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Benthic agglutinated foraminifera and organic-walled dinoflagellate cysts from Late Cretaceous oceanic deposits at Kalwaria Zebrzydowska, Flysch Carpathians, Poland: biostratigraphy and palaeoenvironment

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Abstract. Microfossil analysis of Late Cretaceous oceanic deposits exposed in vicinity of Kalwaria Zebrzydowska (Silesian Nappe, Polish Flysch Carpathians) has been carried out. Samples from the variegated shales and the Godula beds have been analysed for their agglutinated foraminifera and organic-walled dinocyst content. Age-assessment of the sediments in question suggests Early Turonian-Early Santonian age of the variegated shales and Late Santonian-Early/Middle Campanian age of the Godula beds. Palaeoenvironmental analysis of foraminifera and dinocysts shows a significant change during Late Cretaceous in this part of the Silesian basin. Sedimentation of hemipelagic/pelagic variegated shales was associated with limited organic matter supply, which resulted in aerobic conditions both in bottom waters and in sediment. Beginning of turbiditic sedimentation of the Godula beds resulted in increased influx of organic matter to the deeper parts of the basin, which caused oxygen depletion in sediment. Changes in dinocyst assemblage composition in the Godula beds succession reflect increasing resedimentation from marginal areas of the Silesian basin.

Key words: foraminifera, dinoflagellate cysts, palaeoecology, oceanic deposits, biostratigraphy, Late Cretaceous, Flysch Carpathians

Introduction

Non-calcareous pelagic/hemipelagic deposits characterized by predominantly reddish colour – the so-called "variegated shales" are typical for Upper Cretaceous of the Flysch Carpathians. This facies has been distinguished as several lithostratigraphic units such as the Malinowa Shale Formation (Magura Nappe; Birkenmajer & Oszczypko, 1989) originally described from the Grajcarek Unit of the Pieniny Klippen Belt (Birkenmajer, 1977), the variegated shales or the Godula shales of the Silesian and the Sub-Silesian nappes (e.g., Ślączka, 1959). The "variegated shales" occur also locally in the Late Cretaceous successions of the Skole and Dukla nappes (Ślączka & Kaminski, 1998). Red-coloured fine-grained deposits are also known from the Pieniny Klippen Belt: the Macelowa Marl Member and the Pustelnia Marl Member (Birkenmajer, 1977; see also Bąk, 1998).

These "variegated shales" (reddish shales intercalated with greenish ones) were deposited in Carpathian basin during period of deep marine, oceanic sedimentation below the local calcite compensation depth (CCD; see e.g., Leszczyński & Uchman, 1991). Tectonic movements of the Laramian phase divided uniform Carpathian basin into several basins separated by uplifted areas of intrabasinal ridges. Palaeorelief and tectonic activity were the reasons of increased flysch sedimentation that terminated in large areas of Carpathian basins the sedimentation of hemipelagic/pelagic variegated facies. Turbiditic Godula beds followed by the lower Istebna sandstone were deposited in the Silesian Nappe, the Jarmuta Formation and the Inoceramian beds in the Magura Nappe (Birkenmajer & Oszczypko, 1989; Oszczypko, 1992) and the siliceous marls and the Inoceramian (Ropianka) beds in the Skole Nappe (Kotlarczyk, 1985).

This considerable change of sedimentation mode during Late Cretaceous in deep Carpathian basin has significantly altered the environmental conditions. Our study of foraminifera and organic-walled dinoflagellate cysts (hereafter dinocysts) from both hemipelagic/pelagic and turbiditic facies is an attempt to add new information on reconstruction of the change of depositional environments during Late Cretaceous. Its main advantage is tracing the relation between the organic matter supply to the basin (palynofacies and dinocysts) and the bottom water conditions (agglutinated foraminifera). In this purpose we have studied palynology (PG) and foraminifera (AL) from the same set of samples consisting of reddish, greenish and greyish fine-grained lithofacies representing the Late Cretaceous variegated shales and the Godula beds exposed in vicinity of Kalwaria Zebrzydowska.

Geological setting

Kalwaria Zebrydowska is situated in Pogórze Lanckorońskie (Fig. 1A), which geologically represents the Silesian Nappe. The Silesian Nappe east of Skawa dislocation consists of two series. The southern series repre-

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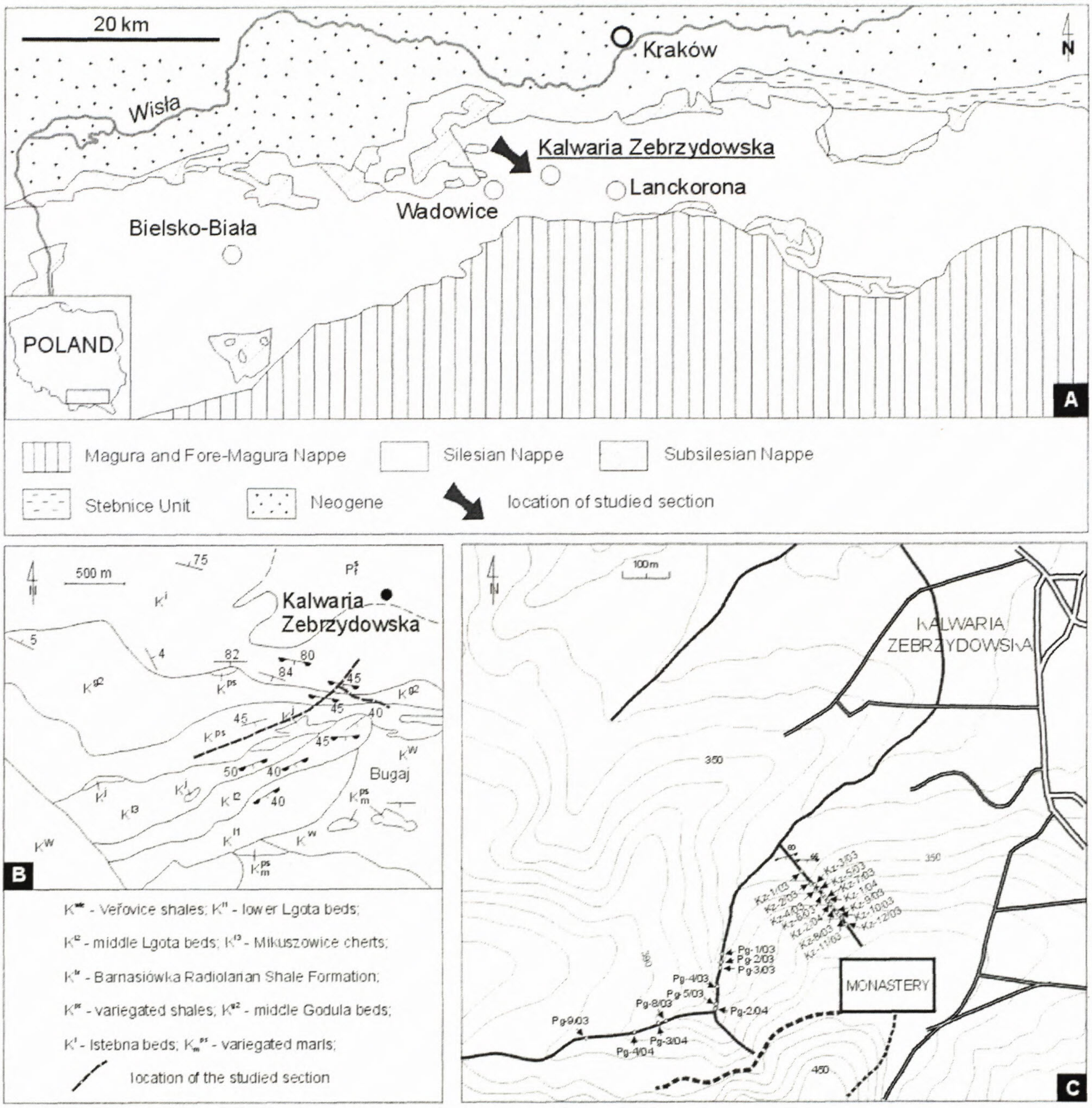

Fig. 1. Location of study area. A – Geological sketch-map of western part of Polish Carpathians with location of studied section (after Szymakowska & Żytko 1965); B – Geological map of Kalwaria Zebrzydowska vicinity with location of studied section (after Szymakowska & Żytko 1965); C – Location of studied outcrops.

sents Palaeogene strata (mainly the Krosno beds) whereas the northern one (i.e. the Pogórze Lanckorońskie) consists mainly of Cretaceous deposits (Książkiewicz., 1951, 1972; Słomka, 1995). The Upper Cretaceous of the northern series includes uppermost part of the Lgota beds, the Barnasiówka Radiolarian Shale Formation, the variegated shales, the Godula beds and the lower Istebna sandstones (Fig. 1B). The Godula beds in this area are developed as thin-bedded fine-grained deposits and/or the variegated shales (Fig. 2). Such development of the Godula beds is distinguished as the Lanckorona facies, contrary to the Godula beds west of the Skawa dislocation, which consist mainly of thick-bedded sandstones and reach thickness exceeding 2000 m (Książkiewicz, 1951, 1972).

