S T U D I A   G E O L O G I C A   P O L O N I C A
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Geology of the Pieniny Klippen Belt and the Tatra Mts, Carpathians
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Part XVIII

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Dinocysts from Upper Cretaceous deep-water marine variegated facies (Malinowa Shale Formation), Pieniny Klippen Belt, Poland: example from the Potok Trawne creek[2]

(Figs 1–7)

Abstract. Dinocysts have been described for the first time from Upper Cretaceous deep-water marine variegated deposits of the Pieniny Klippen Belt, Poland. They have been found in the Malinowa Shale Formation (Grajcarek Succession) exposed at the Potok Trawne creek. Latest Turonian–Coniacian dinocysts occur in dark-coloured shale intercalations. Their assemblage consists mainly of well preserved small peridinioids (*Palaeohystrichophora infusorioides* and *Alterbidinium* sp.) and gonyaulacoids (*Pterodinium* and *Spiniferites*). Their motile stages inhabited offshore waters of the Magura Basin during Late Cretaceous. Dominance of peridinioids may indicate eutrophic conditions in the photic zone of the offshore waters induced by upwelling.

Key words: Palaeoenvironment, variegated facies, dinocysts, Late Cretaceous, Malinowa Shale Formation, Pieniny Klippen Belt, Poland.

INTRODUCTION

Fossil organic-walled Dinoflagellate cysts (dinocysts) have been described from several lithostratigraphic units of the Pieniny Klippen Belt in Poland, including Jurassic (the Szlachtowa, Opaleniec and Sokolica Radiolarite formations; Birkenmajer & P. Gedl, 2004, 2007; P. Gedl, 2007) and Cretaceous (the Pomiedznik, Wronine, Hulina and Hałuszowa formations; Jamiński, 1990; E. Gedl, 2007; P. Gedl, 2007) ones. All these units consist of dark coloured deposits, which reflected limited oxygen content during their sedimentation, optimal for dinocyst preserva-

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tion. As a contrary, Carpathian red-coloured deep-water marine facies, which were formed under high oxygen content conditions during slow sedimentation, are not favourable for dinocyst preservation. Practically, they do not contain palynological organic matter (e.g., Lemańska & P. Gedl, 2005). The Malinowa Shale Formation, an Upper Cretaceous lithostratigraphic unit distinguished by Birkenmajer (1977) in the Grajcarek Succession (Magura Basin), consists chiefly of cherry-red shales with subordinate green and variegated ones (see also Birkenmajer & Oszczypko, 1989). It represents a deep-water marine sediment deposited below the calcium carbonate compensation depth (CCD; Bąk *et al.*, 2000). Rare intercalations of thin-bedded sandstones occur in basal and upper parts of this unit (Birkenmajer, 1977, p. 133). Thin layers of dark coloured shales, which occasionally overlie these sandstone layers, looked promising for finding organic dinocysts. This was already the case with Eocene variegated facies of the Magura Basin, which contains dinocysts in darker coloured (greenish to grey) layers only, whereas red ones were barren (P. Gedl & Lemańska, 2005).

Material. The studied outcrop of the Malinowa Shale Formation is located on the eastern bank of the Potok Trawne creek, south of the Rogoźnik village, west of Nowy Targ (Fig. 1; GPS coordinates: N49°26.182'; E019°57.178', ±4m). The Malinowa Shale Formation consists here chiefly of cherry-red clayey shales with intercalations of greyish to greenish shale layers dipping 30–50° N (Fig. 2). A few thin, fine-grained sandstone intercalations occur there. Dark grey to black, thin clay layers appear sometimes just above the sandstone bands (for more detailed description of this lithostratigraphic unit at Potok Trawne creek – see Bąk *et al.*, 2000, p. 2). Three samples, Trw1-3, were taken from these dark-coloured sediments (Figs 2, 3).

Sample Trw1 (Fig. 3A) consists of soft, black or dark grey marly shale; sample Trw2 (Fig. 3B) – of grey, marly (highly calcareous) shale; sample Trw3 (Fig. 3C) – of dark grey or black, marly shale.

Methods. The samples were processed in the Micropalaeontological Laboratory of the Institute of Geological Sciences (Polish Academy of Sciences, Kraków Research Centre) according to the following procedure: 30 G of cleaned and crushed rock was treated with 38% chloric acid (HCl) to remove carbonates, sieved on 15 μm sieve (with ultrasonic treatment), treated with 40% hydrofluoric acid (HF) to remove silicates, neutralized and sieved again on 15 μm sieve (with ultrasonic treatment). The organic matter was separated from undissolved or insoluble particles with heavy liquid ($ZnCl_2$+HCl; s. g. = 2.0 G/cm^3), sieved on 15 μm nylon sieve and transferred into glycerine water for storing. Glycerine-gelatine jelly was used as a mounting medium; two slides were made from each sample. No nitric acid (HNO_3) treatment was applied. The rock samples, palynological residuum and slides are stored in the collection of the Institute of Geological Sciences (Kraków Research Centre), Polish Academy of Sciences in Kraków.

The slides were examined under transmitted light microscope CARL ZEISS Axiolab. Microphotographs were taken with the use of CARL ZEISS Axiolab microscope, SONY DSC-S75 camera and ZEISS Plan-NEOFLUAR 100x/1.30 Oil Pol objective.

