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Dinoflagellate cysts from the Szlachtowa Formation (Jurassic) and adjacent deposits (Jurassic–Cretaceous) of the Grajcarek Unit at Szczawnica-Zabaniszcze (Pieniny Klippen Belt, Carpathians, Poland)

Przemysław GEDL[1,] *

[1] Institute of Geological Sciences, Polish Academy of Sciences, Senacka 1, 31-002 Kraków, Poland

Gedl P. (2013) Dinoflagellate cysts from the Szlachtowa Formation (Jurassic) and adjacent deposits (Jurassic–Cretaceous) of the Grajcarek Unit at Szczawnica-Zabaniszcze (Pieniny Klippen Belt, Carpathians, Poland). Geological Quarterly, **57** (3): 485–502, doi: doi: 10.7306/gq.1106

The Jurassic–Cretaceous fine-clastic dark deposits of the Grajcarek Unit (Pieniny Klippen Belt, Carpathians, Poland) show lithological similarities, which may lead to erroneous age correlations. Their well-exposed outcrop at Szczawnica--Zabaniszcze allows detailed sampling for their precise age determination. For this purpose, dinoflagellate cysts have been studied from a set of samples collected from the Szlachtowa, Opaleniec, Pieniny Limestone, Kapuśnica and Wronine formations exposed at that site (additional sample from the Pieniny Limestone Formation was studied). The Szlachtowa Formation, a very characteristic lithostratigraphic unit, which consists of black shale and sandstones extremely rich in mica flakes, occasionally referred to literature as the so-called “black flysch”, yielded rich and well-preserved assemblages. Their age is Middle Jurassic, spanning the Aalenian to Lower Bajocian. The exposures of the Szlachtowa Formation at Szczawnica-Zabaniszcze are located close to the outcrops of the Opaleniec Formation. The calcareous spotted shale from this lithostratigraphic unit yielded rich dinoflagellate cyst assemblage characteristic for Late Bathonian (Early Callovian?). The Opaleniec Formation tectonically contacts with very similar non-calcareous spotted shale of the Wronine Formation. Its age, based on infrequent dinoflagellate cysts is Aptian–Albian. Similar, Lower Aptian age was concluded for the Kapuśnica Formation. Late Barremian–earliest Aptian dinoflagellate cysts have been found in the underlying topmost part of the Pieniny Limestone Formation.

Key words: Szlachtowa Formation, “black flysch”, biostratigraphy, Jurassic, Cretaceous, Pieniny Klippen Belt.

INTRODUCTION

The Szlachtowa Formation is a lithostratigraphic unit described by Birkenmajer (1977). It occurs in the klippen successions of the Pieniny Klippen Belt (except in the Czorsztyn Succession) and in the Magura Nappe, tectonically incorporated into the Pieniny Klippen Belt structure (known as the Grajcarek Unit; Birkenmajer, 1977, 1986). In the latter unit it reaches a maximum thickness of over 220 m, and is widely distributed there. The Szlachtowa Formation consists of dark-coloured (black to dark grey) flysch deposits including calcareous shale and very characteristic sandstone layers with abundant mica flakes; the latter occur extensively in shaly mudstone, being less frequent in clay shale. The dark colour of these flysch deposits led early researchers to the conclusion that they were Cretaceous in age, by comparison with black flysch and flyschoid Cretaceous strata of the Outer Carpathians (e.g., Uhlig, 1890). But, later findings of Jurassic macrofossils suggested a Middle Jurassic age for these strata (e.g., Andrusov, 1929, 1938). Discussion of the age of the Szlachtowa Formation was renewed by Sikora (1962; see also 1971) who suggested a Cretaceous age for this unit. This age-interpretation was, however, undermined by further evidence of Middle Jurassic age, mainly microfossils, in the Szlachtowa Formation (e.g., Birkenmajer and Pazdro, 1968; Birkenmajer et al., 1970; Pazdro, 1979; Dudziak, 1986). The problem of the age of the Szlachtowa Formation was once again raised by Oszczypko et al. (2004) who opted for a Cretaceous age. This view was criticized by Birkenmajer et al. (2008). Despite the latest results of micropalaeontological studies showing an undoubted Middle Jurassic age for the deposits in question (e.g., Gedl, 2008d), Oszczypko et al. (2012) presented their opposing interpretation (see also Barski et al., 2012). Because the results of their studies are, in my opinion, based on erroneously collected material, I sampled the exposure of the Szlachtowa Formation and adjacent units at Szczawnica-Zabaniszcze, which was also investigated by those authors. The results of the present studies and comparison with earlier studies are given in this paper.

GEOLOGICAL SETTING

The Pieniny Klippen Belt forms a narrow structure at the boundary with the Outer Carpathians separating it from the Inner Carpathians (Fig. 1A). This structure, over 600 km long and from 1 to 20 km wide, was formed during the Laramian orogeny when the Tethyan Upper Triassic–Cretaceous succession was

* E-mail address: ndgedl@cyf-kr.edu.pl

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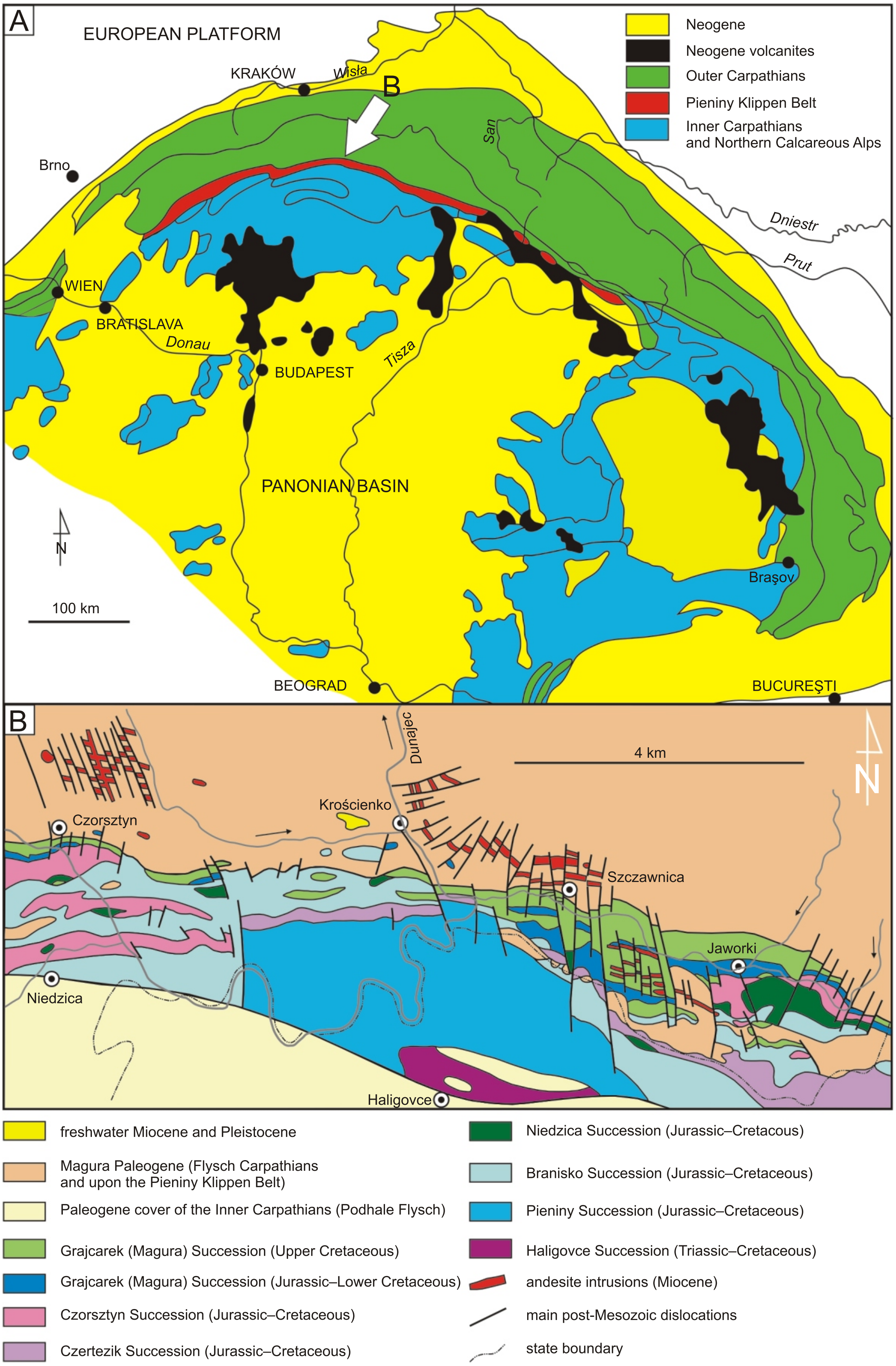

Fig. 1. Geological maps of the Carpathians (A) and the eastern sector of the Pieniny Klippen Belt in Poland (B; from Birkenmajer, 1977)

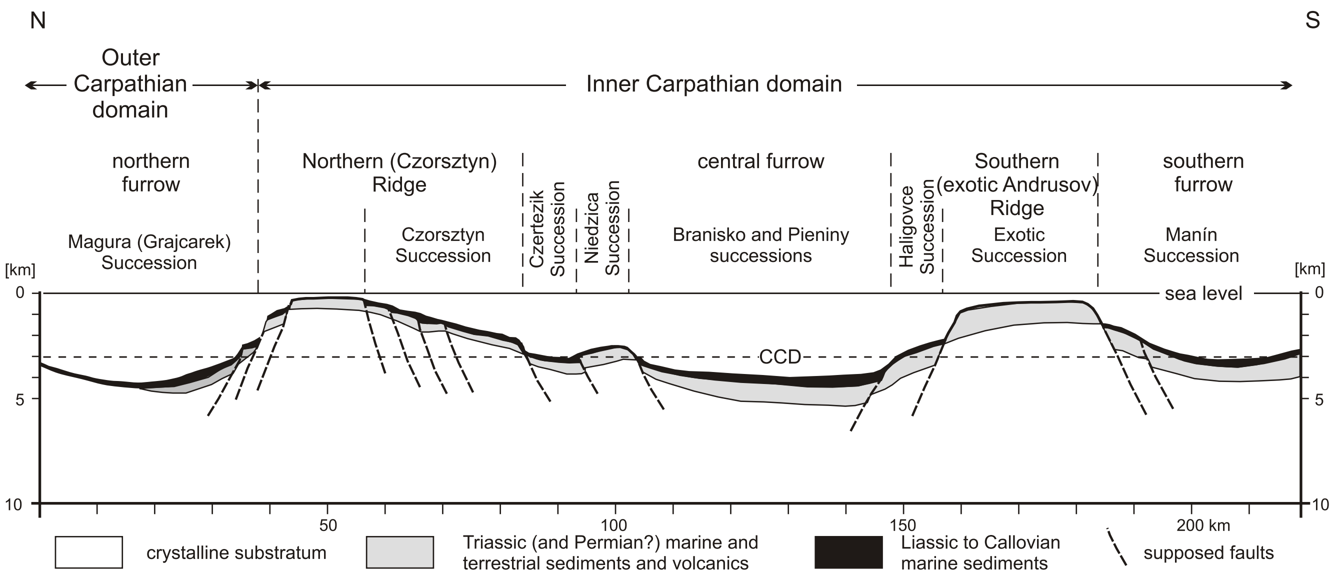

Fig. 2. Palinspastic reconstruction of the Pieniny Klippen Belt Basin and the southern part of the Magura Basin during the Callovian (from Birkenmajer, 1977)