The oldest deposits of the Late Cretaceous succession of the Pogórze Lanckorońskie are the uppermost part of the Lgota beds and locally occurring marly deposits (Fig. 3). They are followed by the Late Cenomanian-earliest Turonian Barnasiówka Radiolarian Shale Formation, which consists of thin-bedded glauconitic siliceous sandstones and light-greenish and green non-calcareous shales (Bąk *et al.*, 2001). This lithostratigraphic unit is overlied by the variegated shales consisting of brick-reddish shales and subordinar intercalations of green shales (Fig. 3). Thin-bedded glauconitic sandstones occur occasionally.

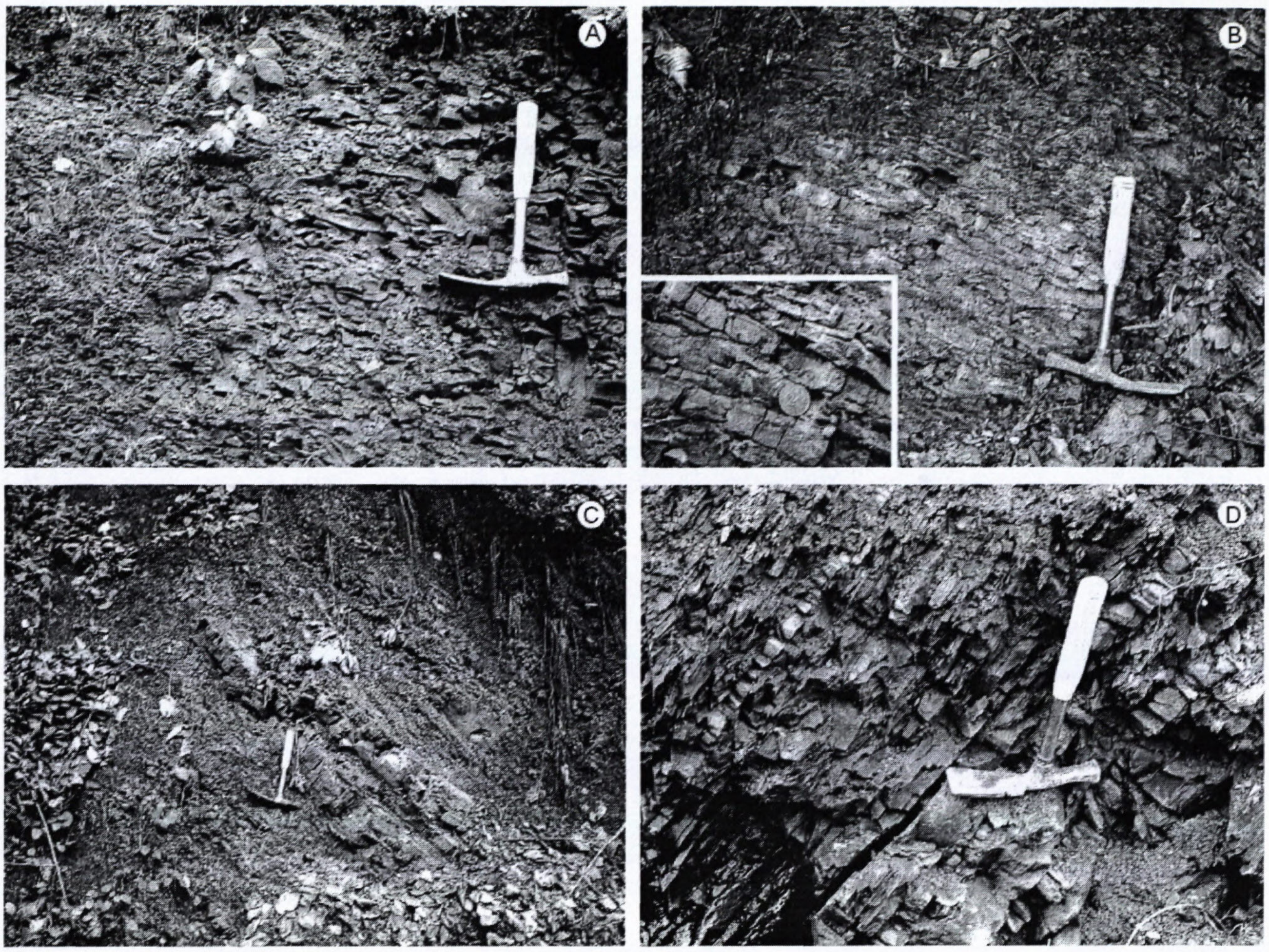

Fig. 2. Lithology of studied variageted shales and Godula beds exposed at northern slopes of Góra Lanckorońska Hill (photo: P. Gedl). A – clayey variegated shales; B – variegated shales with frequent thin-bedded sandstones (coin diameter = 18 mm); C – medium-bedded sandstone within upper part of variegated shales; D – thin-bedded turbiditic Godula beds.

Increasing number of thin-bedded glauconitic sandstones and mainly greenish-grey colour of shales characterize lower part of the succeeding Godula beds. Red shales are thin and infrequent here, whereas they occur more frequently in the upper part of the Godula beds. In the area of study the thickness of the variegated shales is about 150-250 meters (Książkiewicz, 1951) and that of the Godula beds reaches from 200 to 600 meters (Słomka, 1995). The youngest deposits exposed in studied area are the lower Istebna sandstones (Fig. 3).

Material and methods

The studied samples have been collected from outcrops in a small unnamed creek and its tributary that cuts the northern slopes of the Lanckorońska Góra Hill south of Kalwaria Zebrzydowska (Fig. 1C). The variegated shales exposed in studied section consist of non-calcareous reddish shales with intercalations of non-calcareous greenish shales (Fig. 2A). Thickness of the latter is variable, from few millimetres to 30 centimetres. Thin-bedded (mainly up to 2 cm – Fig. 2B, occasionally up to 10 cm – Fig. 2C) fine grained sandstones occur within this lithostratigraphic unit. The Godula beds in the studied section consist of thin- and middle-bedded glauconitic sandstones, which are interlayered by greyish, grey-greenish non-calcareous shales (Fig. 2D). Infrequent red shales occur in the topmost part of the Godula beds in this section. Thirty samples have been collected from red and green shales of the variegated shales and grey-greenish and red shales of the Godula beds. Their position is shown in Figure 3.

Samples for foraminifera, about 0.5 kg each, have been processed following standard method including boiling with Glaubert salt, freezing and washing through sieves with mesh diameters > 63 μm. 300 specimens of foraminifera have been picked out from each sample and mounted on cardboard microscope slides. For morphogroup analysis of fragments of tubular species and multichambered, uniserial forms (*Reophax*, *Caudammina*) were counted individually and then their number was recalculated taking into account dimensions of unchanged forms. Scanning electron microscope photomicrographs have been taken in the Laboratory of Field Emission Scanning Electron Microscopy and Microanalysis in the Institute of Geological Sciences of the Jagiellonian University.

The same set of samples was processed for palynology. 30 g of cleaned and crushed rock was taken for each