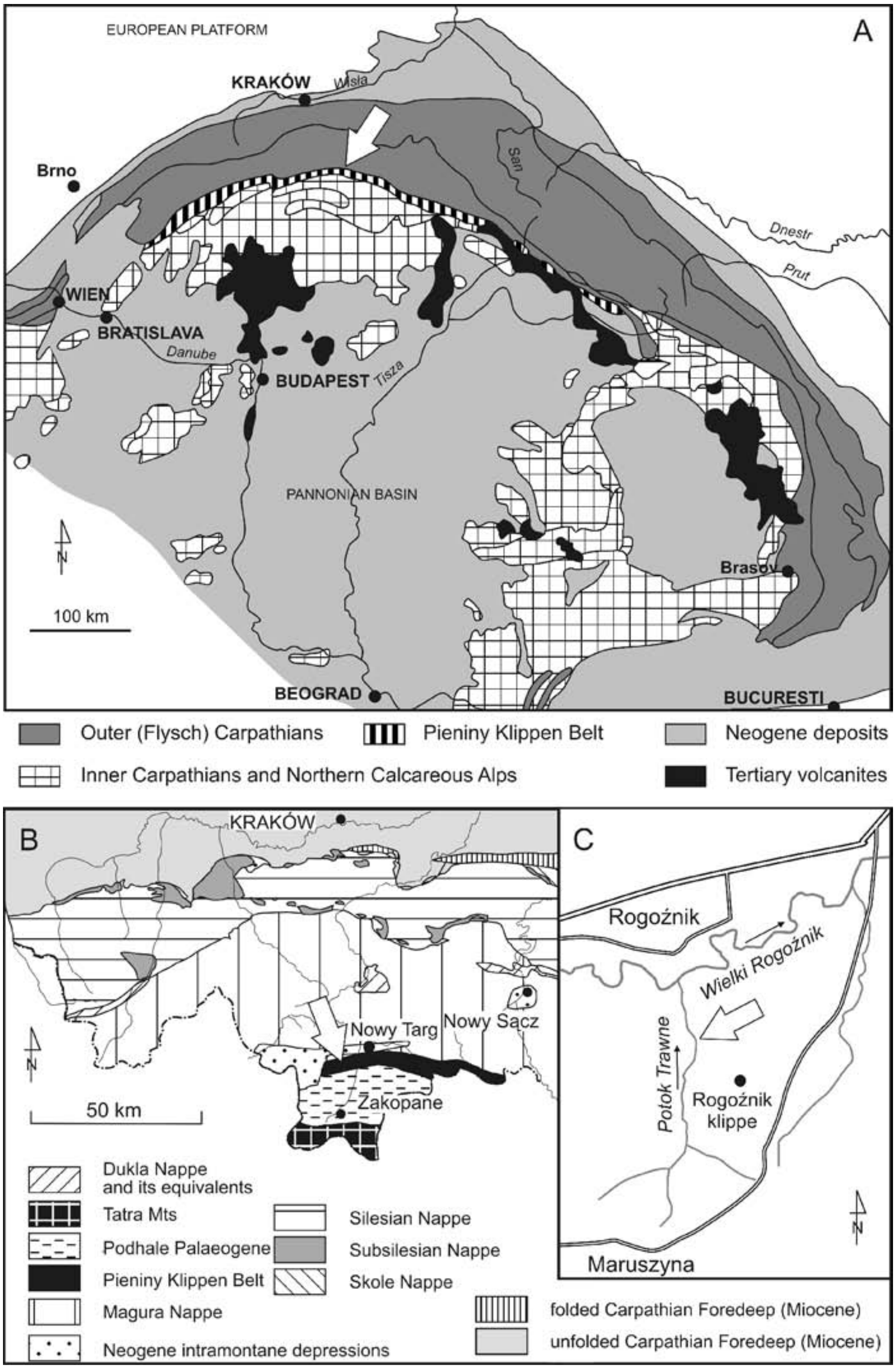

Fig. 1. **A.** Location of studied section (arrowed) against geological sketch of the Carpathians; **B.** Location of the Potok Trawne creek section (arrowed) in southern sector of Polish Carpathians (adapted from Książkiewicz, 1977); **C.** Location of studied section (arrowed) on eastern bank of the Potok Trawne creek

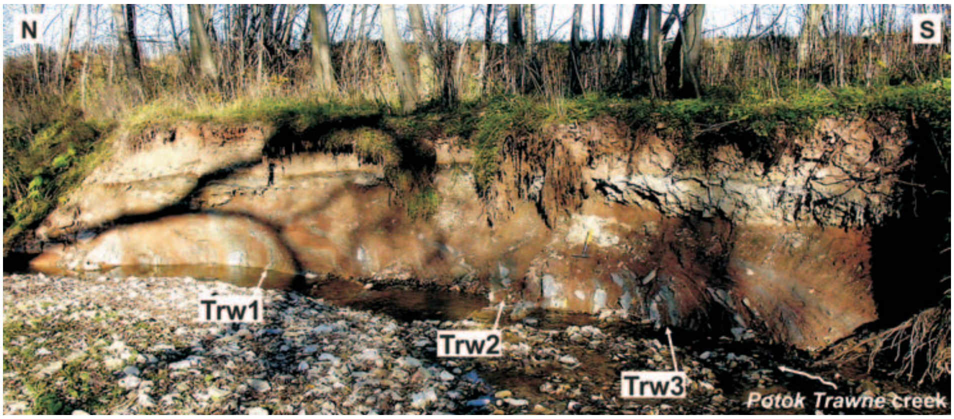

Fig. 2. Exposure of the Malinowa Shale Formation (Grajcarek Succession) on eastern bank of the Potok Trawne creek, with position of collected samples

PALYNOLOGICAL CONTENT

All studied samples (dark-coloured clayey shales) contain palynological organic matter (i. e., organic particles of diameter larger than 15 μm). Samples Trw1 and Trw2 contain very low amounts of organic particles, as compared with sample Trw3. Palynofacies of the first two samples consists of black, opaque, equidimensional phytoclasts only. Very rare, mainly well preserved, pale-yellowish dinocysts occur in these samples. Single sporomorphs, characterised by dark colouration, have also been found. Palynological content of sample Trw3 differs significantly, both quantitatively and qualitatively, from that of samples Trw1 and Trw2. It is characterised by much higher amount of palynological organic matter, which, although dominated by black, opaque phytoclasts, contains up to 20% of cuticle remains and dark brown structured land plant debris. Such phytoclasts are absent in other samples. Relatively infrequent sporomorphs (less than 1%) are represented mainly by spores. Dinocysts from sample Trw3 (2% of the palynofacies), although much more frequent than in samples Trw1 and Trw2, are qualitatively similar.