CCD – carbonate compensation depth

folded, overthrusted and squeezed between the North European Platform and northwards migrating African plates. Birkenmajer (1977), in the Polish sector, distinguished five successions, from basinal (Pieniny and Branisko successions), through transitional (Niedzica, Czertezik) to the shallowest one located on the Czorsztyn Ridge, which limited the Pieniny basin system from the north. It separated the Pieniny basins from the Magura Basin of the Outer Carpathian domain, which existed during the Jurassic–Cretaceous (Fig. 2). A part of the Magura Succession, known as the Grajcarek Unit, was incorporated into the Pieniny Klippen Belt system during the Laramian orogeny (Birkenmajer, 1977). The Grajcarek Unit succession starts with the Szlachtowa Formation (dark-coloured shaly flysch of Middle Jurassic age) representing the oldest phase of the Magura Basin development (Fig. 3). Gradual deepening of the basin is reflected by appearance of the Fleckenmergel facies (the Opaleniec and Stembrow formations), which passes into Middle–Upper Jurassic radiolarian deposits (the Sokolica Radiolarian Formation, the Czajakowa Radiolarian Formation) overlain by Upper Jurassic–Lower Cretaceous pelagic limestone (Czorsztyn Limestone Formation and Pieniny Limestone Formation). A mid-Cretaceous bottom oxygen-depleted phase is reflected by dark-coloured fine-grained deposits of the Kapuśnica, Wronine and Hulina formations. An interval of well-oxygenated pelagic sedimentation (Late Cretaceous) is reflected by deposition of predominantly red-coloured clay (the Malinowa Shale Formation) followed by Upper Cretaceous flysch-facies (Hałuszowa Formation). The Laramian orogenic phase, responsible for incorporation of the Grajcarek Unit into the Pieniny Klippen Belt, is manifested by deposition of the coarse-grained conglomerates of the Jarmuta Formation (Maastrichtian).

MATERIAL

The exposures studied at Szczawnica-Zabaniszcze crop out in a small tributary of the Grajcarek Creek (Jarmucki Potok *vel* Zabaniszcze Stream), just behind an old house (Fig. 4; see also Oszczypko et al., 2012: fig. 4C). It is located near the classic site of a condensed succession of the Grajcarek Unit exposed several tens of metres downstream, along the southern bank of Grajcarek Creek (see e.g., Birkenmajer, 1977). Thick-bedded conglomerates of the Jarmuta Formation form a distinct morphological threshold in the stream bed, some 80 m from the junction with the Grajcarek Creek (GPS coordinates: N 49°25.160', E 020°29.260' ± 17 m); they crop out over a distance of 5–6 metres (Fig. 5A). Vertically dipping strata of the Jarmuta Formation pass into the red shale of the Malinowa Shale Formation (some 150 cm), which are in tectonic contact with the vertically dipping Middle Jurassic Sokolica Radiolarite Formation (ca. 6 m; Fig. 5A, B). The latter passes into the Czajakowa Radiolarite Formation and the Pieniny Limestone Formation; both lithostratigraphic units form a small klippe (Fig. 5A, C). The uppermost part of the Pieniny Limestone Formation consists of dark grey to black limestone with intercalations of cherty limestone and black calcareous shale (the latter lithology was sampled – SzZ27; Fig. 5A). It passes into 80–110 cm thick black and dark olive spotted, partly siliceous, calcareous shale of the Kapuśnica Formation (sample SzZ28 was collected 30 cm above the top of the Pieniny Limestone Formation). Farther to the SE, the Kapuśnica Formation passes into willow green to dark green and blackish spotted non-calcareous clay shale attributed by Birkenmajer (1977) to the Wronine Formation (Fig. 5A; see also Oszczypko et al., 2012: fig. 4C), which crops out over a distance of ca. 80–100 cm (there are no farther exposures on this creek bank – being covered with black muddy weathered material, presumably from the Szlachtowa Formation, washed from higher parts of the slope). Sample SzZ29 was collected from the basal part of the Wronine Formation, 50 cm above sample SzZ28 (Fig. 5A).

Further outcrops of the Grajcarek Unit are well-exposed on the opposite (northeastern) bank of the creek (Fig. 5D). Here, the succession starts with the Pieniny Limestone Formation (there is a slickenside on its top; Fig. 5E). The overlying Kapuśnica Formation is tectonic reduced here to merely 10–30 cm of thickness (dark greenish and black calcareous shale with lenses of silicified shale: sample SzZ30A is soft,

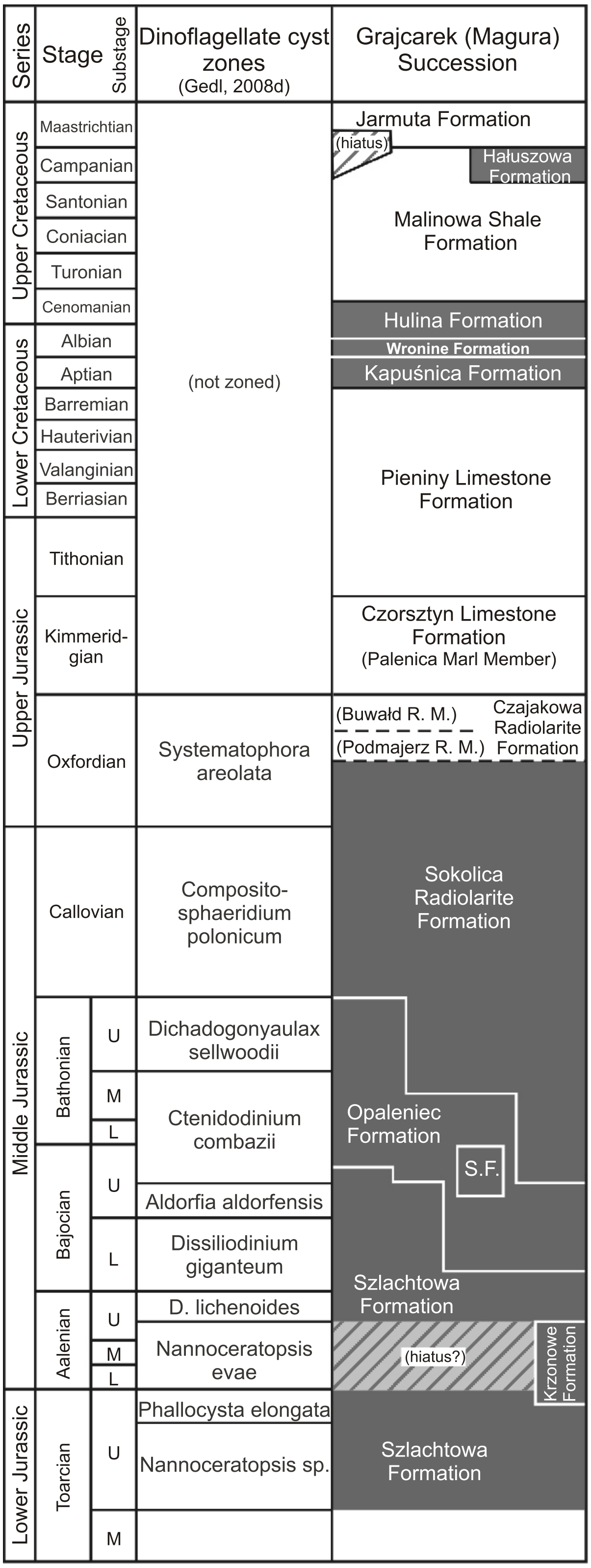

Fig. 3. Lithostratigraphic division of the Grajcarek Unit (based on Birkenmajer, 1977, modified in the Aalenian–Bathonian part by Gedl, 2008d)

R. M. – Radiolarite Member; S. F. – Stembrow Formation

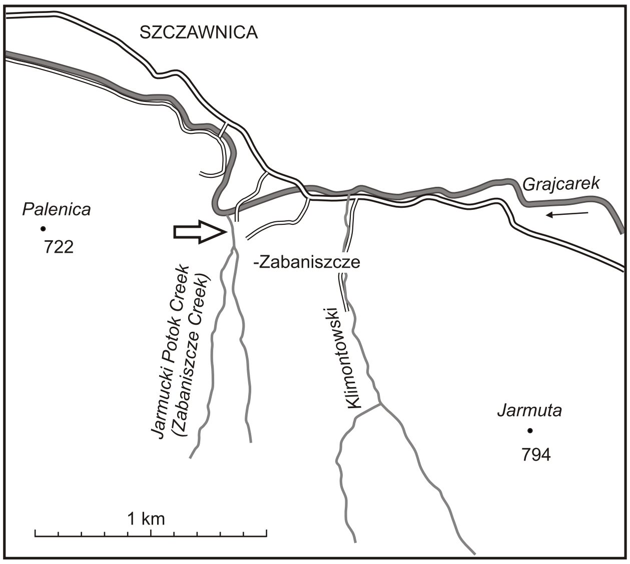

Fig. 4. Location of the section studied at Szczawnica-Zabaniszcze (arrowed)

highly weathered, pale greenish-grey, calcareous clay shale, and SzZ30B is hard, black, silicified, highly calcareous, cubic-fracturing shale; Fig. 5D, E). The Kapuśnica Formation, as on the opposite creek bank, passes into non-calcareous greenish massive clay shale with black spots and the black (manganiferous) and rusty (ferruginous) weathering coating of the Wronine Formation, which dips 40–50° SE (Fig. 5D, E). Samples SzZ31–33, representing the Wronine Formation, were collected in the following positions: SzZ31 – 5 cm from the SzZ30, just from the basal part of the Wronine Formation; SzZ32 – 60 cm from the top of the Pieniny Limestone Formation; red shale layers occur between SzZ31 and SzZ32 (Fig. 5D, E). Sample SzZ33, collected 50 cm from SzZ32, represents a calcareous greenish spotty massive shale. Starting from sample SzZ33 strata dip at a lower angle (ca. 30° SE). Farther, non-calcareous spotted shale with thin (under 1 cm) black lamina occur (SzZ34 – 70 cm from SzZ33).

Sample SzZ35 was taken 100 cm farther, from calcareous fine-splitting shale. 70 cm farther, a clear tectonic boundary occurs: the outcrop is cut at 30–40° by an overthrust of pale-grey calcareous fine-splitting shale (samples SzZ36, SzZ37 and SzZ38 were taken very close to each other from the overthrust: the first one from the NW part, two others from the SE part; Fig. 5D, F). Pale grey calcareous fine-splitting shale that occurs close to the overthrust is highly tectonized; no clear bedding is visible. Bedding is seen some 30–40 cm from the overthrust showing vertical dip (SzZ39 – 60 cm from SzZ36). Farther, at a distance of 3 m (Fig. 5G), massive greenish spotted, calcareous shale with a rusty coating (similar to the shale that occurs NW of the overthrust; SzZ40, SzZ42) overlies fine-splitting, spotted greyish calcareous shale (SzZ41, SzZ43, SzZ44). Starting from sample SzZ43, shales dip 40–50° SE. The exposure ends with a small waterfall (Fig. 5D).