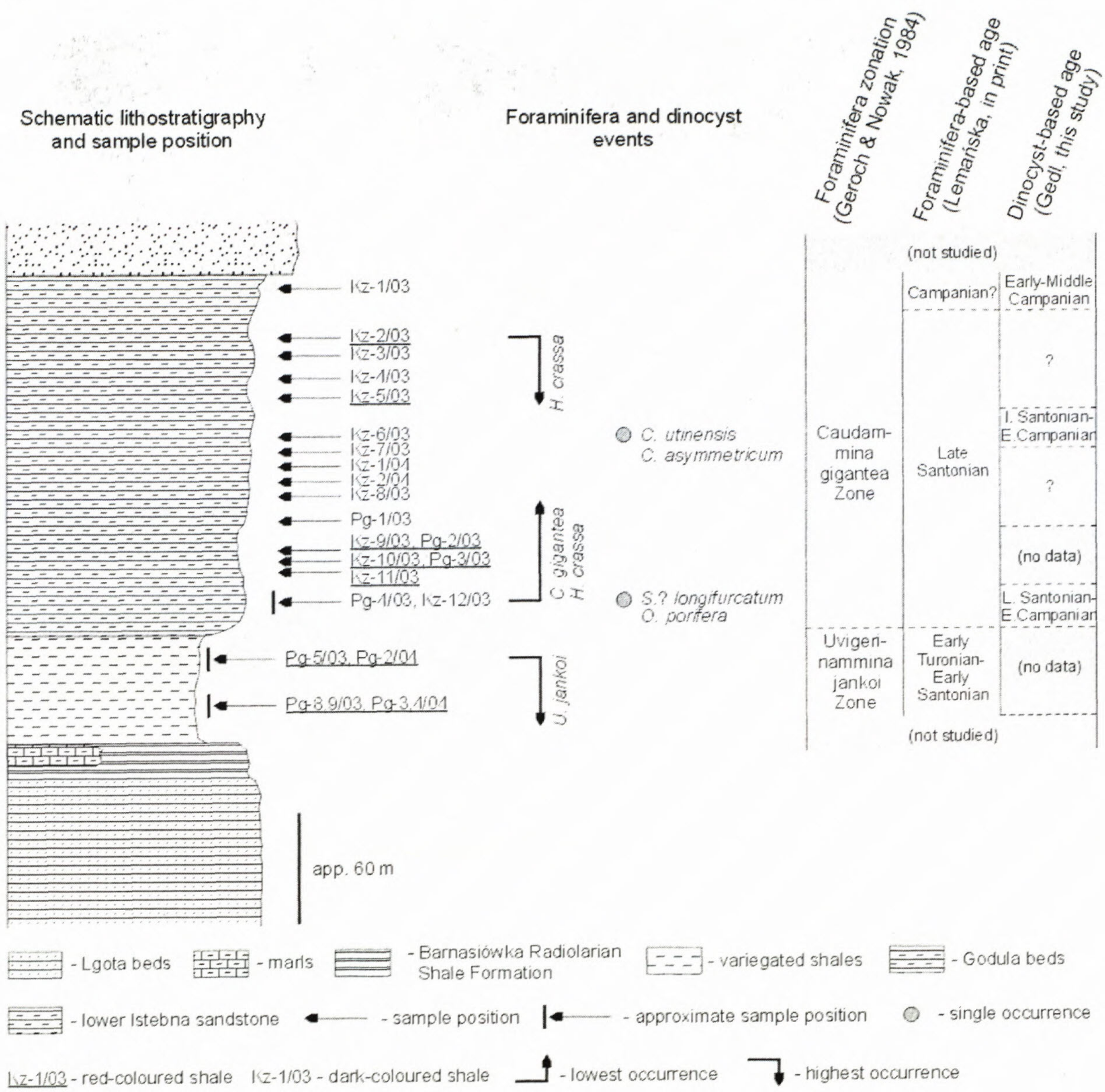

Fig. 3. Schematic lithostratigraphical column of studied deposits. Sample positions are indicated tentatively due to tectonics and non-continuous exposures. Foraminifera and dinocyst events indicated. Abbreviations: *C. gigantea – Caudammina gigantea*; *H. crassa – Hormosina crassa*; *U. jankoi – Uvigerinammina jankoi*; *C. utinensis – Cannosphaeropsis utinensis*; *C. asymmetricum – Callaiosphaeridium asymmetricum*; *S.? longifurcatum – Surculosphaeridium? longifurcatum*; *O. porifera – Odontochitina porifera*; l. Santonian – latest Santonian; L. Santonian – Late Santonian; E. Campanian – Early Campanian.

sample. Samples were subjected to standard palynological procedure including 38% hydrochloric acid (HCl) treatment, 40% hydrofluoric acid (HF) treatment, heavy liquid ($ZnCl_2$+HCl; density 2.0 g/cm^3) separation, ultrasound for 10-15 s and sieving at 15 μm nylon-mesh. Two slides were made from each sample using glycerine jelly as a mounting medium. The rock samples, palynological residues and slides are all stored in the collection of the Institute of Geological Sciences, Polish Academy of Sciences, Kraków.

Results

Variegated shales. Foraminifera assemblage from this lithostratigraphic unit is composed of agglutinated species only (Pl. 1). The poor assemblage consists of badly preserved small-sized specimens including *Rhabdammina*, *Rhizammina*, *Bathysiphon*, *Ammodiscus*, *Glomospira*, *Haplophragmoides*, *Trochamminoides*, *Recurvoides* and *Trochammina*. Relatively frequent are also *Gerochammina stanislawi*, *Gerochammina obesa* and *Uvigerinammina jankoi*. Foraminifera are associated with frequent sponge spicules and radiolaria. The variegated shales, both the red and greenish shales, are devoid of dinocysts.

Godula beds. Foraminifera from the Godula beds are also representing by the agglutinated forms only (Pl. 1, 2). However, their assemblage is characterized by higher taxonomic diversity. In contrast to the assemblage from the variegated shales, the foraminifera from the Godula beds consist mainly of large-sized coarse-grained genera. The

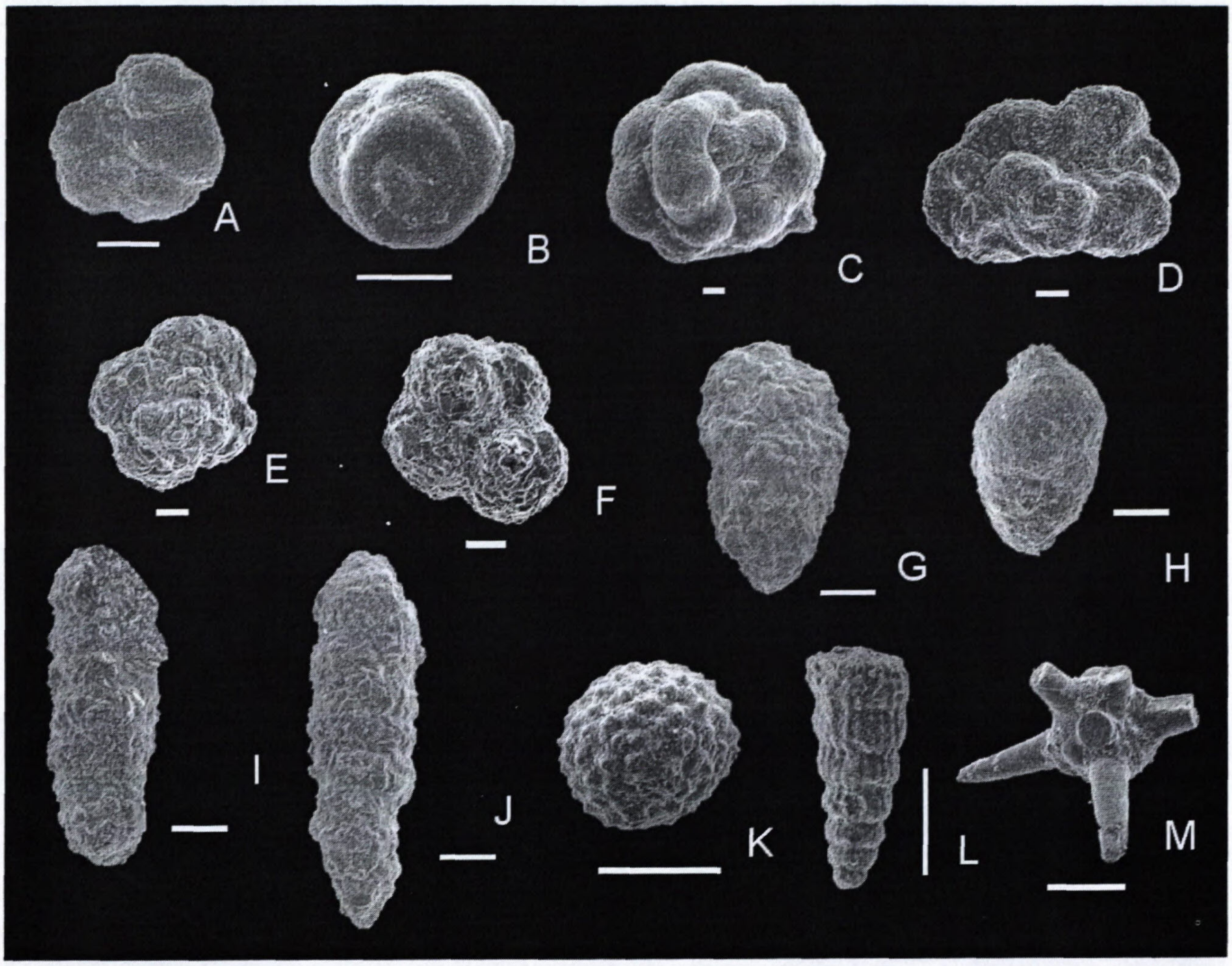

Plate. 1. Agglutinated foraminifera from variegated shales and Godula beds at Kalwaria Zebrzydowska (scale bar – 100 μm). **A** – *Haplophragmoides miatliuke* (Maslakova), Pg-8/03 (variegated shales); **B** – *Glomospira charoides* (Jones & Parker), Pg-8/03 (variegated shales); **C** – *Paratrochamminoides olszewskii* (Grzybowski), Kz-2/03 (Godula beds); **D** – *Paratrochamminoides irregularis* (White), Kz-10/03 (Godula beds); **E**, **F** – *Trochammina globigeriniformis* (Jones & Parker), Kz-10/03 (Godula beds); **G** – *Gerochammina obesa* (Neagu), Kz-9/03 (Godula beds); **H** – *Uvigerinammina jankoi* (Majzon), Pg-3/04 (variegated shales); **I** – *Gerochammina conversa* (Grzybowski), Kz-2/03 (Godula beds); **J** – *Gerochammina stanislawi* (Neagu), Kz-2/03 (Godula beds); **K**, **L** – radiolaria, Pg-5/03 (variegated shales); **M** – sponge spicule, Pg-5/03 (variegated shales).

most frequent are the representatives of *Rhabdammina*, *Nothia*, *Psammosphaera* and *Reophax*. *Caudammina gigantea* (Geroch) and *Caudammina ovulum* (Grzybowski) occur frequently whereas other taxa like *Bathysiphon*, *Ammodiscus*, *Glomospira*, *Trochammina*, *Trochamminoides* and *Paratrochamminoides* are less frequent. Single specimens of *Hormosina crassa* (Geroch) have been found in the Godula beds too.