A characteristic feature of dinocysts (Figs 4–7) from studied samples is their taxonomical impoverishment. Dinocyst assemblages from all three samples are dominated by Peridinioids represented by *Palaeohystrichophora infusorioides* and *Alterbidinium* sp. They constitute up to 90% of all dinocysts. Remaining taxa are represented by *Spiniferites ramosus*, *Pterodinium cingulatum*, *Odontochtina operculata* and a few other gonyaulacoid species (mainly single specimens).

Sample Trw1 contains the following additional species: *Rhiptocorys veligera*, *Hystrichostrogylon*? sp., *Dapsilidinium multispinosum*, *Florentinia mantellii*, *F.* sp. A, *Endoscrinium campanula*, *Hystrichodinium* sp., *Adnatosphaeridium* sp., *Senoniasphaera rotundata*.

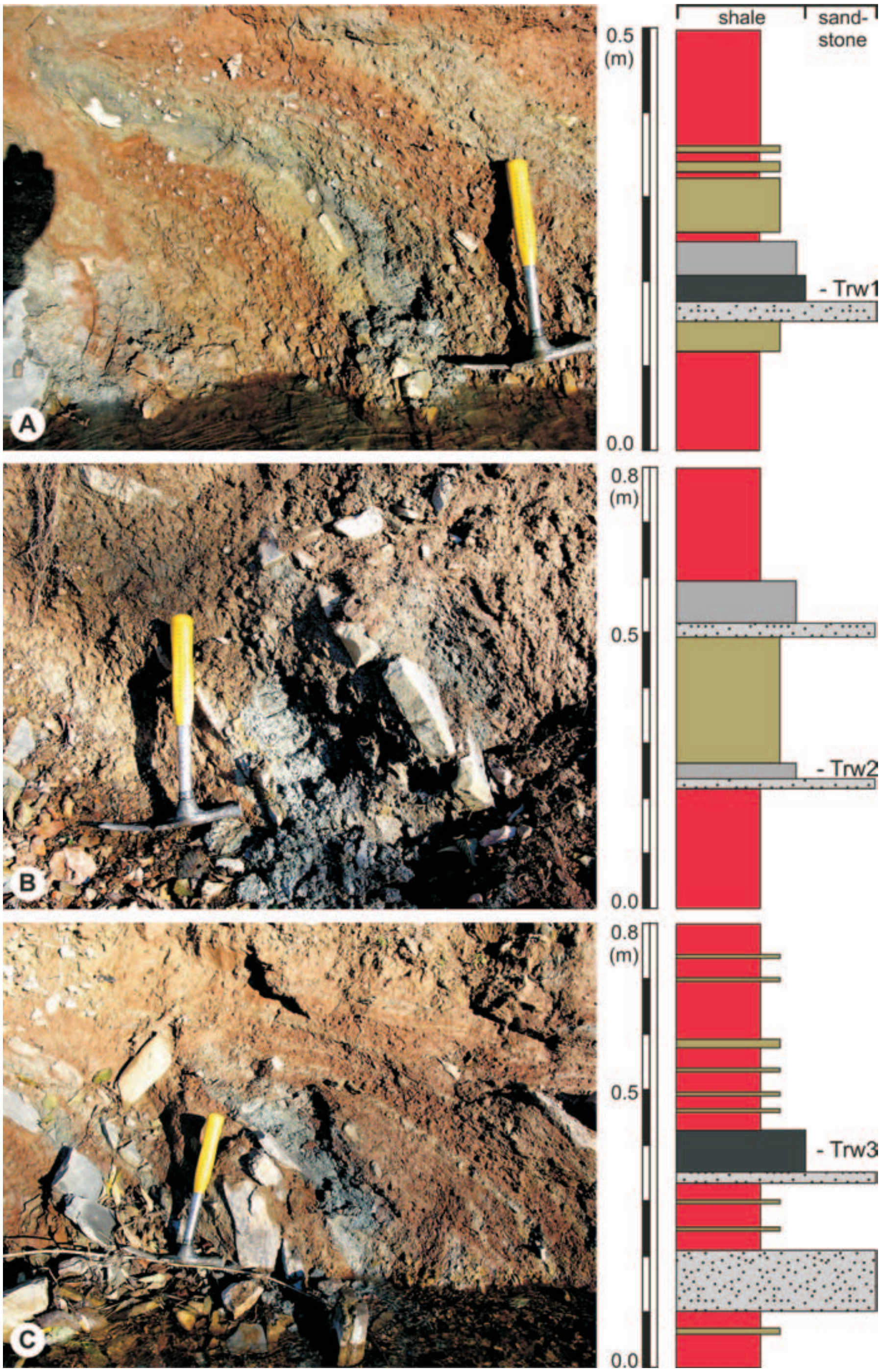

Fig. 3. Sampled sections. Position of collected samples indicated in lithological logs. Sandstone layers spotted, other lithologies represent shales with different colours. A – sample Trw1; B – sample Trw2; C – sample Trw3