There are no exposures on this creek bank for a distance of 12 m (the opposite bank is covered with slope debris derived from the Szlachtowa Formation shale and sandstones). The next exposure is a small outcrop of the Szlachtowa Formation (black calcareous muddy shale with abundant mica flakes and thin-bedded sandstones: sample SzZ45; Fig. 5D). Its strata dip 45° NW (lack of exposure between this and the previous one

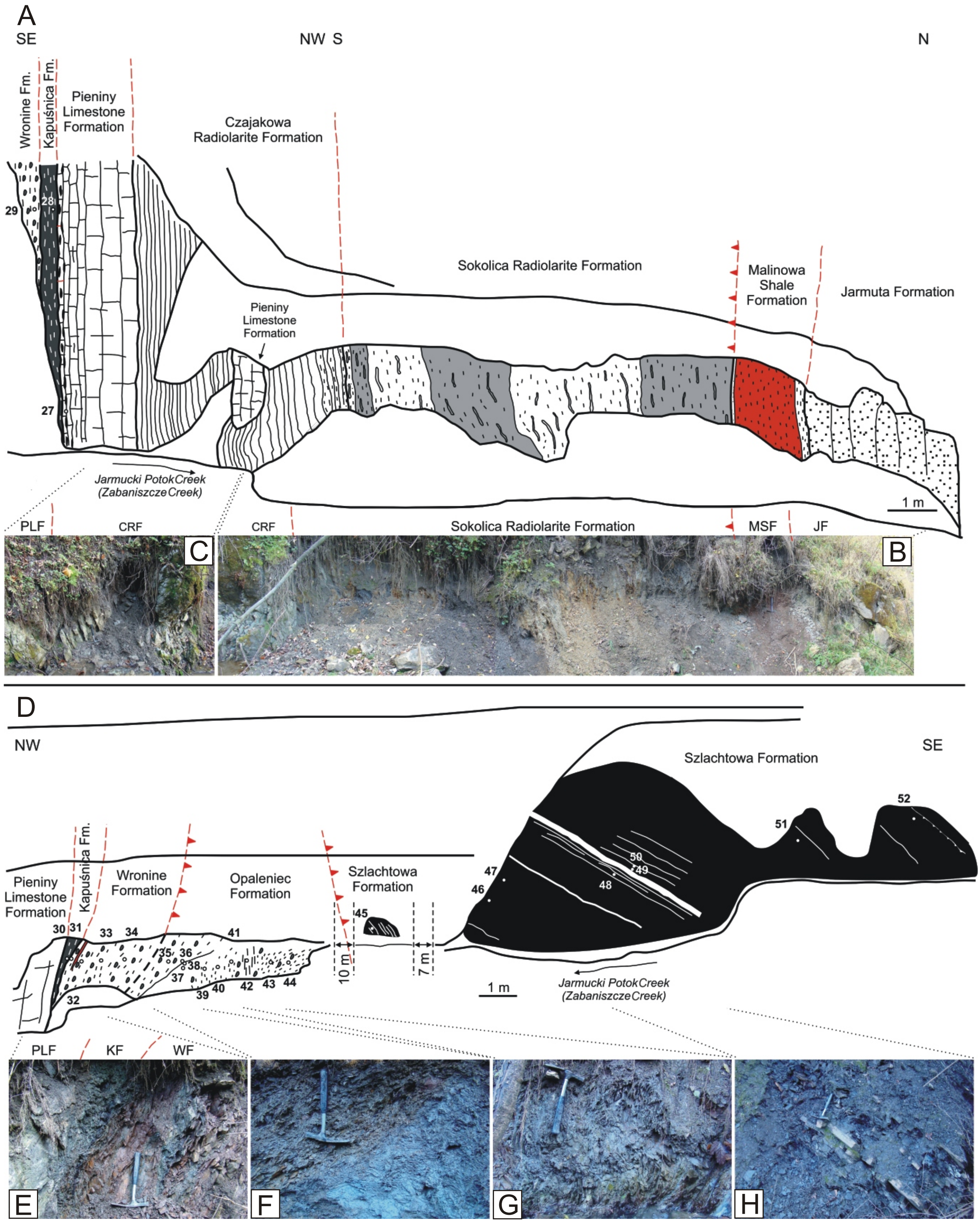

Fig. 5. Exposures of Middle Jurassic–Upper Cretaceous strata of the Grajcarek Unit at Szczawnica-Zabaniszcze

A – exposure on the western bank of the Jarmucki Potok and sample positions; **B** – photograph of the Jarmuta Formation (JF; right) and the red shale of the Malinowa Shale Formation (MSF) in tectonic contact with the Sokolica Radiolarite Formation and the Czajakowa Radiolarite Formation (CRF; left); **C** – photograph of the Czajakowa Radiolarite Formation (CRF) and the Pieniny Limestone Formation (PLF); **D** – exposure on the northeastern bank of the Jarmucki Potok (just above the exposure in A) and sample positions; **E** – photograph of the passage from the Pieniny Limestone Formation (PLF; right), tectonically squeezed Kapuśnica Formation (KF) to the spotted shale of the Wronine Formation (WR; note red shale occurrence within the latter); **F**, **G** – tectonically disturbed marly shale of the Opaleniec Formation; **H** – NW dipping strata of the Szlachtowa Formation (samples SzZ48–51 were collected near thick sandstone layer close to the hammer); B, C scales as in A; E–I – hammer as a scale (28 cm) does not allow tracing their contact, which, given the differences in dip, seems to be tectonic).

There are no exposures for a farther 8 m until a large exposure of the Szlachtowa Formation starts in the creek scarp (Fig. 5D). This lithostratigraphic unit is very well-exposed here continuously over a distance of several metres. The Szlachtowa Formation consists here of black calcareous clay and muddy shale, the latter being enriched in mica flakes. Sandstones are rare, usually thin-bedded (2–4 cm), occasionally thicker up to 20 cm (Fig. 5H). Sole marks on the bottom surfaces of sandstone layers, as well as the continuous passage of sandstone to mudstone, show that this succession lies normally, dipping 40–45° NW. Six further samples from the Szlachtowa Formation were collected (SzZ46–51; Fig. 5D). All of them represent clayey shale except for sample SzZ49 collected from a 2 cm thick mudstone just above a 20 cm sandstone layer.

METHODS

The samples were processed in the Micropalaeontological Laboratory of the Institute of Geological Sciences, Polish Academy of Sciences, Kraków. The applied standard palynological procedure included 38% hydrochloric-acid (HCl) treatment, 40% hydrofluoric-acid (HF) treatment, heavy-liquid ($ZnCl_2$ + HCl; density 2.0 $g \cdot cm^{-3}$) separation, ultrasound for 10–15 s and sieving at 10 μm on a nylon mesh. No nitric-acid (HNO_3) treatment was applied.

The quantity of rock processed was 30 g for each sample. Palynological slides were made from each sample using glycerine jelly as a mounting medium. The rock samples, palynological residues and slides are stored in the collection of the Institute of Geological Sciences, Polish Academy of Sciences, Kraków.

RESULTS

The Pieniny Limestone Formation. Sample SzZ27 collected from the top of this unit contains palynofacies dominated by black opaque phytoclasts (partly showing dark brown, translucent edges) and dinoflagellate cysts (up to 30%; however, their precise ratio is difficult to determine due to their commonly fragmentary preservation; Fig. 6) dominated by *Cerbia tabulata* and *Oligosphaeridium* spp. (Fig. 7).

The Kapuśnica Formation. Palynofacies of samples from this unit are characterized by a high ratio of sporomorphs: over 60% (mainly spores) in SzZ28 and 25% (mainly pollen grains) in SzZ30B. Dinoflagellate cyst assemblages vary between samples (Fig. 6). They are relatively rare in SzZ28; the most frequent species is *Odontochitina operculata*. Samples from the Kapuśnica Formation from the northern creek bank (SzZ30A and SzZ30B) contain assemblages dominated by *Valensiella* (mainly *V. reticulata*), which in sample SzZ30B form an acme (Fig. 8).

The Wronine Formation. Samples from this lithostratigraphic unit contain a very uniform palynofacies: it is composed almost entirely of black phytoclasts, usually with translucent edges. Cuticles are absent, whereas sporomorphs are represented by spore specimens occurring as two to three specimens per slide; they are well-preserved being dark yellow-brownish. Samples from the Wronine Formation differ slightly in various ratios of aquatic palynomorphs, and in their preservation. Sample SzZ29 yielded only two dinoflagellate cyst specimens (*Odontochitinia operculata*, ?*Hystricho-*

Lithostratigraphy	Pieniny L.F.	Kapuśnica Formation			Wronine Formation				
Taxon / Sample	SzZ27	SzZ28	SzZ30A	SzZ30B	SzZ29	SzZ31	SzZ32	SzZ33	SzZ34
Chlamydophorella sp.	x								
Pterodinium alliferum	x								
Pterodinium premnos	c	x							
Pterodinium cingulatum	x		x						
Pterodinium sp.	x		x					x	
Rhynchodiniopsis aptiana	c	x							
Tanyosphaeridium regulare	x	x							
Tanyosphaeridium sp.	x							x	
Oligosphaeridium asterigerum	x	x							
Oligosphaeridium complex	c	x		x					x
Oligosphaeridium albertense	c								
O. complex brevispinum	x								
Oligosphaeridium sp.	x			x			x		
Prolixosphaeridium parvispinum	c	c	x				x		
Ellipsodinium reticulatum	x								
Cerbia tabulata	c			x			x		
Dapsilidinium multispinosum	x	x	x	x					
Subtilisphaera sp.	x								
Spiniferites ramosus	x	x		x					
Spiniferites spp.	x	x		x				x	
Escharisphaeridia sp.	x								
Batiacasphaera spp.	x			a					
Lithodinia stoveri	x								
Kiokansium sp.	x	x	x					x	
Cometodinium habibii	x								
Mendicodinium sp.		x		x					
Odontochitina operculata		c		x	x	x	x	x	
Odontochitina imparilis		x							
Tehamadinium sp.		c							
Chytroeisphaeridia sp.		x							
Valensiella reticulata		c	a						
Druggidinium? sp.		c							
Heslertonia heslertonensis		x							
Circulodinium distinctum		x							
Gonyaulacysta? *kleithria*		x							
Gonyaulacysta sp.		x							
Diphasiosphaera stolidata		x							
Exiguisphaera plectilis		x							
Protoellipsodinium? sp.		x	x	x					
Aptea securigera		x							
Taleisphaera hydra		x							
Dapsilidinium warrenii		x						x	
Kleithriasphaeridium sp.		x							
Wallodinium krutzschi		x							
Valensiella spp.			c	A					
Circulodinium sp.			x					x	x
Cribroperidinium sp.				x					
?*Hystrichosphaeridium* ?*phoenix*					x				
Dinogymnium? sp.							a		
Surculosphaeridium? sp.								x	