Greenish and greyish shales from the Godula beds contain dinocysts (Pl. 3-6). Their assemblage consists of very well preserved specimens characterized by pale-yellow colour as well forms showing features of mechanical damage and maturity changes (dark yellow, brownish colour). The most frequent dinocyst taxa found in the Godula beds represent Gonyaulacoids: these are mainly chorate forms like *Spiniferites ramosus*, and less frequent *Achomosphaera* spp., *Exochosphaeridium* spp., *Tanyosphaeridium* spp., *Hystrichodinium* spp. and *Hystrichosphaeridium* spp. Relatively frequent *Pterodinium* spp. dominates among the proximochorate Gonyaulacoids. Peridinioids are much less frequent in sediments in question. *Palaeohystrichophora infusorioides* occurs frequently in samples from the basal (samples Pg/4/03 and Kz/12/03) part of the Godula beds where the red shales occur, *Palaeoperidinium cretaceum*, *Cerodinium* sp. and *Subtilisphaera* sp. occur subordinarly. Rare specimens of *Chatangiella* and small-sized *Isabelidinium* have been found.

Biostratigraphy

Foraminifera biostratigraphy of deposits in question was studied by Lemańska (in print). According to her, the variegated shales exposed in the creek at the Lanckorońska Góra Hill represents the Uvigerinammina jankoi Zone *sensu* Geroch & Nowak (1984) whereas the Godula beds represent Caudammina gigantea Zone *sensu* Geroch & Nowak (1984). The age of the younger

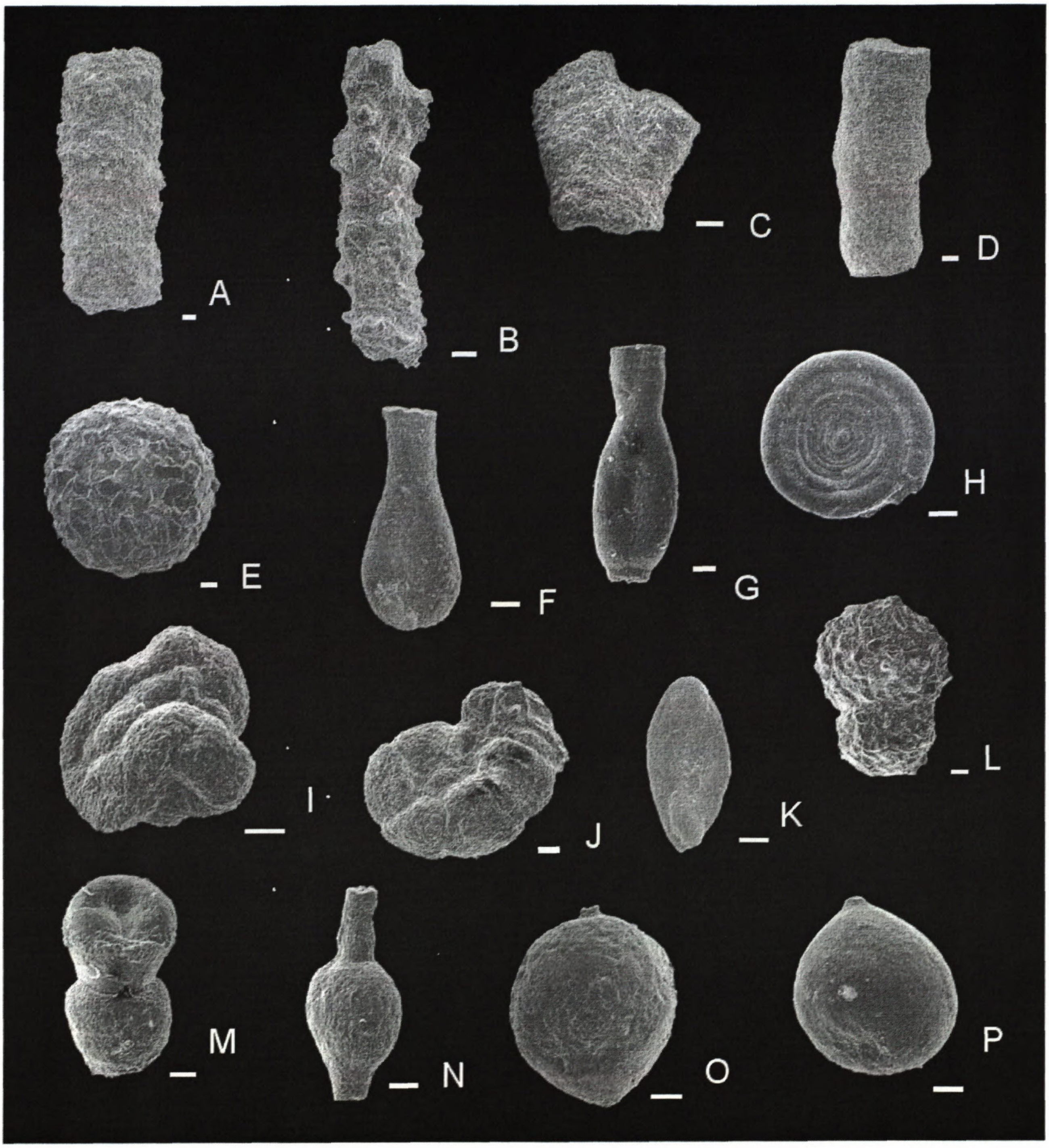

Plate. 2. Agglutinated foraminifera from Godula beds at Kalwaria Zebrzydowska (scale bar – 100 μm). **A** – *Rhabdammina* sp., Kz-10/3; **B** – *Rhabdammina cylindryca* (Glaessner), Kz-10/03; **C** – *Nothia excelsa* (Grzybowski), Kz-8/03; **D** – *Bathisiphon microrhaphidus* (Samuel), Kz-8/03; **E** – *Psammosphaera fusca* (Schultze), Kz-7/03; **F** – *Hyperammina elongata* (Brady), Kz-8/03; **G** – *Kalamopsis grzybowskii* (Dylążanka), Pg-3/03; **H** – *Ammodiscus cretaceous* (Reuss), Kz-4/03; **I** – *Glomospira irregularis* (Grzybowski), Kz-2/03; **J** – *Trochamminoides proteus* (Karrer), Kz-6/03; **K** – *Rzehakina minima* (Cushman & Renz), Kz-6/03; **L** – *Reophax duplex* (Grzybowski), Kz-6/03; **M** – *Hormosina velascoensis* (Cushman), Pg-3/03; **N** – *Hormosina crassa* (Geroch), Pg-2/03; **O, P** – *Caudammina gigantea* (Grzybowski), Kz-1/03.

foraminifera assemblage with *Caudammina gigantea* (Geroch) was estimated as Late Santonian (Fig. 3). This was based on the co-occurrence of the index species, which is known to appear throughout Late Santonian-Early Campanian (Olszewska, 1997) and *Hormosina crassa* (Geroch), which stratigraphic range is Barremian-early Senonian (Morgiel & Olszewska, 1981). However, the latter species has not been found in the stratigraphically highest sample Kz-1/03. This may suggest Campanian age of the topmost part of the Godula beds exposed in vicinity of Kalwaria Zebrzydowska. The age of the variegated shales in studied section was estimated on Early Turonian-Early Santonian (Lemańska, in print). This is based on the stratigraphic range of

Uvigerinammina jankoi (Majzon), which first appearance is known from Early Turonian (Geroch, 1957; Geroch, & Nowak, 1984; Kuhnt, 1992; Bąk, 1998).

Dinocyst age-assessment of the Godula beds (the variegated shales contain no dinocysts) in the area of study based on dinocyst must be treated as preliminary only (Fig. 3). Dinocysts have been only found in few samples representing dark-coloured lithofacies where stratigraphically important species occur as very rare specimens. Their occurrences generally confirm the age interpretation of this lithostratigraphic unit based on foraminifera.

The base of the Godula beds contains *Odontochitina porifera*, species that according to several authors (e. g., Stover *et al.*, 1996) appeared during Coniacian and Early Santonian. However, most recently Williams *et al.* (2004) proposed Late Santonian-Late Campanian range of this species in mid-latitudes of northern hemisphere. In the same rock interval *Surculosphaeridium*? *longifurcatum* was found. This species appears for the last time during Early Campanian (Williams *et al.* (2004). Hence, depending on the range interpretation of *O. porifera*, Coniacian-Early Santonian or Late Santonian-Early Campanian beginning of the Godula beds sedimentation in this area of Silesian basin can be suggested. The latter interpretation coincides with foraminifera datations based on first appearance of *Caudammina gigantea* in basal part of the Godula beds (Fig. 3).