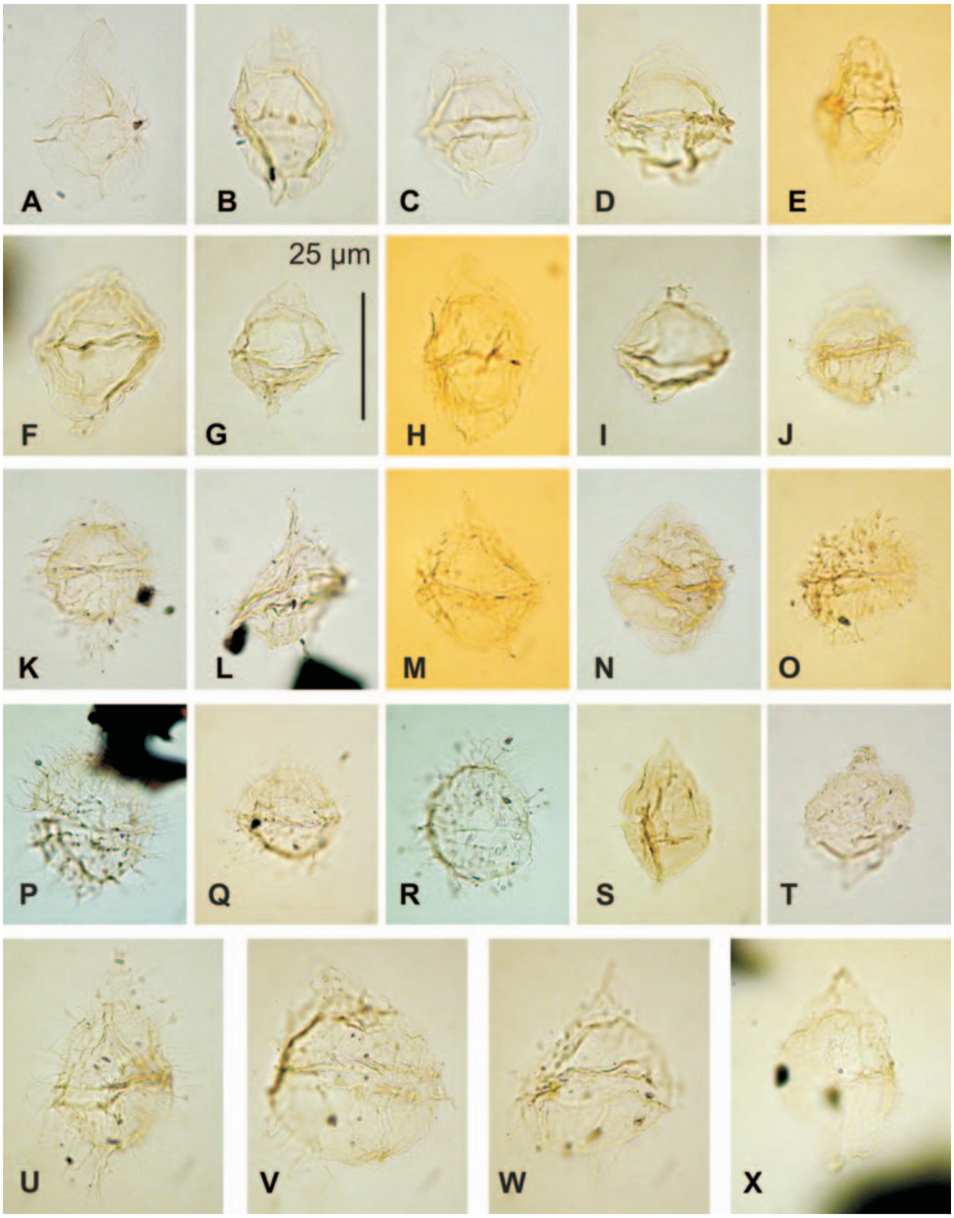

Fig. 4. Dinocysts from the Malinowa Shale Formation, Potok Trawne creek. The assemblage of peridinioids is interpreted as having inhabited offshore areas of the Magura Basin. Scale bar in G represents 25 μm and refers to all other microphotographs. **A-J**, **X** – *Alterbidinium* sp. (A-C, X: sample Trw1; D-J: sample Trw2); **J-R**, **U-W** – *Palaeohystrichophora infusorioides* (J-L: sample Trw1; M, O, P, U, V: sample Trw2; Q, R, W: sample Trw3); **S** – *Biconidinium* sp. (sample Trw2); **T** – undetermined peridinioid (sample Trw1)