Fig. 6. Dinoflagellate cyst distribution in the Pieniny Limestone Formation, the Kapuśnica Formation and the Wronine Formation at Szczawnica-Zabaniszcze

x – single to rare; c – frequent (10–50 specimens); a – abundant (over 50 specimens); A – mass occurrence (acme)

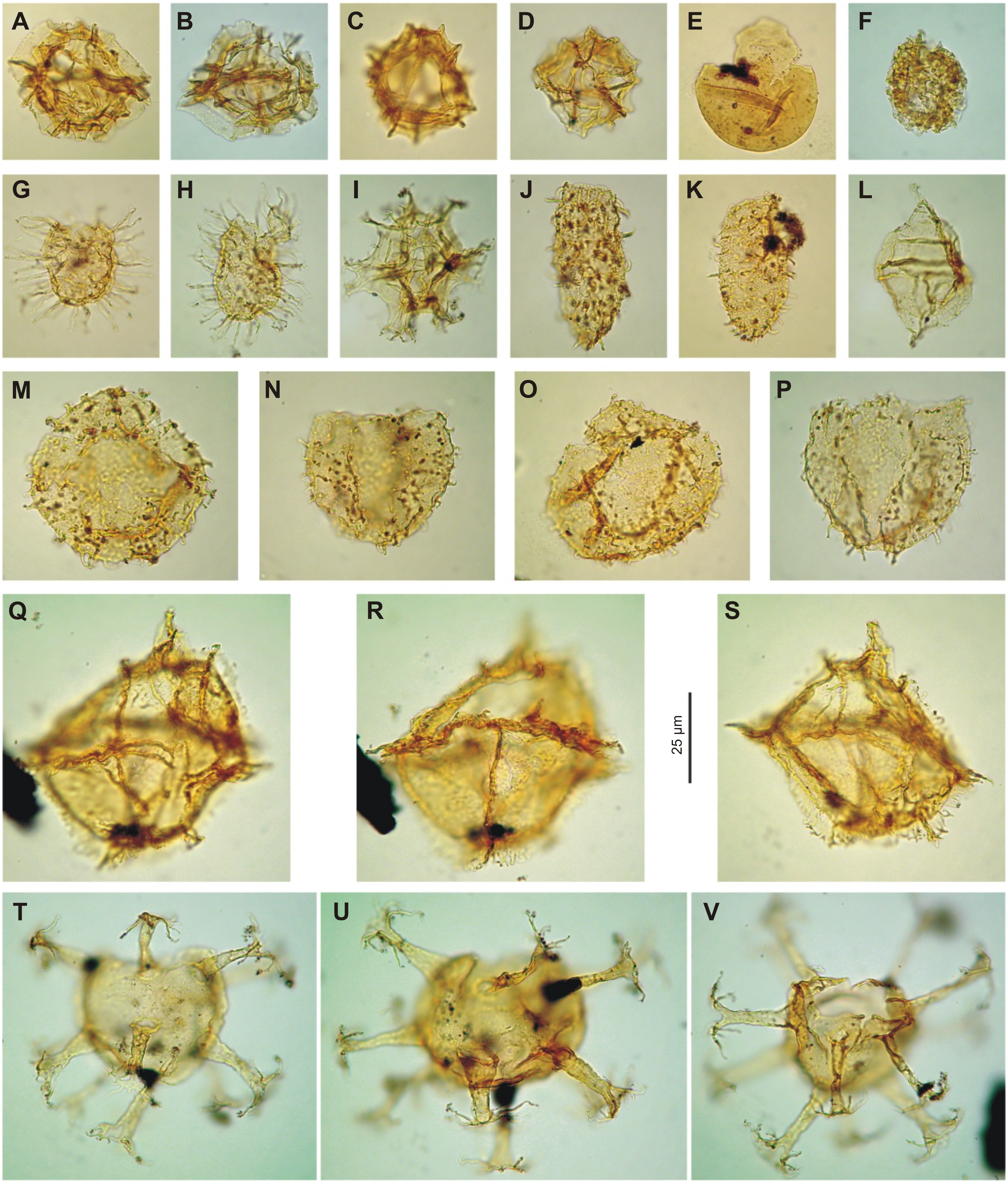

Fig. 7. Dinoflagellate cysts from the top of the Pieniny Limestone Formation at Szczawnica-Zabaniszcze (sample SzZ27)

A, **B** – *Pterodinium premnos*; **C** – *Pterodinium cingulatum*; **D** – *Pterodinium* sp.; **E** – *Escharisphaeridia* sp.; **F** – *Chlamydophorella* sp.; **G** – *Tanyosphaeridium regulare*; **H** – *Tanyosphaeridium* sp.; **I** – *Spiniferites* sp.; **J**, **K** – *Prolixosphaeridium parvispinum*; **L** – *Subtilisphaera* sp.; **M**–**P** – *Cerbia tabulata*; **Q**–**S** – *Rhynchodiniopsis aptiana* (Q, R: same specimen, various foci); **T**–**V** – *Oligosphaeridium complex*

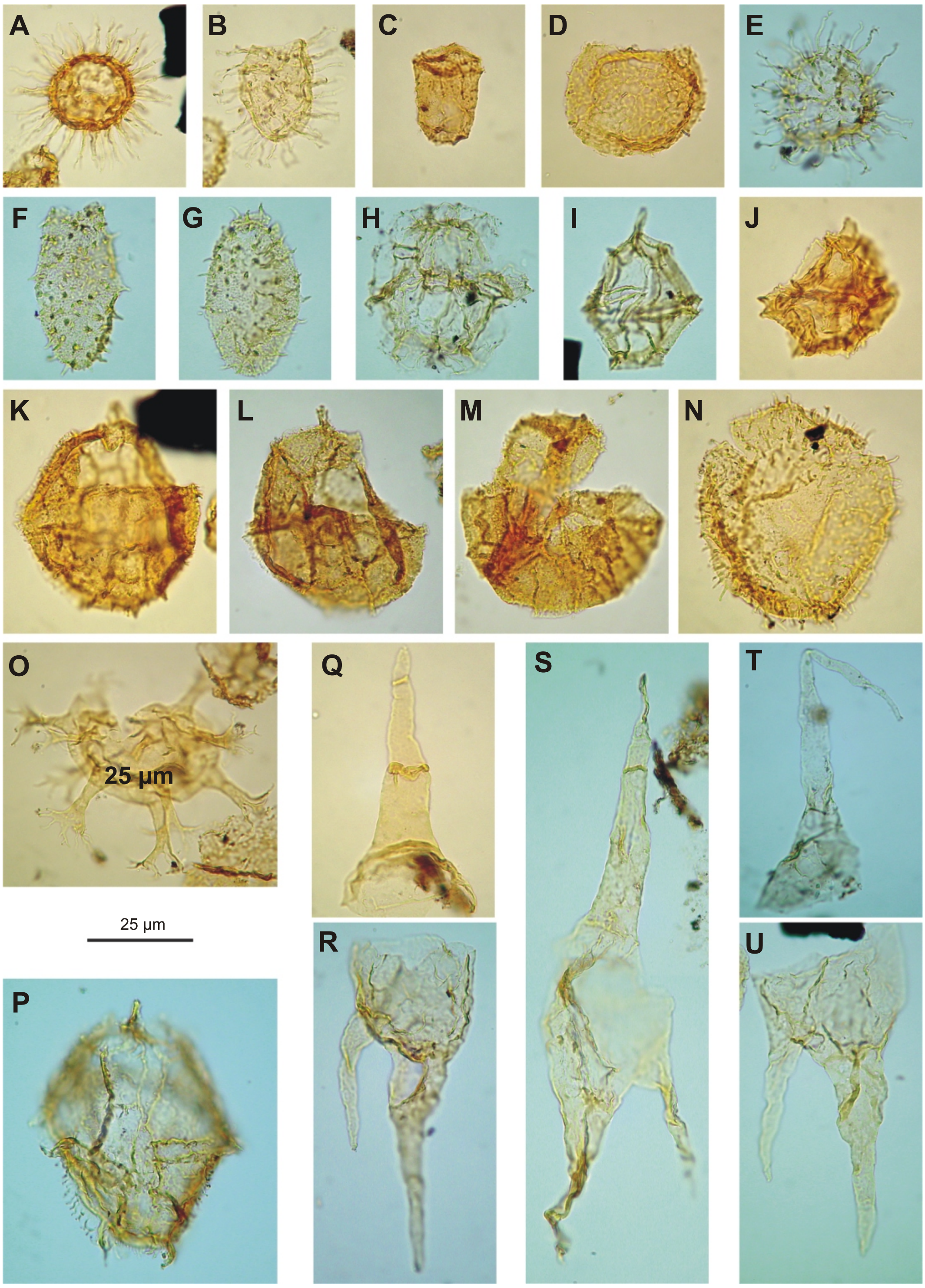

Fig. 8. Dinoflagellate cysts from the Kapuśnica Formation at Szczawnica-Zabaniszcze (sample SzZ28)

A – *Dapsilidinium multispinosum*; **B** – *Tanyosphaeridium isocalamum*; **C** – *Druggidinium*? sp.; **D** – *Valensiella reticulata*; **E** – *Kiokansium* sp.; **F**, **G** – *Prolixosphaeridium parvispinum*; **H** – *Heslertonia heslertonensis*; **I** – *Gonyaulacysta*? *kleithria*; **J** – *Gonyaulacysta* sp.; **K**–**M** – *Tehamadinium* sp.; **N** – *Circulodinium distinctum*; **O** – *Oligosphaeridium complex*; **P** – *Rhynchodiniopsis aptiana*; **Q**, **R** – *Odontochitina operculata*; **S** – *Odontochitina imparilis*; **T**, **U** – *Odontochitina operculata* *sphaeridium ?phoenix*). Both specimens are dark coloured and show traces of corrosion. Sample SzZ31 yielded a single, highly corroded specimen of *Odontochitina operculata*. Sample SzZ32 contains up to 10% of aquatic palynomorphs. Their assemblage consists of small sub-spherical forms, the majority of uncertain taxonomic affinities. Some of them represent *Pterospermella* and presumably *Cyclopsiella*-like forms. The other are dinoflagellate cysts questionably determined as *Dinogymnium* sp.; they are thin-walled, well-preserved and rather pale-coloured. This preservation contrasts with highly corroded specimens (e.g., *Cerbia tabulata*, *Prolixosphaeridium parvispinum*, *Oligosphaeridium* sp.), the maturity of which suggesting that they are reworked (Fig. 9). Sample SzZ34 contains moderately preserved, single specimens of *Circulodinium* and *Oligosphaeridium complex*.

The Opaleniec Formation. Samples collected from the further part of the exposure treated here as the Opaleniec Formation (calcareous spotted shale: SzZ35–44) yielded palynofacies characterized by a high ratio of sporomorphs (10–35%) and dinoflagellate cysts (5–30%); assemblages of the latter are generally taxonomically diverse, although slightly varying between different samples (Fig. 10). Sample SzZ35 contains dinoflagellate cysts dominated by *Chytroeisphaeridium chytroides*, *Endoscrinium asymmetricum* and *Epiplosphaera* specimens. *Lithodinia* and *Ctenidodinium* are frequent in sample SzZ37, whereas sample SzZ38 yielded dominant *Nannoceratopsis pellucida*. The latter species dominates in sample SzZ41, which as in sample SzZ38 contains palynofacies dominated by black opaque phytoclasts. A further three samples yielded gradual decrease in the palynomorph ratio, which reaches the lowest value (8–10%) in samples SzZ43 and SzZ44. Dinoflagellate cyst assemblages from these samples show some taxonomic differences: the one from SzZ42 is relatively diverse, whereas the ones from the remaining two samples are impoverished, being dominated by *Lithodinia* specimens (Fig. 11).

