantic Ocean, Leg 6, Deep Sea Drilling Project. *Init. Rep. Deep Sea Drilling Project,* 36, 519–573.

Sliter W.V. & Baker R.A., 1972: Cretaceous bathymetric distribution of benthic foraminiferids. *J. Foraminiferal Res.,* 2, 167–183.

Švábenická L., 1995: The stratigraphical correlation of the Campanian low- and high-latitude calcareous nannofossils in Southern Moravia (Western Carpathians). *Geol. Carpathica,* 46, 297–302.

Teisseyre H., 1947: Geology of the Węglówka Area. *Nafta,* 3, 5–9 (in Polish).

Thierstein H.R., 1976: Mesozoic calcareous nannoplankton biostratigraphy of marine sediments. *Mar. Micropaleontol.,* 1, 325–362.

Uhlig V., 1883: Beitraege zur Geologie der West-Galizischen Karpathen. *Jb. k. kön. Geol. R-A*., Wien, 32, 3.

Winkler W., 1984: Rhabdammina-Fauna: What relations to turbidites? Evidence from the Gurnigel-Schlieren Flysch. *Benthos'83, 2nd Symposium on Benthic Foraminifera,* Pau, April 1983, 611–617.

Winkler W. & Stuijvenberg Van J., 1982: Flysch-type agglutinated foraminifera and the Maastrichtian to Paleogene history of the Labrador and North seas — comments. *Mar. Micropaleontol.,* 7, 359–361.

Wise S.W. Jr., 1983: Mesozoic and Cenozoic calcareous nannofossils recovered by Deep Sea Drilling Project Leg 71 in the Falkland Plateau Region, Southwest Atlantic Ocean. *Init. Rep. Deep Sea Drilling Project,* 7, 71, 481–550.