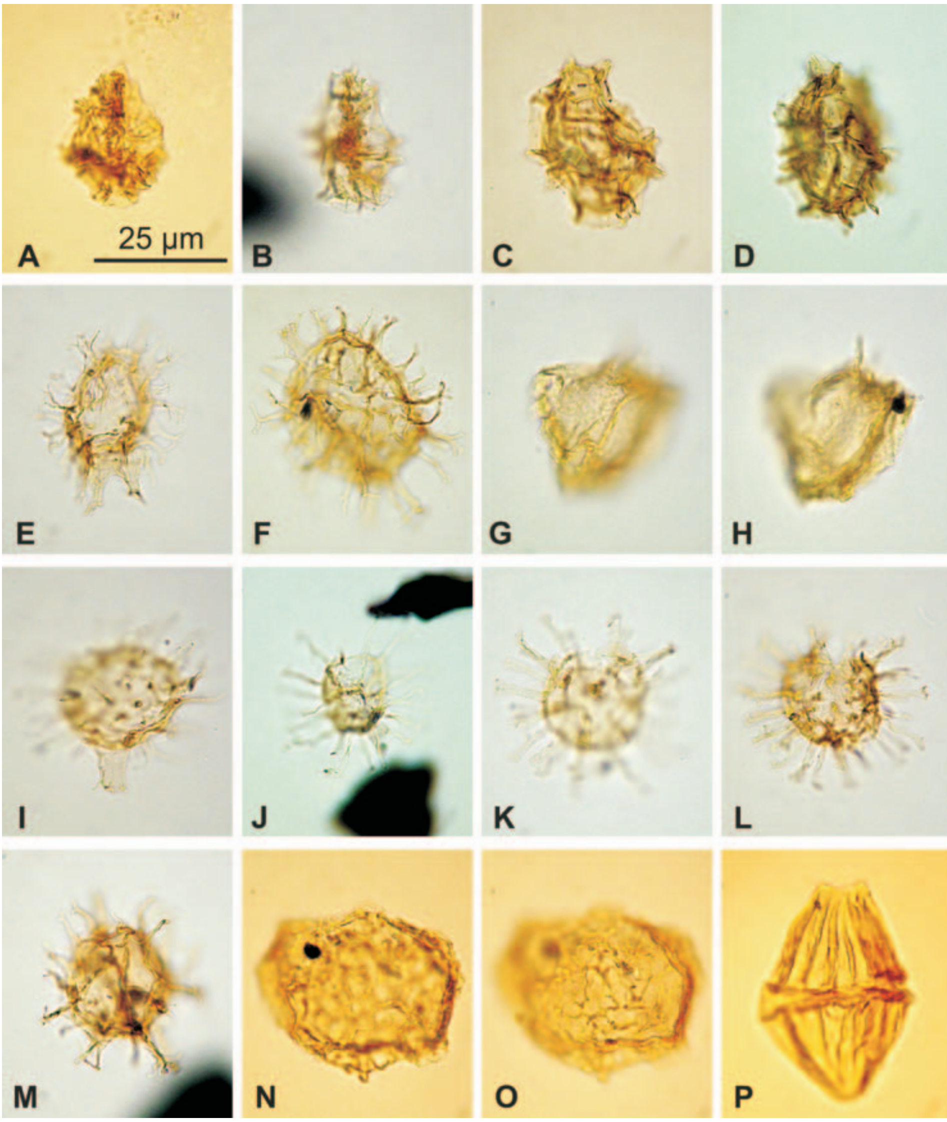

Fig. 5. Dinocysts from the Malinowa Shale Formation, Potok Trawne creek. The assemblage of gonyaulacoids is interpreted as having inhabited offshore areas of the Magura Basin. Scale bar in A represents 25 µm and refers to all other microphotographs. **A**–**D** – *Pterodinium cingulatum* (A, B: sample Trw1; C, D: sample Trw3); **E**, **F** – *Spiniferites ramosus* (E: sample Trw1; F: sample Trw2); **G**, **H** – *Rhiptocorys veligera* (sample Trw1, same specimen, various foci); **I** – *Diphyes*? sp. (sample Trw1); **J** – *Prolixosphaeridium* sp. (sample Trw3); **K**, **L** – *Dapsilidinium multispinosum* (both specimens from sample Trw1); **M** – *Spiniferites ramosus* (sample Trw1); **N**, **O** – *Senoniasphaera rotundata* (Trw1, same specimen, various foci); **P** – *Dinogymnium albertii* (Trw2)