The Szlachtowa Formation. Samples from the Szlachtowa Formation (SzZ45–52) contain a uniform palynofacies dominated by land-derived palynodebris. Dinoflagellate cysts are generally subordinate, although their ratio oscillates between 2–15% (except for sample SzZ49, which contains almost exclusively terrestrial palynodebris; Fig. 12). Dinoflagellate cysts from all samples of the Szlachtowa Formation are fairly well-preserved. Sample SzZ45 contains an assemblage (app. 20% of palynofacies) dominated by the genus *Nannoceratopsis* (various species: *N. ?gracilis*, *N. spiculata*, *N. dictyambonis*, *N. raunsgaardii*) and thin-walled specimens of *Kallosphaeridium*. A further sample SzZ46, collected from a large exposure, yielded palynofacies dominated by palynodebris; aquatic palynomorphs include dinoflagellate cysts (up to 5%) and single specimens of foraminiferal organic linings and acritarchs. Dinoflagellate cysts are dominated by *Nannoceratopsis gracilis*; *Dissiliodinium* and *Kallosphaeridium* are subordinate. A following sample SzZ47 contains similar palynofacies but differs by a different composition of the dinoflagellate cyst assemblage, which contains a higher ratio of *Dissiliodinium* compared to less frequent *Nannoceratopsis gracilis*. Samples SzZ48 and SzZ50 (collected from just below a 20 cm thick sandstone layer, and 25 cm above it, respectively), in turn, contain assemblages (over 15%) dominated by *Nannoceratopsis* (*N. ambonis*, *N. gracilis*, *N.* sp.) – *Dissiliodinium* is represented by a few specimens only (*D. lichenoides*, *D. psilatum*); rare *Batiacasphaera* and *Kallosphaeridium* occur. A completely different palynofacies was yielded by sample SzZ49 taken from a mudstone just above the 20 cm sandstone layer: it consists almost exclusively of terrestrial palynodebris; rare, highly dispersed dinoflagellate cysts are poorly preserved, but taxonomically their assemblage resembles that from the previous sample (it consists of *Nannoceratopsis*, *Dissiliodinium*, *Kallosphaeridium* and *Batiacasphaera* specimens). A higher sample SzZ51, collected from the NE part of the exposure, yielded palynofacies with infrequent dinoflagellate cysts (2–3%). Their assemblage is similar to the ones from samples SzZ48 and SzZ50 by the presence of the same taxa, but differs by their different ratio – *Dissiliodinium lichenoides*, *D. psilatum* and *Kallosphaeridium* sp. are much more frequent than subordinate *Nannoceratopsis ambonis* and *N. gracilis*. The highest sample SzZ52 yielded, in turn, a much more frequent (10%) assemblage with common *Dissiliodinium* and *Kallosphaeridium* specimens; it is distinguished by the occurrence of *Dissiliodinium giganteum* (Fig. 13).

AGE INTERPRETATION

The presence of dinoflagellate cysts in all samples studied allows their dating (Fig. 14). In most cases their interpretation is consistent within a particular lithostratigraphic unit.

The Pieniny Limestone Formation. A single sample collected from the topmost part of this lithostratigraphic unit at Szczawnica-Zabaniszcze (Fig. 5A) yielded a Late Barremian–earliest Aptian assemblage. This interpretation is based on the co-occurrence of *Rhynchodiniopsis aptiana*, and *Cerbia tabulata*. According to Stover et al. (1996) *Cerbia tabulata* appeared during the late Early Barremian–Aptian. *Rhynchodiniopsis aptiana*, in turn, has stratigraphical range in the Tethyan Realm limited to the latest Hauterivian–earliest Aptian (Torricelli, 2000). A similar age was inferred by E. Gedl (2007) for the uppermost part of the Pieniny Limestone Formation exposed at the bank of the Grajcarek Creek several tens of metres from this site.

The Kapuśnica Formation. Sample SzZ28 collected from the most basal part of the unit (Fig. 5A) contains *Rhynchodiniopsis aptiana* but lacks *Cerbia tabulata*. This may indicate an earliest Aptian age. The other species from this sample, such as *Diphasosphaera stolidata*, *Heslertonia heslertonensis*, *Pterodinium premnos*, *Gonyaulacysta? kleithria*, have their highest occurrences in the Lower Aptian (Duxbury, 1983). Samples SzZ30A and SzZ30B contain species non-diagnostic of age. The only noticeable feature is the frequent occurrence of *Valensiella reticulata*.

The Wronine Formation. Non-calcareous spotted shale exposed just above (in a stratigraphical sense) the Kapuśnica Formation (Fig. 14) yielded infrequent mid-Cretaceous dinoflagellate cysts such as *Odontochitina operculata* (Barremian–Early Maastrichtian; Stover et al., 1996). Precise dating of their assemblages is thus impossible. *Cerbia tabulata* from sample SzZ32 (as in sample SzZ30B) is likely reworked. E. Gedl (2007) described, from the Wronine Formation exposed at the bank of the Grajcarek Creek, various assemblages, characteristic of the Aptian and Albian, and suggesting either tectonic repetition of the section studied or reworking.

The Opaleniec Formation. This lithostratigraphic unit was distinguished in the section studied by the presence of taxonomically consistent Jurassic dinoflagellate cysts (samples SzZ35-44; Fig. 5D). Most of the species determined appeared for the first time in the Late Bajocian: all samples contain *Ctenidodinium combazii*, *Endoscrinium asymmetricum* and *Chytroeisphaeridium chytroides*; *Nannoceratopsis pellucida* was found in samples SzZ38–43 and *Dichadogonyaulax*

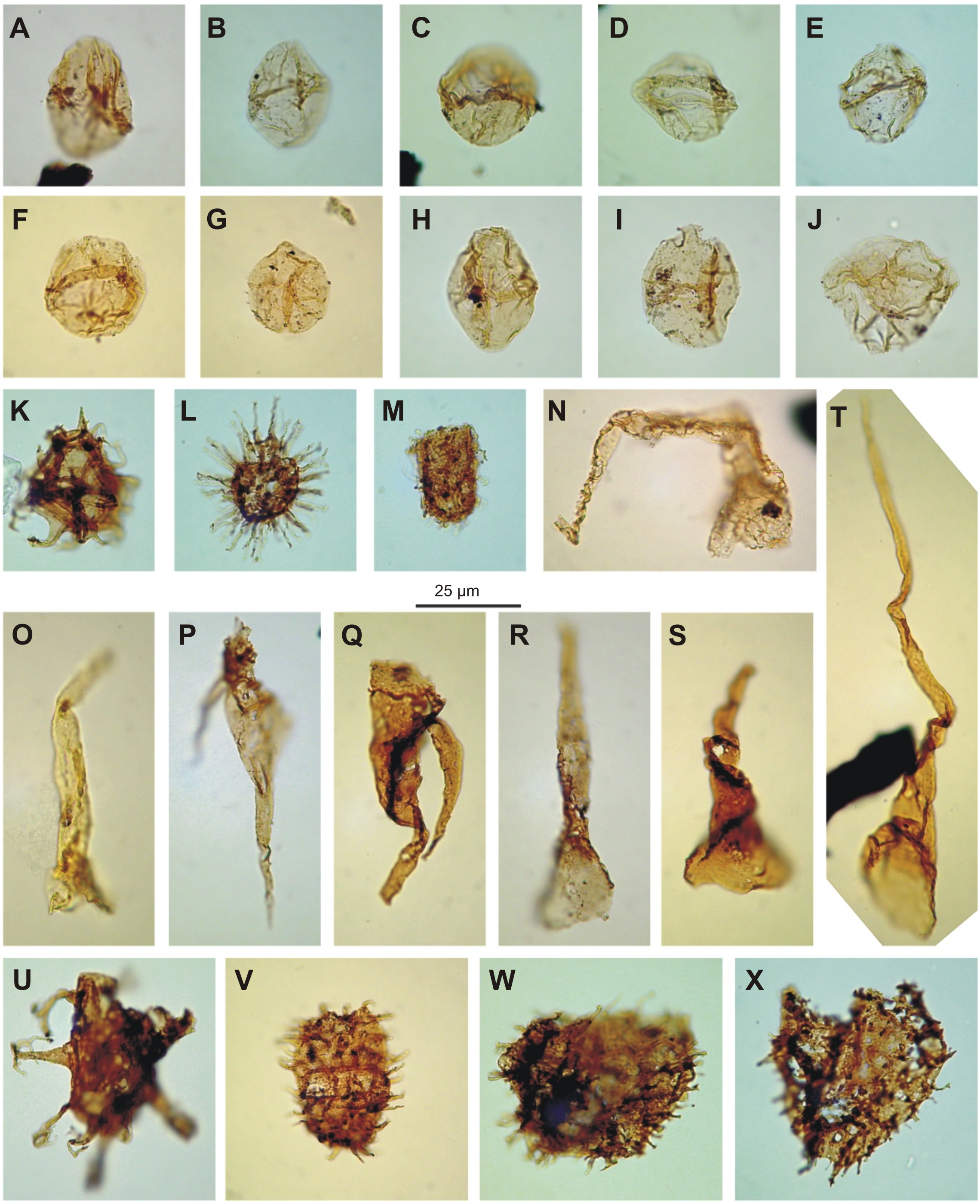

Fig. 9. Dinoflagellate cysts from the Wronine Formation at Szczawnica-Zabaniszcze (samples SzZ29: O; SzZ31: N; SzZ32: A–J, U–X; SzZ33: K–M, T)

A–**J** – *Dinogymnium*? sp.; **K** – *Spiniferites* sp.; **L** – *Dapsilidinium warrenii*; **M** – *Tanyosphaeridium* sp.; **N**–**T** – *Odontochitina operculata*; **U** – *Oligosphaeridium* sp.; **V** – *Prolixosphaeridium parvispinum*; **W**, **X** – *Cerbia tabulata*

sellwoodii occurs in two samples SzZ36 and SzZ37 (e.g., Feist-Burkhardt and Monteil, 1997; Bucefalo Palliani and Riding, 1997). However, the presence of a few species, namely *Atopodinium prostatum*, *Sirmiodiniopsis orbis* and *Dingodinium minutum* may indicate a younger, Bathonian age for the Opaleniec Formation studied (see e.g., Feist-Burkhardt and Wille, 1992). An even younger, Callovian, age may be suggested by the presence of the chorate species *Systematophora penicillata* and *Surculosphaeridium*? *vestitum* found in most samples. These species are known from Callovian and younger strata (e.g., Prauss, 1989; Feist-Burkhardt and Wille, 1992). *Atopodinium* sp. A (a morphological variety of *Atopodinium*) was illustrated by Feist-Burkhardt and Wille (1992: pl. 3.3) as an Early Callovian species.