Another stratigraphically important dinocyst species found in sediment in question is *Cannospahaeropsis utinensis*, which occurs in middle part of the Godula beds (sample Kz-6/03; Fig. 3). According to Williams *et al.* (2004) this species appeared for the first time during latest Santonian in mid-latitudes of the northern hemisphere. In the same sample *Callaiosphaeridium asymmetricum* has been found. This species has last appearance during the Early or Middle Campanian (Stover et al., 1996; Williams *et al.*, 2004, respectively). Co-occurrence of these dinocyst species suggests that sedimentation of the middle part of the studied Godula beds took place during latest Santonian-Early/Middle Campanian.

Several dinocyst species from the topmost part of the Godula beds (sample Kz-1/03) are long ranging with stratigraphic top-ranges limited to earliest-Early Maastrichtian (e. g., *Palaeohystrichophora infusorioides*, *Xenascus ceratioides*, *Laciniadinium arcticum*; Stover *et al.*, 1996). However, single specimen of *Odontochitina* sp. A *sensu* Kirsch (1991) has been found here. Range of this species was estimated by Kirsch (1991) as Early-Middle Campanian. This would suggest that sedimentation of the Godula beds in this part of the Silesian basin terminated during Early-Middle Campanian.

Summarising, interpretation of our data suggests that sedimentation of the Godula beds in this part of the Silesian basin lasted throughout Late Santonian and was presumably terminated during the Early-Middle Campanian (Fig. 3).

Reconstruction of palaeoenvironment

Microfossils that have been found in the variegated shales during our studies consist of agglutinated foraminifera, sponge spicules and radiolaria. Neither dinocysts nor phytoclasts have been found. Detailed analysis of foraminifera assemblage from this lithostratigraphic unit (Lemańska, in print) shows dominance of epifaunal and shallow and deep infaunal forms whereas suspension feeding forms comprise 10% of the assemblage. Their life strategy – living buried in the sediment (based on e. g., Kaminski *et al.*, 1995; Nagy *et al.*, 1995; Kuhnt *et al.*, 1996; Bąk *et al.*, 1997), was interpreted as indicative for well oxygenated bottom waters, low sedimentation rate and limited food supply (Lemańska, in print). This interpretation agrees well with interpretation of palynological data: lack of dinocysts and phytoclasts suggests highly aerobic environment resulting from very slow sedimentation rate and limited organic matter supply. Red-green colour variations of the variegated shales, which result from Fe^{3+}/Fe^{2+} ratio depending on amount of organic matter (e. g., Potter *et al.*, 1980), are not reflected in palynological content: samples representing both lithotypes contain no palynological organic matter (i. e., organic particles larger that 15 μm). This suggests that even during sedimentation of greenish shales, which presumably represent hemipelagic sediment of diluted turbidite currents (see Leszczyński & Uchman, 1996), oxygen content in bottom waters was high enough to oxidize organic matter.

Beginning of the Godula beds sedimentation, i. e. increase of flysch-type sedimentation in this part of the Silesian basin, resulted in major change of bottom environment. Agglutinated formaninifera assemblage from this lithostratigraphic unit consists mainly of suspension feeding forms – 45%. Epifaunal forms represent 32% of the whole benthos whereas infaunal forms comprise only 16% (Lemańska, in print). Such assemblage, composed predominantly of coarse-grained large-sized foraminifera, suggests high flux of organic matter, which seems to be resedimented from more proximal areas. This is indicated by the occurrence in dark-coloured shales of the Godula beds of dinocysts, which inhabit mainly the near-shore waters. However, their ratio is variable. It is the lowest in the samples taken from the basal part of the Godula beds, which contain frequent dinocyst that lived in offshore waters (*Spiniferites ramosus*, *Pterodinium* spp.). Moreover, frequent occurrence in this part of succession of *Palaeohystrichophora infusorioides*, a species distinguished by very good state of preservation, may be related to blooms of its motile stage in oceanic waters. This might be a record of *in situ* primary productivity of oceanic waters, which has not been masked by resedimentation – palynofacies of these samples consist of black opaque phytoclasts, typical component of pelagic deposits. Frequent occurrence of Peridinioids in pelagic/hemipelagic deep-water deposits was described by Gedl (2004) from Maastrichtian of Flysch Carpathians in Moravia. Higher up the section, the frequency of near-shore dinocysts increases. It is a result of increased resedimentation from marginal parts of the basin. Another record of this resedimentation is increasing occurrence of land plant tissue remains. Its maximum is evidenced in the top-most part of the Godula beds where dinocyst diversity is the highest and near-shore species (e. g., *Odon-*

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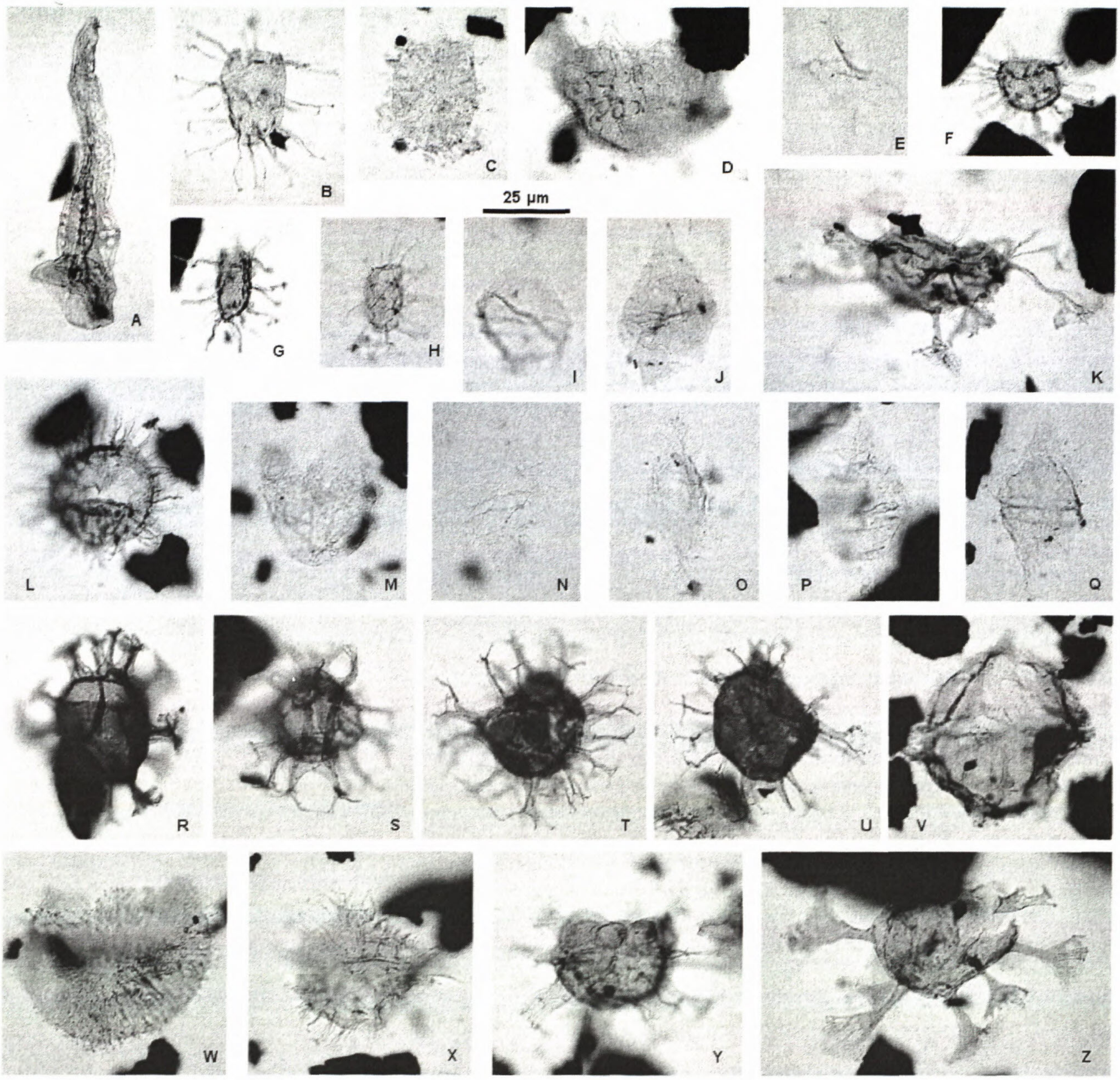

Plate 3. Dinoflagellate cysts from Godula beds at Kalwaria Zebrzydowska. **A** – *Odontochitina porifera*, Pg-4/03; **B**, **G**, **H** – *Tanyosphaeridium* sp., B: Kz-6/03, G, H: Kz-12/03; **C** – *Prolixosphaeridium* sp., Pg-4/03; **D** – *Systematophora* sp., Pg-4/03; **E** – *Palaeotetradinium silicorum*, Pg-4/03; **F** – *Dapsilidinium* sp., Kz-12/03; **I**, **J** – *Subtilisphaera* sp., Pg-4/03; **K** – *Stiphrosphaeridium anthophorum*, Pg-4/03; **L** – *Pervosphaeridium* sp., Kz-6/03; **M** – *Kallosphaeridium* sp., Pg-4/03; **N-Q** – *Palaeohystrichophora infusorioides*, Kz-12/03; **R** – *Achomosphaera* sp., Kz-12/03; **S-U** – *Spiniferites ramosus*, Kz-12/03; **V** – *Cribroperidinium* sp., Pg-4/03; **W** – *Circulodinium distinctum*, Pg-4/03; **X** – *Exochosphaeridium* sp., Pg-4/03; **Y** – *Hystrichosphaeridium* sp., Pg-4/03; **Z** – *Oligosphaeridium pulcherrimum*, Pg-4/03

tochitina sp.) occur frequently. Also land derived plant remains (phytoclasts and sporomorphs) are the most frequent here.