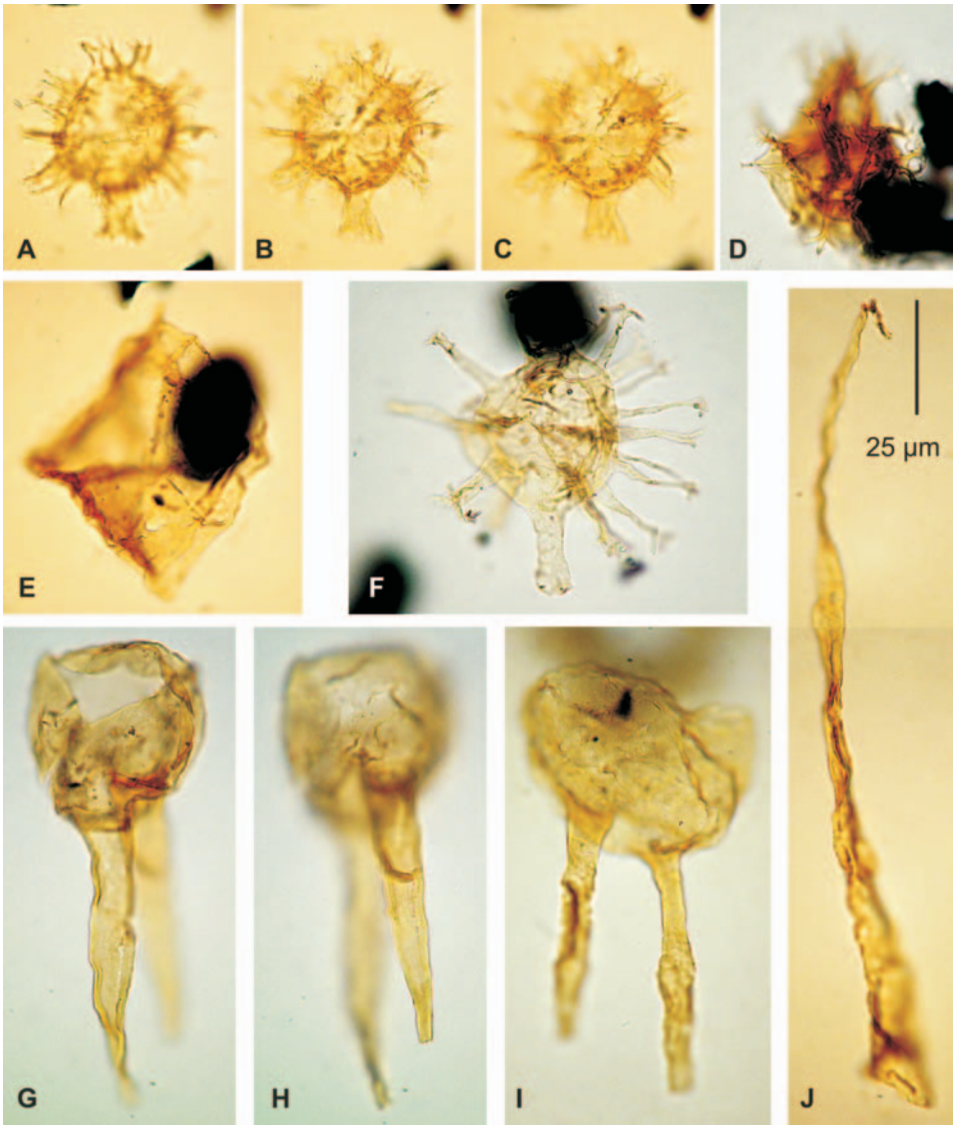

Fig. 6. Dinocysts from the Malinowa Shale Formation, Potok Trawne creek. The assemblage is interpreted as resedimented from proximal to offshore areas of the Magura Basin. Scale bar in J represents 25 µm and refers to all other microphotographs. **A**–**C** – *Florentinia* sp. A (same specimen various foci; Trw1); **D** – *Hystrichostrogylon*? sp. (Trw1); **E** – *Endoscrinium campanula* (Trw1); **F** – *Florentinia mantellii* (Trw1); **G**, **H** – *Odontochitina operculata*, hypocyst (same specimen various foci; Trw1); **I** – *Odontochitina operculata*, hypocyst (Trw2); **J** – *Odontochitina operculata*, epicyst (Trw2)

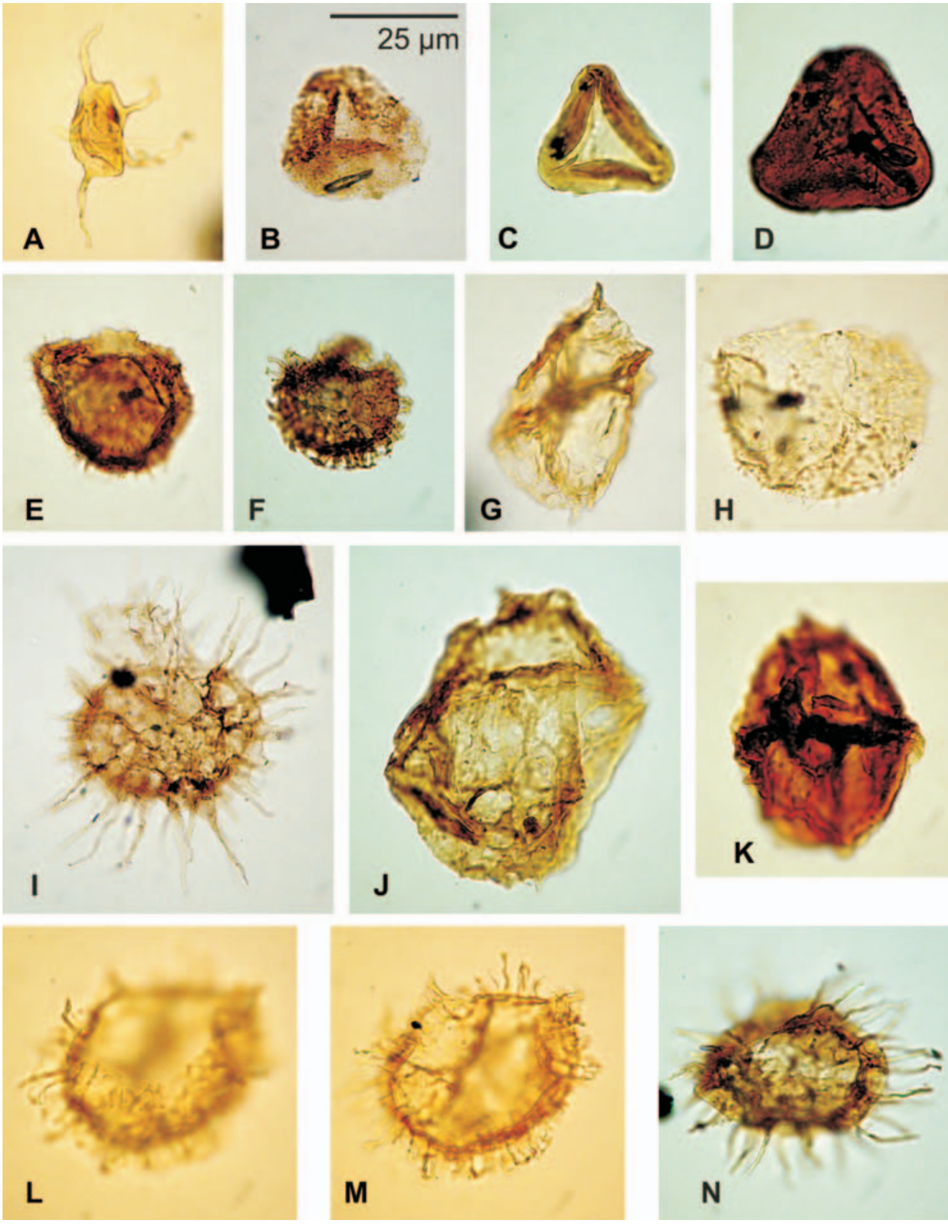

Fig. 7. Sporomorphs and marine palynomorphs from the Malinowa Shale Formation, Potok Trawne creek. Scale bar in A represents 25 µm and refers to all other microphotographs. **A** – acritarch (Trw3); **B**–**D** – spores (B: Trw1, C: Trw3, D: Trw3); **E** – *Circulodinium* sp. (sample Trw2); **F** – *Chlamydophorella* sp. (Trw3); **G** –*Endoscrinium campanula* (Trw1); **H** – *Circulodinium* sp. (Trw3); **I** – *Hystrichodinium* sp. (Trw1); **J** – *Apteodinium* sp. (Trw3); **K** – *Leptodinium*? sp. (Trw2); **L**, **M** – *Adnatosphaeridium* sp. (Trw1); **N** – *Pervosphaeridium* sp. (Trw3)

Dinocysts from sample Trw2 are dominated by *Palaeohystrichophora infusorioides* and *Alterbidinium* sp. Other species found in this sample include very rare specimens of *Odontochitina operculata*, *Spiniferites ramosus*, *Spinidinium* sp. and *Dinogymnium albertii*.