The assemblage found during the present study in the Opaleniec Formation can be correlated with the youngest one distinguished among three assemblages from this lithostratigraphic unit in the Grajcarek Succession by the author

Lithostratigraphy	Opaleniec Formation									
Taxon \ Sample	SzZ35	SzZ36	SzZ37	SzZ38	SzZ39	SzZ40	SzZ41	SzZ42	SzZ43	SzZ44
Endoscrinium asymmetricum	c	x	x	x	x	x	x	x	x	x
Epiplosphaera spp.	c	x	x	x	x	x	x	x	x	x
Chytroeisphaeridium chytroides	c	x	x	x	x	x	x	x	x	x
Chytroeisphaeridium sp.	x									
Escharisphaeridia sp.	x	x	x							
Surculosphaeridium? vestitum	x	x	x		x	c		x	x	
Systematophora penicillata	x	x	x		x	x	x	x	x	
Batiacasphaera spp.	x	x	x	x	x		x			
Ctenidodinium combazii	x	x	c	x	c	x	c	x	x	x
Ctenidodinium sp.	x									
Polygonifera sp.	x	x				x		x		
Endoscrinium sp.	x	x	x					x		
Tubotuberella eisenackii	x		x			x				
Epiplosphaera? sp.	x								x	
Cleistosphaeridium iaculigerum	x				x		x	x		
Sentusidinium spp.	x	x	x		x		x	x	x	
Lithodinia jurassica		x	x							
Lithodinia caytonensis		x	c	x	c	c		c	c	c
Atopodinium sp. A		x	x	x	x	x		x		
Chytroeisphaeridium cerastas		x	x							
Cribroperidinium sp.		x								
Dichadogonyaulax sellwoodii		x	x							
Batiacasphaera? sp.		x		x						
Gonyaulacysta jurassica adecta		x								
Pareodinia sp.		x								
Chlamydophorella sp.		x	x	x						
Dingodinium minutum		x	x		x			x		
Kallosphaeridium? sp.		x			x				x	
Tubotuberella dangeardi		x								
Tubotuberella apatela		x								
Gonyaulacysta jurassica		x	x	x						
Tubotuberella egemeni		x								
Systematophora ?orbifera		x	x					x	x	
Sirmiodiniopsis orbis		x	x		x					
Atopodinium prostatum			x							
Nannoceratopsis pellucida				a	x	x	a	x	x	
Leptodinium mirabile				x	x					
Wanaea sp.					x					
Ctenidodinium continuum						x				
Gonyaulacysta pectinigera							x			
Leptodinium sp.							x			
Apteodinium sp.								x		

Fig. 10. Dinoflagellate cyst distribution in the Opaleniec Formation at Szczawnica-Zabaniszcze

Explanations as in Figure 6

(Gedl, 2008d). An Upper Bathonian assemblage with infrequent *Ctenidodinium combazii*, and *Atopodinium polygonale* and *Dingodinium minutum* was found in the upper part of the Opaleniec Formation at Sztolnia, Krupianka and Hulina Mt. *Atopodinium* sp. A (as *A. prostatum*) was found at Sztolnia (Szt28). However, it cannot be excluded that these assemblages are Callovian, because as with the one from this study, they contain chorate species of *Systematophora* and *Surculosphaeridium* (due to poor preservation determined by Gedl, 2008d to generic level only).

The Szlachtowa Formation. All eight samples from this lithostratigraphic unit contain dinoflagellate cysts. Their age-interpretation confirms observations from the exposure suggesting normal attitude of the strata (they dip at an angle of 40–50° north-west), which means that the oldest part of the Szlachtowa Formation is exposed in the northwestern part (sample SzZ45), getting younger to the south-east (Fig. 5D).

The assemblage from sample SzZ45 contains species which commonly appeared during the latest Toarcian through the earliest Bajocian: *Moesiodinium raileanui*, *Nannoceratopsis ambonis*, *Nannoceratopsis dictyambonis*, *Nannoceratopsis raunsgaardii*, *Phallocysta elongata*. But there are no species that appeared during the Middle–Late Aalenian (e.g., *Dissiliodinium* spp., *Carpathodinium* sp. A), which occur in stratigraphically younger part of the exposure. Another stratigraphically important taxon is *Hyalosphaera*? sp. found in SzZ45 only. *Hyalosphaera ephemera* is known from the Upper Toarcian–Lower Aalenian (levesquei-opalinum; Prauss, 1989). Therefore, an Aalenian, presumably an Early Aalenian age can be suggested for northernmost part of the Szlachtowa Formation (Fig. 14). However, an older, latest Toarcian age cannot be excluded since the assemblage from sample SzZ45 lacks *Nannoceratopsis evae*, a species known from the Aalenian–Bajocian. On the other hand, this species is relatively rare in other outcrops of the Szlachtowa Formation (Gedl, 2008d), and in the present material only a single specimen was found in a younger sample SzZ52. An Early Toarcian age for this sample might be also supported by the presence of *Valvaeodinium* cf. *koessianum*. This was described by the author from the Szlachtowa Formation at Krzonowe (sample KrzS1) and interpreted as latest Toarcian–Aalenian (Gedl, 2008d). Wille and Gocht (1979) described similar morphotypes from the Pliensbachian-Lower Toarcian of SW Germany.

The higher part of the Szlachtowa Formation, which forms continuous outcrop (samples SzZ46–51; Fig. 14) yielded assemblages, which might be interpreted as Middle–Late Aalenian. This interpretation is based on the presence of frequent *Dissiliodinium* specimens (mainly *D. lichenoides*), and absence of typical Early Bajocian (*Dissiliodinium giganteum*) or younger taxa (e.g., *Ctenidodinium* spp.) known from younger parts of the Szlachtowa Formation (e.g., Gedl, 2008d).

Dissiliodinium giganteum has its lowest occurrence in the section studied in the highest sample SzZ52 (Fig. 14). This species, known to have appeared for the first time during the earliest Bajocian (e.g., Feist-Burkhardt, 1990; Feist-Burkhardt and Monteil, 2001), is widespread in the middle part of the Szlachtowa Formation of the Pieniny Klippen Belt in Poland (Gedl, 2008d; Barski et al., 2012). Its presence in the topmost part of the exposure studied points to a lowermost Bajocian age.

The dinoflagellate cyst assemblages described above, and their age-interpretation, allow correlation with previously described assemblages from other exposures of the Szlachtowa Formation in the Pieniny Klippen Belt. The oldest assemblage from sample SzZ45 can be correlated with the Phallocysta elongata Dinoflagellate Cyst Zone of Gedl (2008d) found in the

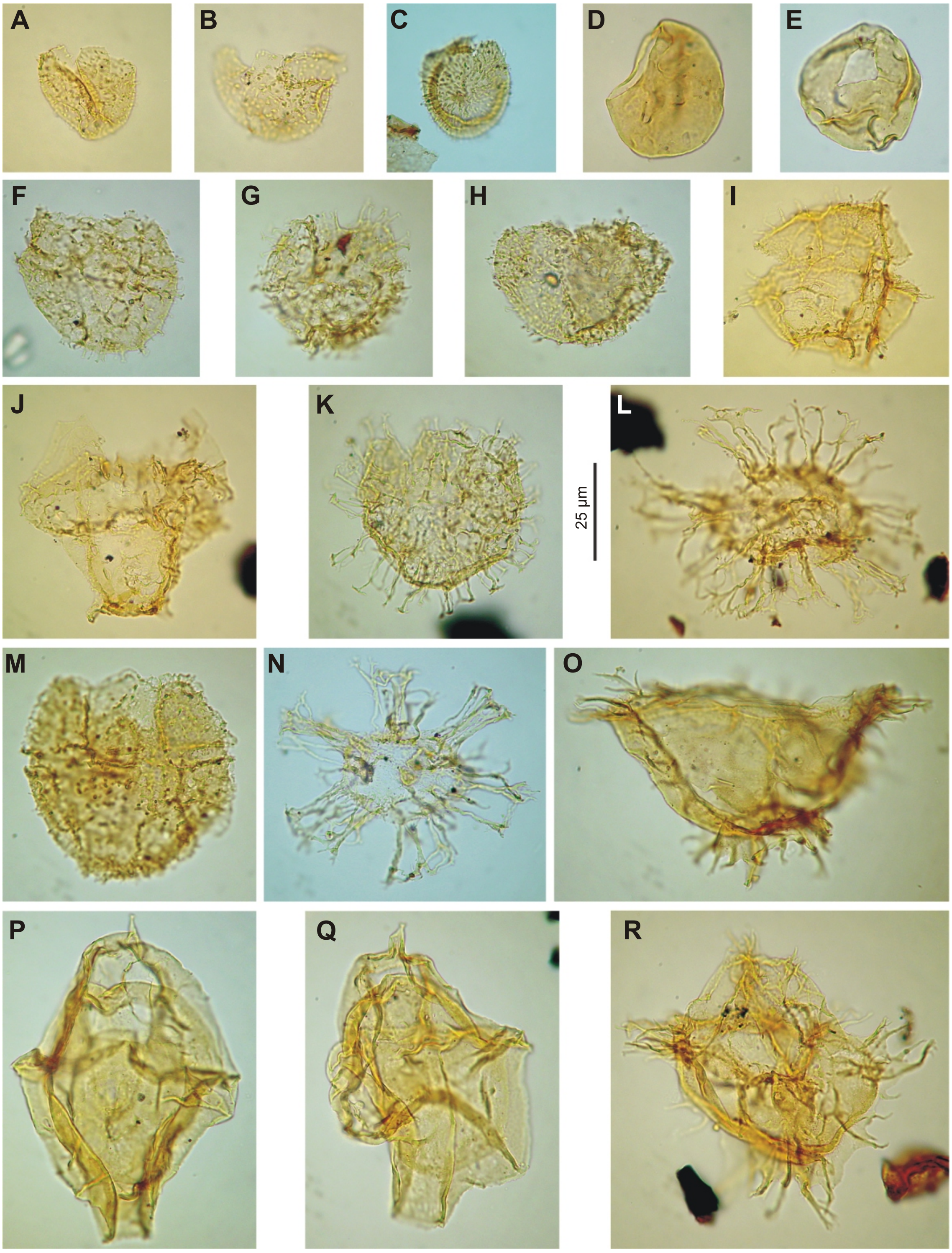

Fig. 11. Dinoflagellate cysts from the Opaleniec Formation at Szczawnica-Zabaniszcze (SzZ36: A–K, M, O, P; SzZ37: L, N, Q, R)

A–C – *Sentusidinium* spp.; **D**, **E** – *Chytroeisphaeridium chytroeides*; **F**, **G** – *Epiplosphaera* spp.; **H** – *Sentusidinium* sp.; **I –** *Dichadogonyaulax sellwoodii*; **J** – *Atopodinium prostatum*; **K** – *Surculosphaeridium*? *vestitum*; **L** – *Systematophora penicillata*; **M** – *Lithodinia caytonensis*; **N** – *Systematophora* ?*orbifera*; **O** – *Ctenidodinium combazii*; **P** – *Endoscrinium luridum*; **Q** – *Endoscrinium asymmetricum*; **R** – *Ctenidodinium combazii*