Higher influx of organic matter during turbiditic sedimentation of the Godula beds caused also changes in chemistry of sediment. Lower oxygen concentration in sediment than it was during sedimentation of the variegated shales is indicated by low amounts (16%) of infaunal forms. It results from bacterial decay of larger amounts of organic matter and causes green colour of sediment related to the Fe^{3+}/Fe^{2+} ratio. The red colour of sediment appears when this ratio is high whereas the green colour is associated with low ratio (Dominik, 1977; Potter *et al*., 1980).

The Fe^{3+}/Fe^{2+} ratio depends on oxidation conditions within sediment, which, in turn, is controlled by organic matter amount. Our study shows that dark coloured shales of the Godula beds in vicinity of Kalwaria Zebrzydowska contain relatively high amounts of organic matter of marine and land origin. Reddish shales of this lithostratigraphic unit must have been deposited during periods of calm, hemipelagic/pelagic sedimentation with limited supply of organic matter from marginal areas of the Silesian basin. Contrary, the differences in sedimen-

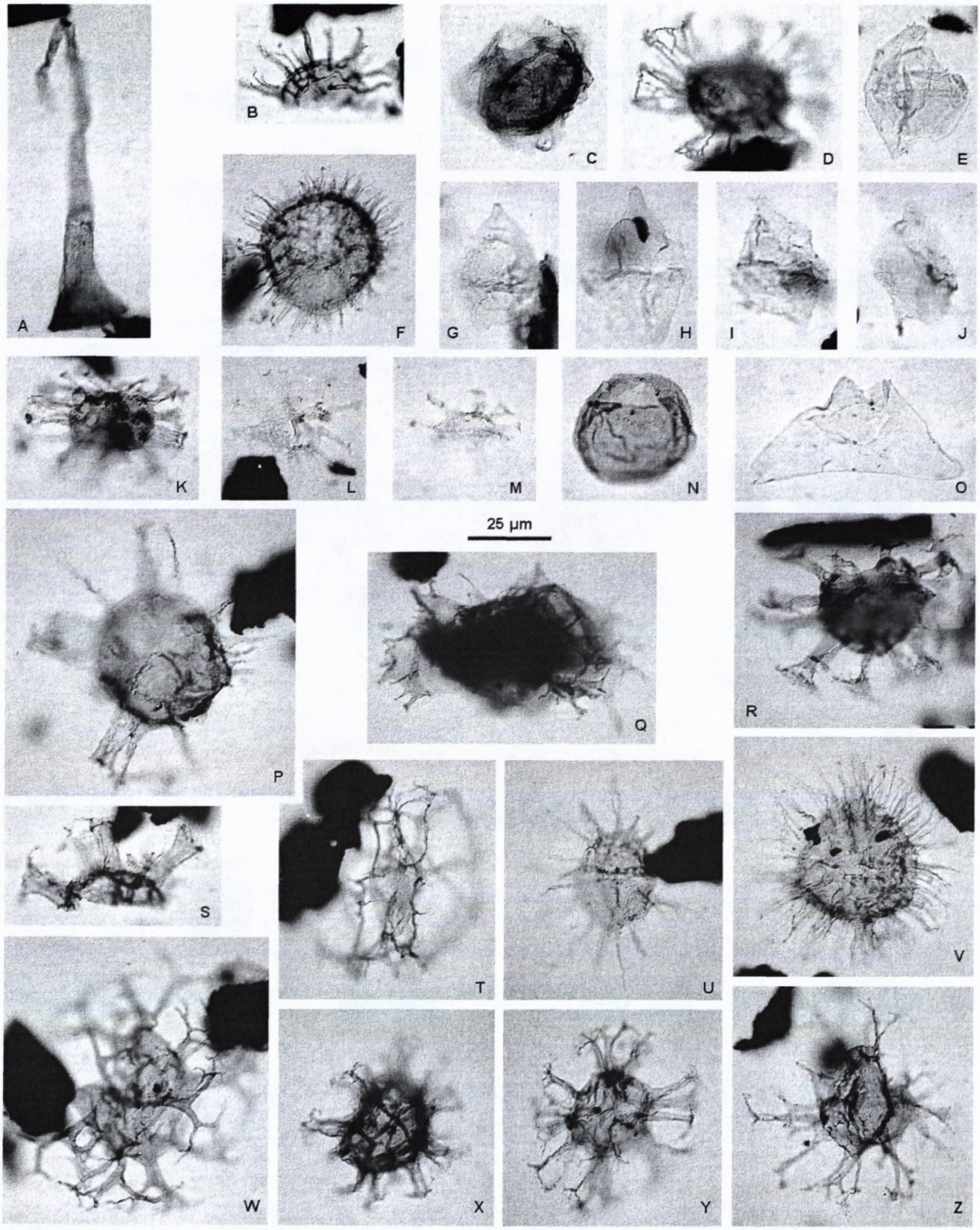

Plate 4. Dinoflagellate cysts from Godula beds at Kalwaria Zebrzydowska. **A** – *Odontochitinia operculata*, Kz-6/03; **B** – *Surculosphaeridium? longifurcatum*, Kz-12/03; **C** – *Senoniasphaera rotundata*, Kz-12/03; **D** – *Hystrichosphaerina?* sp., Pg-4/03; **E** – *Ovoidinium?* sp., Pg-4/03; **F** – *Operculodinium* sp., Kz-6/03; **G-J** – *Isabelidinium* spp., Pg-4/03; **K-M** – *Hystrichosphaeridium* spp., K, L: Kz-6/03, M: Pg-4/03; **N** – "round-brown", Kz-12/03; **O** – *Trigonopyxidia ginella*, Pg-4/03; **P** – *Florentinia* sp., Kz-6/03; **Q** – ?*Palynodinium* sp., Kz-6/03; **R** – *Hystrichosphaeridium tubiferum*, Kz-6/03; **S** – *Callaiosphaeridium asymmetricum*, Kz-6/03; **T** – *Cannosphaeropsis utinensis*, Kz-6/03; **U** – *Hystrichodinium pulchrum*, Kz-6/03; **V** – *Exochosphaeridium* sp., Kz-6/03; **W, Z** – *Achomosphaera* sp., Kz-6/03; **X, Y** – *Spiniferites ramosus*, Kz-6/03

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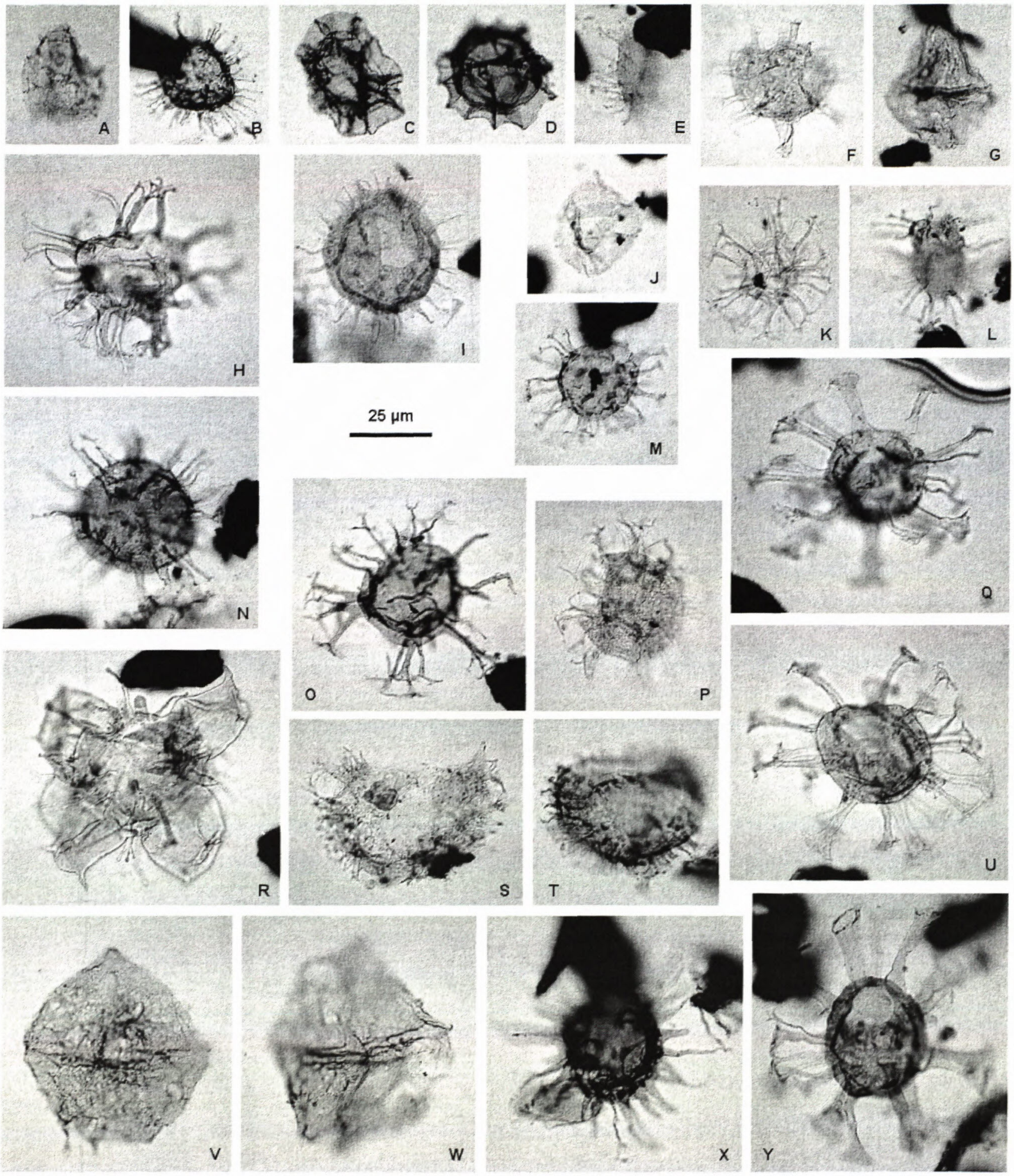