A similar, although much more frequent, dinocyst assemblage dominated by *Palaeohystrichophora infusorioides* (up to 70% of total dinocysts) occurs in sample Trw3: *Pterodinium cingulatum* and *Spiniferites ramosus* occur there in relatively high numbers. Besides, single specimens of *Circulodinium* sp., *Odontochitina operculata*, *Pervosphaeridium* sp., *Apteodinium* sp. and *Prolixosphaeridium* sp. have been found.

The majority of dinocysts that occur in studied samples are well preserved, pale-coloured, thin-walled peridinioids: *Palaeohystrichophora infusorioides* and *Alterbidinium* sp., and thicker-walled species: *Pterodinium cingulatum*, *Dapsilidinium multispinosum*, *Florentinia* spp., *Endoscrinium campanula* and some specimens of *Spiniferites ramosus*. Several much darker-coloured dinocyst specimens are slightly poorer preserved: e. g., some specimens of *Spiniferites ramosus*, and single specimens of *Pervosphaeridium* sp. and *Apteodinium* sp. A few dark brown specimens of *Circulodinium* sp., *Chlamydophorella* sp. and *Leptodinium*? sp. have also been found. This may suggest that these specimens have been resedimented from a more proximal shelf area or recycled, whereas well-preserved pale-yellow specimens inhabited offshore waters.

AGE OF DINOCYST ASSEMBLAGES

Dinocyst taxa found in the Malinowa Shale Formation at the Potok Trawne creek are rather long ranging. *Palaeohystrichophora infusorioides* and *Odontochitina operculata* are known from uppermost Albian to lowermost Maastrichtian, and Barremian to lowermost Maastrichtian, respectively (Stover *et al.*, 1996). The upper age boundary of the assemblage may be estimated to be not younger than Coniacian, based on the occurrence of *Endoscrinium campanula* (uppermost Berriasian to Coniacian; Stover *et al.*, 1996). *Senoniasphaera rotundata* found in sample Trw1 is known to have appeared during Coniacian–earliest Maastrichtian (Stover *et al.*, 1996). A similar range is given for the genus *Dinogymnium* (represented in the present material by *D. albertii*) by Stover *et al.* (1996): uppermost Turonian–Maastrichtian. The same authors give Late Turonian as the highest occurrence of *Florentinia mantellii* (sample Trw1). Thus, a Late Turonian–Coniacian age of the Trawne assemblage seems justified. This interpretation agrees with that by Birkenmajer & Geroch (1961) who, on the basis of mainly arenaceous foraminifera, established an Upper Cenomanian–Campanian age of the Malinowa Shale Formation. A similar age range of the Malinowa Shale Formation was accepted by Jednorowska (1980) and Bąk *et al.* (2000) on the basis of foraminifera and radiolaria.

REMARKS ON PALAEOENVIRONMENT

Dinocysts found in the Malinowa Shale Formation at the Potok Trawne creek may be helpful in reconstruction of palaeoenvironmental conditions within photic zone of the Magura Basin during latest Turonian–Coniacian. A characteristic feature of their assemblage is dominance of peridinioids represented by *Palaeohystrichophora infusorioides* and *Alterbidinium* sp. State of preservation of these dinocysts, as compared to some other specimens of gonyaulacoid affinity, suggests that these taxa represented motile stages that inhabited offshore waters of the Magura Basin. The other, relatively poorer preserved specimens, were probably transported by turbidity currents from more proximal areas. The photic zone of the offshore waters of the Magura Basin during Late Cretaceous was probably rich in nutrients, since frequent appearance of peridinioids is often related to eutrophic environments (e.g., Brinkhuis, 1994). This could be associated with an upwelling system (cf., e. g., Powell *et al.*, 1992; but see also critical discussion by Dale, 1996, p. 1269). Freshwater influxes, another source of nutrient supply into marine basins (e. g., Biffi & Grignani, 1983), should rather be excluded, since no traces of high amounts of terrestrial palynomorphs and phytoclasts have been found.

A similar peridinioid-dominated dinocyst assemblage has been found in the approximately coeval flyschoid deposits of the Hałuszowa Formation of the Grajcarek Succession (Magura Basin; P. Gedl, 2007). On the other hand, dinocyst assemblages from pelagic/hemipelagic deposits of the northern part of the Magura Basin at Uzgruň (Maastrichtian, Moravian Carpathians) are dominated by the genera *Impagidinium* and *Pterodinium* (P. Gedl, 2004), i. e., dinocyst taxa characteristic for oligotrophic offshore waters (cf., e. g., Dale, 1996).