Lithostratigraphy	Szlachtowa Formation							
Taxon \ Sample	SzZ45	SzZ46	SzZ47	SzZ48	SzZ49	SzZ50	SzZ51	SzZ52
Batiacasphaera spp.	x	x		x	x	x	x	x
Moesiodinium raileanui	x						x	x
Kallosphaeridium? sp.	x							
Nannoceratopsis ambonis	a			x		c		x
Nannoceratopsis spiculata	x							
Kallosphaeridium praussii	c	x	x	x		x		x
Kalyptea stegasta	x							
Hyalosphaera? sp.	x							
Nannoceratopsis raunsgaardii	x							
Kallosphaeridium spp.	x	x	x	x			x	x
Nannoceratopsis dictyambonis	x					x		
Phallocysta elongata	x	x	x			x		
Pareodinia sp.	x							
Nannoceratopsis sp.	x	x	x	x		x	x	
Valvaeodinium cf. *koessianum*	x						?	
Nannoceratopsis gracilis	x	a	c	a	x	c	x	x
Nannoceratopsis sp. A	x	x	x	x		x	x	
Escharisphaeridia sp.	x			x	x		x	
Dodekovia? sp.	x	x						
Valvaeodinium? sp.	x							
Mendicodinium spp.	x		x					
Korystocysta sp.	x							
Nannoceratopsis senex	x	x				x		
Dissiliodinium lichenoides		c	c	x	x	x	x	x
Dissiliodinium psilatum		c	x	x		x	x	
Dissiliodinium spp.		x	x	x		x	x	c
Dissiliodinium giganteum								x
Valveodinium armatum								x
Carpathodinium sp. A								x
Nannoceratopsis evae								x
Gonyaulacysta? sp.								x

Fig. 12. Dinoflagellate cyst distribution in the Szlachtowa Formation at Szczawnica-Zabaniszcze

? – questionable occurrence; other explanations as in Figure 6

Szlachtowa Formation at Krzonowe (sample KrzS1). Younger samples with *Dissiliodinium* spp. (SzZ46–51) can be correlated with the Upper Aalenian Dissiliodinium lichenoides Dinoflagellate Cyst Zone of Gedl (2008d), which has been distinguished in the Szlachtowa Formation exposed at Krzonowe (sample KrzS2), Szczawnica-Zabaniszcze (exposure at the Grajcarek bank; sample SzRz6), and Podubocze (Branisko Succession). The topmost part of the exposure studied, in turn, can be correlated with the Lower Bajocian Dissiliodinium giganteum Dinoflagellate Cyst Zone of Gedl (2008d). This zone has been distinguished at several sites within the Szlachtowa Formation of the Grajcarek and Branisko successions: Krupianka, Sztolnia, Hałuszowa, Potok Kręty, Podubocze I and Podubocze II (Gedl, 2008d).

DISCUSSION

The data presented in this paper undoubtedly show a Jurassic age for the Szlachtowa Formation. They agree well with results of previous micro- and macrofossil studies from this unit in Polish (e.g., Gąsiorowski, 1962; Birkenmajer and Pazdro, 1963, 1968; Błaszyk, 1968; Birkenmajer et al., 1970; Pugaczewska, 1971; Birkenmajer and Myczyński, 1977; Pazdro, 1979; Głuchowski et al., 1983; Głuchowski, 1987; Dudziak, 1986; Krawczyk et al., 1992; Birkenmajer and Tyszka, 1996; Birkenmajer and Gedl, 2004, 2007; Gedl, 2007, 2008d; Barski et al., 2012) and Slovak (Barski et al., 2012) sectors of the Pieniny Klippen Belt. In the light of these data, the rened suggestions of a Cretaceous age for the Szlachtowa Formation by Oszczypko et al. (2012) is untenable (see also Oszczypko et al., 2004; Birkenmajer et al., 2008; Gedl, 2008a, b, c; Oszczypko et al., 2008). Below, a critical discussion of their thesis is presented.

Oszczypko et al. (2012) suggest that the Szlachtowa Formation (the so-called "black flysch") and the Opaleniec Formation are of Cretaceous age because they are in contact in some outcrops with Cretaceous, mainly Upper Cretaceous units (see also Książkiewicz, 1972). This phenomenon, however, cannot serve as a direct age-indicator in such a tectonically complicated structure as is the Pieniny Klippen Belt, especially given that some outcrops of the Szlachtowa and Opaleniec formations occur in contact with Jurassic units (e.g., Podubocze, Krupianka Creek; see e.g., Birkenmajer, 1979: p. 206, fig. 99B; Gedl, 2008d). To support the thesis of a Cretaceous age for the deposits in question, Oszczypko et al. (2012) present partly new, partly restudied microfaunal data, which in their opinion support this theory. In my opinion, however, their interpretation is erroneous, being based on material that does not represent the Szlachtowa and Opaleniec formations, or that is commonly contaminated.

Oszczypko et al. (2012: p. 424) conclude a Cretaceous age for these units on the basis of taxonomically impoverished foraminifera assemblages of a few samples only (most of their 71 samples studied appeared to be barren or to contain forms non-diagnostic of age), which frequently show features of contamination. Moreover, the samples which yielded these assemblages are usually collected from atypical lithofacies (e.g., red shale, radiolarite) or from deposits of uncertain superposition, usually from tectonic contacts or highly tectonized sections. Three samples which, according to Oszczypko et al. (2012), represent the Szlachtowa Formation exposed at Szczawnica-Zabaniszcze, were taken from contact intervals with the Wronine Formation (samples WP489, 9/10) and the Malinowa Shale Formation (sample WP490/490a; Oszczypko et al., 2012: fig. 4C, D). In fact, a contact between the Wronine Formation and the Szlachtowa Formation does not exist at the site studied. The Wronine Formation is in contact with the lithologically very similar Opaleniec Formation; passage of the latter to the Szlachtowa Formation is not exposed at all (Fig. 5D). Therefore, it may be suggested that the "productive" sample WP490/490a was collected from the Cretaceous Wronine Formation, but not from the Szlachtowa Formation, despite its wide extent in this outcrop (Fig. 5D).

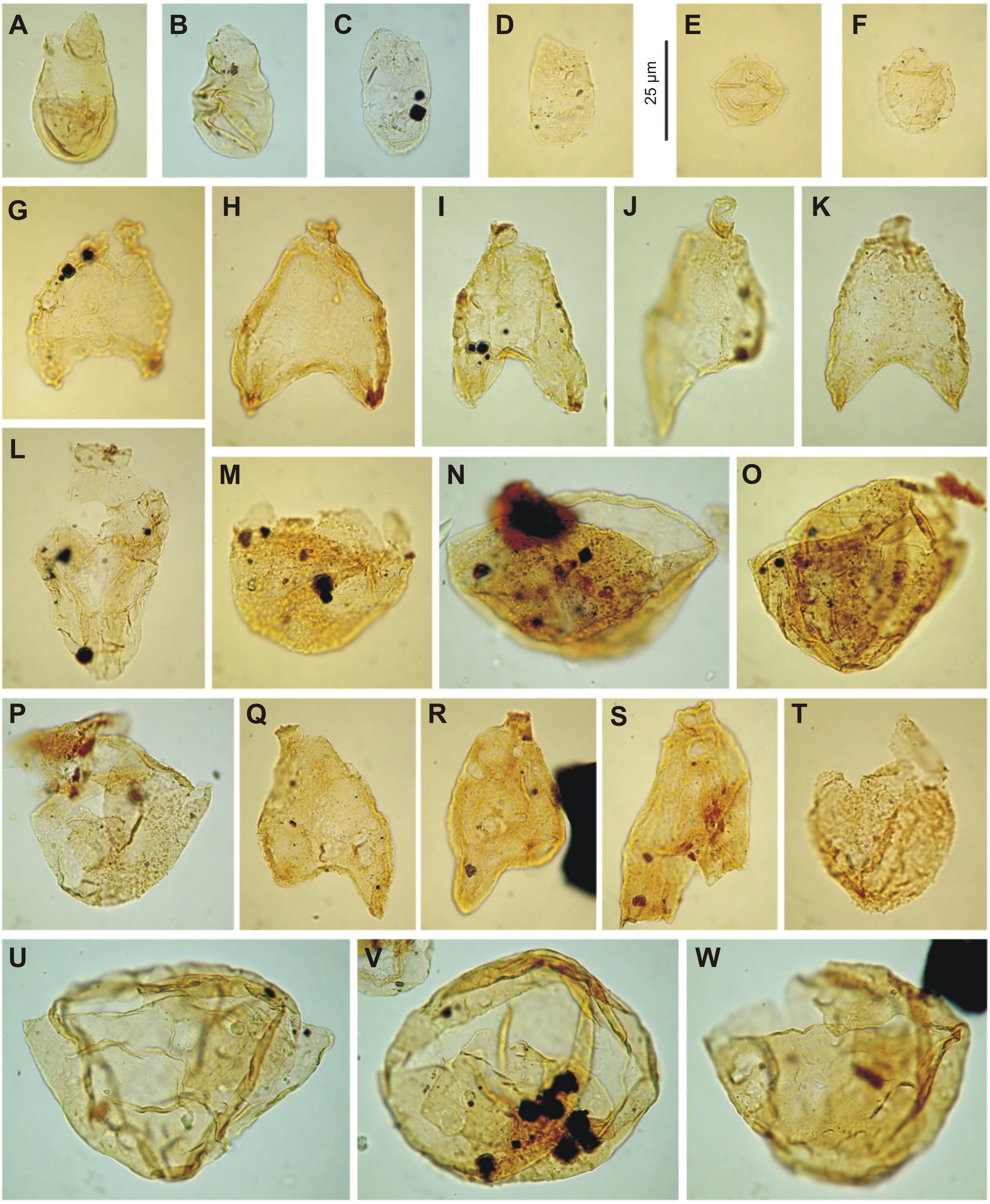

Fig. 13. Dinoflagellate cysts from the Szlachtowa Formation at Szczawnica-Zabaniszcze (SzZ45: A–M; SzZ47: N–P; SzZ48: Q–T; SzZ52: U–W)

A, **B** – *Phallocysta elongata*; **C**, **D** – *Valvaeodinium* cf. *koessianum*; **E**, **F** – *Moesiodinium raileanui*; **G** – *Nannoceratopsis dictyambonis*; **H** – *Nannoceratopsis ambonis*; **I**, **J** – *Nannoceratopsis gracilis*; **K** – *Nannoceratopsis spiculata*; **L** – *Kallosphaeridium praussii*; **M** – *Batiacasphaera* sp.; **N**–**P** – *Dissiliodinium lichenoides*; **Q**, **R** – *Nannoceratopsis gracilis*; **S** – *Nannoceratopsis* sp.; **T** – *Kallosphaeridium* sp.; **U**–**W** – *Dissiliodinium giganteum*