Plate 5. Dinoflagellate cysts from Godula beds at Kalwaria Zebrzydowska. **A** – *Impagidinium* sp., Kz-6/03; **B** – *Kiokansium polypes*, Kz-6/03; **C, D** – *Pterodinium cingulatum*, Kz-6/03; **E, L** – *Tanyosphaeridium* sp., Kz-6/03; **F** – *Diphyes* sp., Kz-1/03; **G** – *Alisogymnium euclaense*, Kz-6/03; **H** – *Surculosphaeridium belowi*, Kz-1/03; **I** – *Operculodinium* sp., Kz-6/03; **J** – dinocyst indet., Pg-4/03; **K** – *Spiniferites ramosus*, Kz-1/03; **M** – ?*Taleisphaera hydra*, Kz-6/03; **N** – *Pervosphaeridium* sp., Pg-1/03; **O** – *Achomosphaera* sp., Pg-1/03; **P** – *Spiniferites crassipelis*, Pg-1/03; **Q, U** – *Hystrichosphaeridium salpingophorum*, Kz-1/03; **R** – *Hystrichokolpoma cinctum*, Kz-1/03; **S** – *Glaphyrocysta ordinata*, Kz-1/03; **T** – *Circulodinium distinctum*, Kz-1/03; **V, W** – *Palaeoperidinium cretaceum*, Kz-12/03; **X** – *Hystrichodinium* sp., Kz-12/03; **Y** – *Kleithriasphaeridium* sp., Pg-4/03

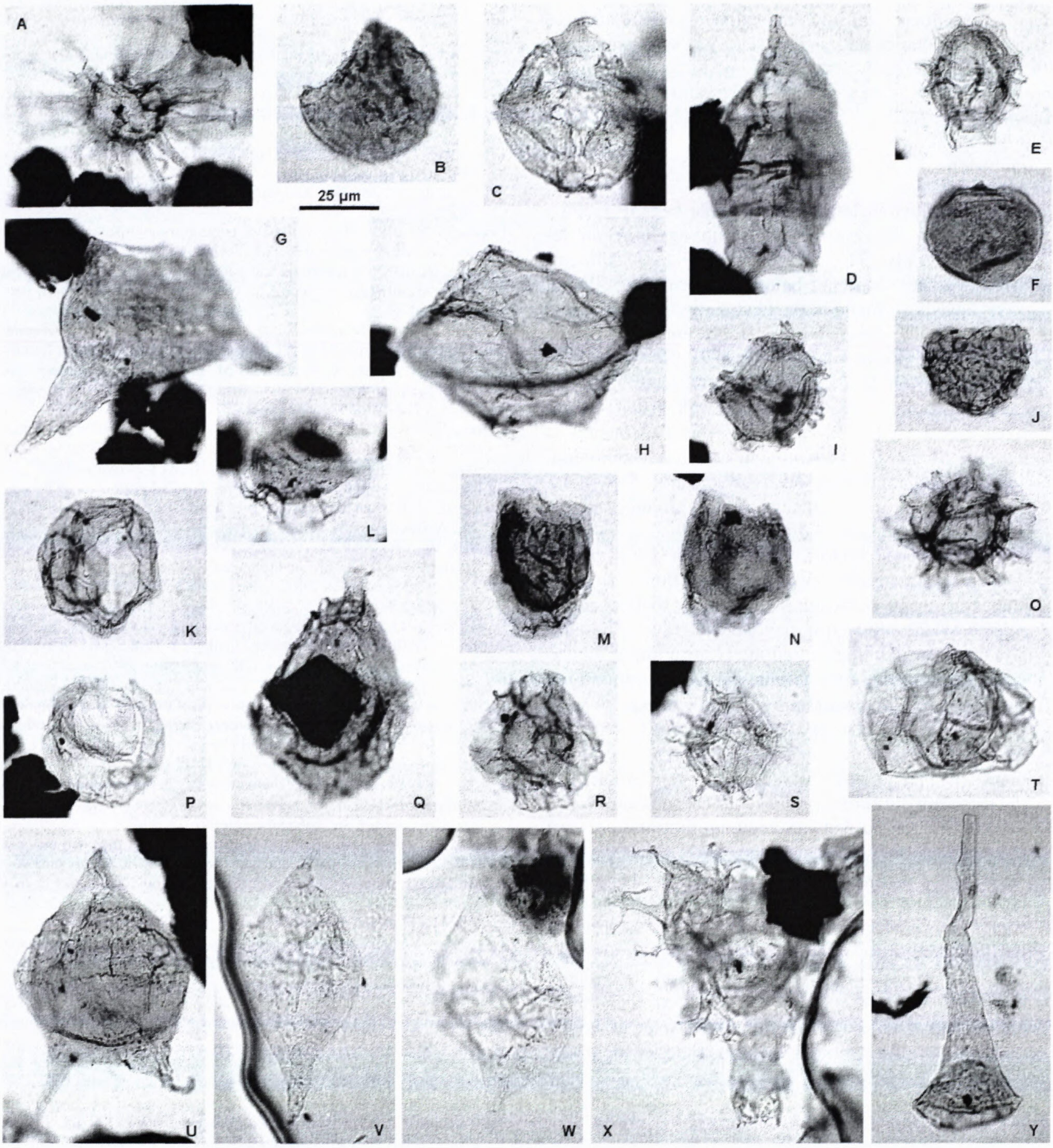

Plate 6. Dinoflagellate cysts from Godula beds at Kalwaria Zebrzydowska. **A** – *Dapsilidinium* sp., Pg-1/03; **B** – dinocyst indet., Kz-1/03; **C**, **Q** – *Cribroperidinium* spp., C: Kz-1/03, Q: Pg-1/03; **D** – *Chatangiella* sp., Pg-1/03; **E**, **I** – *Pterodinium* sp., E: Pg-1/03, I: Kz-1/03; **F** – *Apteodinium* sp., Pg-1/03; **G** – *Odontochitinia* sp. A *sensu* Kirsch (1991), Kz-1/03; **H** – *Palaeoperidinium cretaceum*, Pg-1/03; **J** – *Valensiella reticulata*, Pg-1/03; **K**, **P**, **T** – *Disphaeria* sp., K, P: Pg-1/03, T: Kz-1/03; **L** – *Eatonicysta ursulae sensu* Mahreinecke (1992), Kz-6/03; **M**, **N** – *Leberidocysta chlamydata*, Pg-1/03; **O**, **R** – *Pterodinium aliferum*, Pg-1/03; **S** – *Pterodinium cingulatum*, Kz-1/03; **U** – *Cerodinium* sp., Kz-1/03; **V**, **W** – *Laciniadinium arcticum*, Kz-1/03; **X** – *Xenascus ceratioides*, Kz-1/03; **Y** – *Odontochitina costata*, Kz-1/03

tary environments during deposition greenish and red shales of the variegated shales were not so pronounced. In both cases organic matter content is very low and it was presumably sedimentation rate responsible for colour origin.