DINOCYST OCCURRENCE IN VARIEGATED MARINE FACIES

Variegated deep-water marine shales that occur in basinal sequences of the Polish Carpathians reflect phases of pelagic and/or hemipelagic, quiet and slow deposition in well ventilated bottom water environments. Such conditions were not favourable for preservation of organic-walled Dinoflagellate cysts (dinocysts), which, if present, became oxidized. However, occasional deposition of highly diluted distal turbidites (Leszczyński & Uchman, 1991), relatively rich in organic matter, caused temporary depletion of oxygen content of bottom waters and, as a consequence, greenish to greyish colours appeared within predominantly red shales. Colour change in variegated shales, from red to green-grey depended on Fe^{3+}/Fe^{2+} ratio, which was controlled by amount of organic matter (e. g., Potter *et al.*, 1980). Lower oxygen concentration in bottom sediment during deposition of dark shales, resulted from bacterial decay of larger amounts of organic matter. Red colour of sediment appeared when the Fe^{3+}/Fe^{2+} ratio was high (Dominik, 1977; Potter *et al.*, 1980).

A recent study of dinocyst occurrence in variegated deposits of the Polish Carpathians (P. Gedl & Lemańska, 2005, 2006; Lemańska & P. Gedl, 2005) has shown that it is controlled not only by lithology (i. e., sediment colouration) but also by palaeogeographic factors. Red coloured facies is always devoid of dinocysts, which occur exclusively in dark sediment intercalations. However, some greenish layers of the Upper Cretaceous variegated facies of the Silesian Basin, sampled at Kalwaria Lanckorońska, are also devoid of dinocysts (Lemańska & P. Gedl, 2005). This may be caused by: (i) lack of dinocysts in offshore waters of the Silesian Basin; (ii) inadequate amount of organic matter brought to this basin by infrequent turbidity currents, the decay of which could allow preservation of dinocysts; (iii) slow sedimentation allowing for oxidizing organic particles.

Dinocysts that occur in the approximately coeval Malinowa Shale Formation at the Potok Trawne creek indicate other conditions, presumably a closer location to the southern margin of the basin. A specific water circulation might have imposed upwelling in the southern part of the Magura Basin that caused higher productivity in this area resulting in peridinioid dinocyst blooms.

Results of the present study agree fairly well with the ones obtained on microfaunal analysis from the same section by Bąk *et al.* (2000). Red shales, devoid of dinocysts, contain foraminiferal assemblage with frequent specimens of *Rhizammina* and *Hyperammina*. These foraminifera are typical for basin bottom environmnets depleted in food. On the contrary, dark shales, which were formed by diluted turbidite currents, and contain dinocysts, yielded foraminiferal assemblage indicative for a higher food supply. The latter lithofacies contains also radiolaria, which, like dinocysts, may proliferate from eutrophication due to water column.

CONCLUSIONS

1. Organic-walled dinocysts have been found in dark shales of the Malinowa Shale Formation (Grajcarek Unit, Pieniny Klippen Belt), which overlie turbiditic sandstone layers. The dinocyst assemblage is dominated by *Palaeohystrichophora infusorioides* and *Alterbidinium* sp. *Pterodinium cingulatum* and *Spiniferites ramosus* are relatively frequent, whereas other dinocysts are rare.

2. Two types of variously preserved dinocysts have been distinguished. Well preserved, pale-yellow forms are represented by peridinioids (*Palaeohystrichophora infusorioides*, *Alterbidinium* sp.), and by some gonyaulacoids (e. g., *Pterodinium cingulatum*, also some specimens of *Spiniferites ramosus*). These dinocysts may have lived in offshore waters, whereas the poorly preserved ones (dark brown specimens) were either resedimented from shelf area or they were recycled.

3. Age of the Malinowa Shale Formation at the Potok Trawne creek, as based on dinocysts, corresponds to uppermost Turonian–Coniacian. It is based on co-occurrence of the following species: *Endoscrinium campanula*, *Dinogymnium albertii*, *Florentinia mantellii* and *Senoniasphaera rotundata*.

4. Composition of dinocyst assemblages from the Malinowa Shale Formation at the Potok Trawne creek may have reflected palaeoenvironmnetal conditions in the photic zone of the Magura Basin. Dominance of peridinioids probably resulted from eutrophic conditions in offshore waters, possibly caused by upwelling.

SELECTED TAXONOMY

Florentinia sp. A
(Fig. 6A–C)

Description. Spherical chorate cyst with paratabular processes of two types. Single antapical process large, tubiform, distally expanded, with serrate margin. Remaining processes are solid, grouped in penitabular complexes, united proximally. Paracingular processes free or adjoining each other. Archeopyle paracingular, 1P.
Comparison. This species differs from all the other species of the genus *Florentinia* by the type of the processes, which are formed by penitabular complexes of solid processes, rather than by single processes with tubiform base.

Acknowledgement

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APPENDIX – LIST OF DINOCYSTS

Adnatosphaeridium sp. (Fig. 7L, M)
Alterbidinium sp. (Fig. 4A–J, X)
Apteodinium sp. (Fig. 7J)
Biconidinium sp. (Fig. 4S)
Chlamydophorella sp. (Fig. 7F)
Circulodinium sp. (Fig. 7E, H)
Dapsilidinium multispinosum (Fig. 5K, L)
Dinogymnium albertii (Fig. 5P)
Diphyes? sp. (Fig. 5I)
Endoscrinium campanula (Figs 6E, 7G)
Florentinia mantellii (Fig. 6F)
Florentinia sp. A (Fig. 6A–C)
Hystrichodinium sp. (Fig. 7I)
Hystrichostrogylon? sp. (Fig. 6D)
Leptodinium? sp. (Fig. 7K)
Odontochitina operculata (Fig. 6G–J)
Palaeohystrichophora infusorioides (Fig. 4J–R, U–W)
Pervosphaeridium sp. (Fig. 7N)
Prolixosphaeridium sp. (Fig. 5J)
Pterodinium cingulatum (Fig. 5A–D)
Rhiptocorys veligera (Fig. 5G, H)
Senoniasphaera rotundata (Fig. 5N, O)
Spiniferites ramosus (Fig. 5E, F, M)

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