Conclusions

1. The variegated shales and the Godula beds in vicinity of Kalwaria Zebrzydowska contain agglutinated foraminifera only. This suggests that these sediments were deposited at depth below the local CCD. Dinocysts have been found in the Godula beds only.
2. The studied variegated shales represent Uvigerinammina jankoi Zone *sensu* Geroch & Nowak (1984) whereas the Godula beds represent Caudammina gigantea Zone *sensu* Geroch & Nowak (1984). Their ages, based on foraminifera, have been estimated as Early Turonian-Early Santonian and Late Santonian-Early Campanian? respectively. Late Santonian-Early/Middle Campanian age of the Godula beds is suggested on the base of dinocysts.
3. Well oxygenated bottom water and surface sediment column characterises deposition of the variegated shales in question. Scarcity of organic matter supply related to oceanic setting beyond the reach of intense flysch sedimentation resulted in colonisation of the basin bottom by the epifunal and infaunal foraminifera. Increased resedimentation from more proximal areas (turbiditic sedimentation of the Godula beds), recorded also in dinocyst assemblages altered bottom environments. Higher amounts of organic matter supplied to the sea floor by turbiditic currents caused better food availability for suspension feeding foraminifera and oxygen depletion within sediment.
4. Changes in dinocyst assemblages from the Godula beds reflect intensity of resedimentation from marginal areas of Silesian basin during Late Santonian-Early/Middle Campanian. Presumably *in situ* and offshore dinocysts occur in the basal part of the Godula beds. Higher up the succession, near-shore species begin to dominate. They are the most frequent in the topmost part of the Godula beds overlaid by the lower Istebna sandstone.

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APPENDIX

An alphabetical listing of agglutinated foraminifera and dinocyst taxa found in the Kalwaria Zebrzydowska section is provided below. Numbers in parentheses refer to the appropriate photomicrographs in Plates 1 to 2 (foraminifera) and 3 to 6 (dinocysts).

Foraminifera:

Ammodiscus cretaceus (Reuss, 1845) [Pl. 1H]
Ammodiscus irregularis (d`Orbigny)
Ammodiscus sp.
Bathysiphon microrhaphidus (Samuel, 1977) [Pl. 1D]
Bathysiphon sp.
Caudammina gigantea (Geroch, 1960) [Pl. 1O, P]
Caudammina ovulum (Grzybowski, 1896)
Gerochammina conversa (Grzybowski, 1901) [Pl. 2I]
Gerochammina obesa (Neagu, 1990) [Pl. 2G]
Gerochammina stanislawi (Neagu,1990) [Pl. 2J]
Glomospira charoides (Jones et Parker, 1860) [Pl. 2B]
Glomospira diffundens (Cushman et Renz, 1946)
Glomospira glomerata (Grzybowski, 1898)
Glomospira gordialis (Jones et Parker, 1860)
Glomospira irregularis (Grzybowski, 1898) [Pl. 1I]
Glomospira serpens (Grzybowski, 1898)
Glomospira sp.
Haplophragmoides mjatliuke (Maslakova, 1955) [Pl. 2A]
Haplophragmoides sp.
Hormosina crassa (Geroch, 1966) [Pl. 1N]
Hormosina velascoensis (Cushman, 1926) [Pl. 1M]
Hyperammina elongata (Brady, 1878) [Pl. 1F]
Hyperammina sp.
Kalamopsis grzybowskii (Dylążanka, 1923) [Pl. 1G]
Karrerulina horrida (Mjatliuk, 1970)
Nothia excelsa (Grzybowski, 1898) [Pl. 1C]
Paratrochamminoides irregularis (White, 1928) [Pl. 2D]
Paratrochamminoides olszewskii (Grzybowski, 1898) [Pl. 2C]
Paratrochamminoides sp.
Psammosphaera fusca (Schultze, 1875) [Pl. 1E]
Psammosphaera sp.
Recurvoides spp.
Reophax duplex (Grzybowski, 1869) [Pl. 1L]
Reophax pilulifer (Brady, 1844)
Reophax sp.
Rhabdammina cylindrica (Glaessner, 1937) [Pl. 1B]
Rhabdammina linearis (Brady)
Rhabdammina sp. [Pl. 1A]
Rhizammina sp.
Rzehakina minima (Cushman et Renz, 1946) [Pl. 1K]
Rzehakina sp.
Saccammina sp.
Trochammina globigeriniformis (Jones et Parker, 1865) [Pl. 2E, F]
Trochammina spp.
Trochamminoides folius (Grzybowski, 1898)
Trochamminoides grzybowskii (Kaminski et Geroch, 1993)
Trochamminoides proteus (Karrer, 1866) [Pl. 1J]
Trochamminoides sp.
Uvigerinammina jankoi (Majzon, 1943) [Pl. 2H]

Dinocysts:

Achomosphaera sp. [Pl. 3R; Pl. 4W, Z; Pl. 5O]
Alisogymnium euclaense (Cookson et Eisenack, 1970) Lentin et Vozzhennikova, 1990 [Pl. 5G]
Apteodinium sp. [Pl. 6F]
Callaiosphaeridium asymmetricum (Deflandre et Courteville, 1939) Davey et Williams, 1966 [Pl. 4S]
Cannosphaeropsis utinensis O. Wetzel, 1932 [Pl. 4T]
Cerodinium sp. [Pl. 6U]
Chatangiella sp. [Pl. 6D]
Circulodinium distinctum (Deflandre et Cookson, 1955) Jansonius, 1986 [Pl. 3W; Pl. 5T]
Cribroperidinium sp. [Pl. 3V; Pl. 6C, Q]
Dapsilidinium sp. [Pl. 3F; Pl. 6A]
Diphyes sp. [Pl. 5F]
Disphaeria sp. [Pl. 6K, P, T]
Eatonicysta ursulae sensu Marheinecke, 1992 [Pl. 6L]
Exochosphaeridium sp. [Pl. 3X; Pl. 4V]
Florentinia sp. [Pl. 4P]
Glaphyrocysta ordinata (Williams et Downie, 1966) Stover et Evitt, 1978 [Pl. 5S]
Hystrichodinium pulchrum Deflandre, 1935 [Pl. 4U]
Hystrichodinium sp. [Pl. 5X]
Hystrichokolpoma cinctum Klumpp, 1953 [Pl. 5R]
Hystrichosphaeridium salpingophorum (Deflandre, 1935) Deflandre, 1937 [Pl. 5Q, U]
Hystrichosphaeridium tubiferum (Ehrenberg, 1838) Deflandre, 1937 [Pl. 4R]
Hystrichosphaeridium sp. [Pl. 3Y; Pl. 4K-M]
Hystrichosphaerina? sp. [Pl. 4D]
Impagidinium sp. [Pl. 5A]
Isabelidinium spp. [Pl. 4G-J]
Kallosphaeridium sp. [Pl. 3M]
Kiokansium polypes (Cookson et Eisenack, 1962) Below, 1982 [Pl. 5B]
Kleithriasphaeridium sp. [Pl. 5Y]
Laciniadinium arcticum (Manum et Cookson, 1964) Lentin et Williams, 1980 [Pl. 6V, W]
Leberidocysta chlamydata (Cookson et Eisenack, 1962) Stover et Evitt 1978 [Pl. 6M, N]
Odontochitina costata Alberti, 1961 [Pl. 6Y]
Odontochitina operculata (O.Wetzel, 1933) Deflandre et Cookson, 1955 [Pl. 4A]
Odontochitina porifera Cookson, 1956 [Pl. 3A]
Odontochitinia sp. A *sensu* Kirsch (1991) [Pl. 6G]
Oligosphaeridium pulcherrimum (Deflandre et Cookson, 1955) Davey et Williams, 1966 [Pl. 3Z]
Operculodinium sp. [Pl. 4F; Pl. 5I]
Ovoidinium? sp. [Pl. 4E]

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Palaeohystrichophora infusorioides Deflandre, 1935 [Pl. 3N-Q]
Palaeoperidinium cretaceum Pocock, 1962 [Pl. 5V, W; Pl. 6H]
Palaeotetradinium silicorum Deflandre, 1936 [Pl. 3E]
?*Palynodinium* sp. [Pl. 4Q]
Pervosphaeridium sp. [Pl. 3L; Pl. 5N]
Prolixosphaeridium sp. [Pl. 3C]
Pterodinium aliferum Eisenack, 1958 [Pl. 6O, R]
Pterodinium cingulatum (O. Wetzel, 1933) Below, 1981 [Pl. 5C, D; Pl. 6C]
Pterodinium sp. [Pl. 6E, I]
Senoniasphaera rotundata Clarke et Verdier, 1967 [Pl. 4C]
Spiniferites crassipelis (Deflandre et Cookson, 1955) Sarjeant, 1970 [Pl. 5P]
Spiniferites ramosus (Ehrenberg 1838) Loeblich et Loeblich, 1966 [Pl. 3S-U; Pl. 4X, Y; Pl. 5K]
Stiphrosphaeridium anthophorum (Cookson et Eisenack, 1958) Lentin et Williams, 1985 [Pl. 3K]
Subtilisphaera sp. [Pl. 3I, J]
Surculosphaeridium belowi Yun, 1981 [Pl. 5H]
Surculosphaeridium? *longifurcatum* (Firtion, 1952) Davey et al., 1966 [Pl. 4B]
Systematophora sp. [Pl. 3D]
?*Taleisphaera hydra* Duxbury, 1979 [Pl. 5M]
Tanyosphaeridium sp. [Pl. 3B, G, H; Pl. 5E, L]
Trigonopyxidia ginella (Cookson et Eisenack, 1960) Downie et Sarjeant, 1965 [Pl. 4O]
Valensiella reticulata (Davey, 1969) Courtinat, 1989 [Pl. 6J]
Xenascus ceratioides (Deflandre, 1937) Lentin et Williams, 1973 [Pl. 6X]
"round-brown" [Pl. 4N]