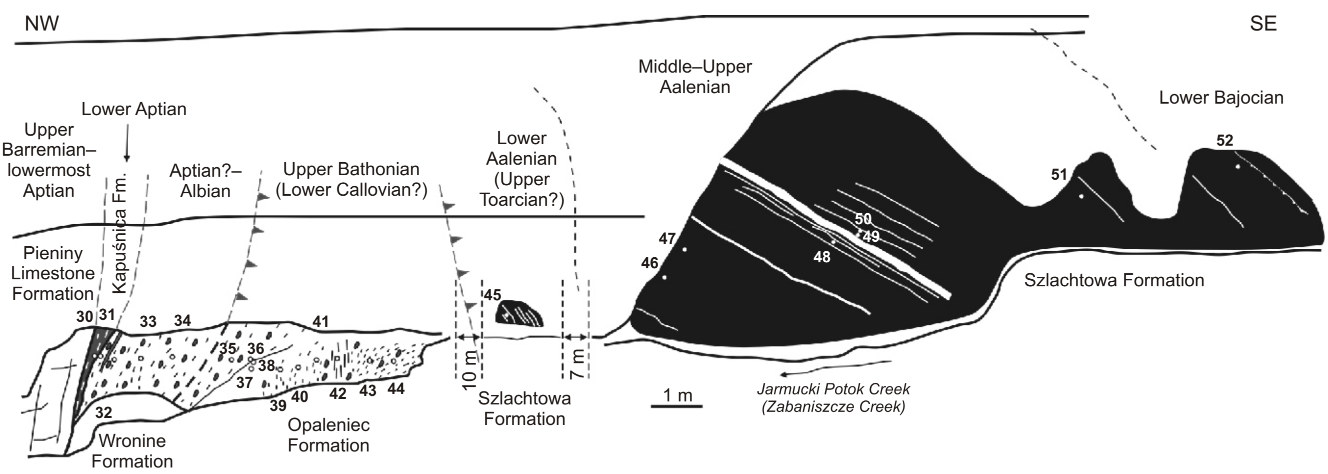

Fig. 14. Age interpretation of the strata of the Grajcarek Succession exposed at Szczawnica-Zabaniszcze

Similarly, an erroneous sampling procedure can be suggested for three samples with Cretaceous foraminifera collected from the southernmost part of exposure known as the "small waterfall" (Sztolnia A; 3/06 and 16/06: Opaleniec Formation, and 17/06: Szlachtowa Formation according to Oszczypko et al., 2012). This part of exposure shows a complicated, poorly exposed structure: the Szlachtowa Formation contacts to the south with: the Cretaceous Hulina Formation (according to Gedl, 2008a: fig. 2B1; see also Birkenmajer and Gedl, 2004: fig. 4; Birkenmajer et al., 2008: fig. 5A), the Cretaceous Malinowa Shale Formation and Jaworki Marl Formation (according to Oszczypko et al., 2004: fig. 7) or the Opaleniec Formation (according to Oszczypko et al., 2012: fig. 5).

Among samples with Cretaceous foraminifera from exposures along the Grajcarek Creek, and attributed by Oszczypko et al. (2012) to the Szlachtowa Formation: samples WP357/2–3 are dark grey shales with red intercalations (Grajcarek–Szlachtowa), sample WP370 is red shale, and sample WP943 is spotted limestone (both samples from the junction of the Sielski Creek with the Grajcarek Creek; Oszczypko et al. (2012: p. 432, fig. 2). Neither red shale nor spotted limestone are typical Szlachtowa Formation lithofacies (Birkenmajer, 1977: p. 27). Although Krawczyk and Słomka (1986, p. 55, fig. 11) noted a red shale occurrence in one section of the Szlachtowa Formation, where this lithology appears as small lenses (up to several centimetres long) and thin laminas within a 85 cm thick black shale layer, but they suggested that this exceptional lithology may be a result of siderite alteration (Krawczyk and Słomka, 1986: p. 100). It is symptomatic that of eight samples collected by Oszczypko et al. (2012) from Grajcarek Creek exposures and attributed to the Szlachtowa Formation, seven are either dark shale with intercalations of red shale (WP357) or green radiolarite with intercalations of red shale overlain by spotted limestone (samples WP370–375 and WP943; Oszczypko et al., 2012, p. 424), despite the Szlachtowa Formation in this area being well exposed and including easily accessible exposures that show typical developments of this lithostratigraphic unit.

Contamination is one of the explanations of the different age-interpretations of the Szlachtowa and Opaleniec formations. Birkenmajer and Pazdro (1968) suggested that Cretaceous foraminifera described by Sikora (1962) in the Szlachtowa Formation exposures from the upper course of the Sztolnia Creek (sections: Sztolnia A and Sztolnia B *sensu* Oszczypko et al., 2012) were a result of contamination (they found dark-coloured agglutinated forms in fresh rock, whereas Late Cretaceous pale-coloured planktonic foraminifera appeared in the washed residuum; the latter were interpreted as washed-out from the Upper Cretaceous Malinowa Shale Formation; see also Birkenmajer, 1977: p. 25–27). Such an explanation was rejected by Oszczypko et al. (2004, 2008, 2012). However, Oszczypko et al. (2012) are not consistent in this matter in the case of their own material: Albian–Turonian *Plectorecurvoides alternans* in a "Lower Cretaceous" section of the Szlachtowa Formation is regarded by Oszczypko et al. (2012: p. 434) as "… specific contamination due to tectonic or other phenomena...". The authors do not explain what they understand by "other phenomena". In some samples treated by Oszczypko et al. (2012) as collected from the Szlachtowa and Opaleniec formations in the upper course of the Sztolnia Creek, they found very rare Early Cretaceous agglutinated, poorly preserved foraminifera (treated as age-diagnostic), associated with Late Cretaceous planktonic species of different colouration. An even more pronounced example of contamination in the material discussed is the occurrence of Paleogene foraminifera reported from the "Opaleniec Formation" in the upper course of the Sztolnia Creek.

An outstanding feature of Blaicher's (1973) foraminifera assemblages mentioned by Oszczypko et al. (2012) is the common mixture of specimens of various ages as in the case of the "Opaleniec" Formation samples from Sztolnia A section, which consist of mixed Jurassic, Early–Late Cretaceous and Paleogene species (Oszczypko et al., 2012: p. 433). Such material has limited value for stratigraphical evaluation. Foraminifera assemblages described by Blaicher (1973) show a characteristic dualism: the ones from the Sztolnia Beds (i.e. the Szlachtowa Formation) are commonly impoverished and poorly preserved, and samples are frequently barren; this contrasts with rich and better preserved assemblages from the Wronine and Hulina formations – a similar pattern characterizes the results of Oszczypko et al. (2012) who reported barren samples from the Szlachtowa Formation, whereas foraminifera have been found in samples from tectonic contacts with the former Cretaceous lithostratigraphic units, or in deposits which, in my opinion, do not represent the deposits in question.

Providing another argument for a Cretaceous age for the Szlachtowa Formation Oszczypko et al. (2012: p. 413) refer to the interpretation of Plašienka et al. (2012: p. 30, fig. 8) who questionably correlated the Szlachtowa Formation from the Jar-1 borehole (Jarabina vicinity, Slovakia) with Albian age. But Oszczypko et al. (2012) do not say that this correlation was not

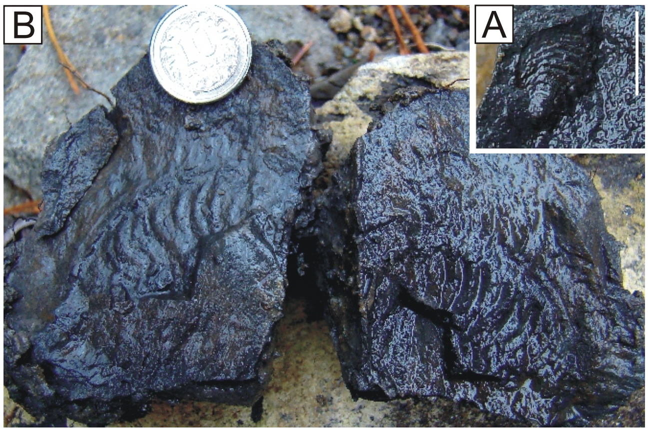

Fig. 15A – Bivalve *Bositra buchi* (scale bar = 4 mm); B – Aalenian ammonite *Brasilia* (*Brasilia*) sp. (B; coin diameter = 16.5 mm) from the Szlachtowa Formation exposed near Jarabina (Slovakia; found by Š. Józsa and D. Plašienka, respectively, during fieldwork in Autumn 2012)

supported by micropalaeontological data. In fact, the Szlachtowa Formation from this borehole contains exclusively Jurassic dinoflagellate cysts (Aalenian–Early Bathonian). Moreover, the Szlachtowa Formation exposed near Jarabina yielded macrofossils: the bivalve *Bositra buchi* (Fig. 15A) and ammonite *Brasilia* (*Brasilia*) sp. (Fig. 15B); the latter points to an Aalenian age (determined by J. Schlögl).

Oszczypko et al. (2012: p. 436) explain the presence of abundant Middle Jurassic fossils in the Szlachtowa Formation by redeposition during erosion of the Czorsztyn Ridge throughout the Aptian–Albian transition. But there is no reasonable explanation given why these "reworked" fossils represent a relatively narrow time interval (Middle Jurassic, mainly Aalenian–Bajocian: e.g., Švábenická *in* Oszczypko et al., 2004; Gedl, 2008d; Barski et al., 2012). Moreover, Oszczypko et al. (2012) do not explain why the Szlachtowa Formation contains no traces of typical Upper Jurassic–Lower Cretaceous lithologies (see e.g., Krawczyk and Słomka, 1986, 1987; Krawczyk et al., 1987); they also do not explain how the paper-thin shells of *Bositra buchi* could be reworked (present in the Szlachtowa Formation, they form a filamentous microfacies in the Opaleniec Formation; e.g., Birkenmajer and Myczyński, 1977; Birkenmajer et al., 2008: fig. 9); there is also no explanation of the presence of Jurassic ammonites in the clayey shale of the Szlachtowa Formation.

Oszczypko et al. (2012) give no explanation of why the Szlachtowa and Opaleniec formations contain no Cretaceous organic-walled dinoflagellate cysts, that are so frequent in true Cretaceous dark-coloured strata of the Pieniny Klippen Belt (Figs. 6–9; see also e.g., Skupien, 2003; E. Gedl, 2007) and the Flysch Carpathians (e.g., Gedl, 1997; E. Gedl, 1999).

Oszczypko et al. (2012: p. 436) pose the question: "Assumption of a Middle Jurassic age for the Szlachtowa and Opaleniec formations is leading to the question: where did the Upper Jurassic-Lower Cretaceous deposits disappear?". But they give the answer themselves by showing the Upper Jurassic to Lower Cretaceous succession of the Grajcarek Unit exposed at Szczawnica-Zabaniszcze (Oszczypko et al., 2012: fig. 4A, C, D): the Sokolica Radiolarite Formation (Bajocian?—Oxfordian?), the Czajakowa Radiolarite Formation (Oxfordian), the Czorsztyn Limestone Formation (Kimmeridgian–Tithonian), the Pieniny Limestone Formation (Tithonian–Barremian), the Kapuśnica Formation (Aptian–Albian) and the Wronine Formation (Albian) overlain by the Hulina Formation (Cenomanian; Fig. 3).

Summarizing, the data presented by Oszczypko et al. (2012) do not allow, in my opinion, acceptance of a Cretaceous age for the Szlachtowa and Opaleniec formations. In my opinion, most of the productive samples that, according to Oszczypko et al. (2012), should witness a Cretaceous age for the strata in question, were collected in fact from other Cretaceous lithostratigraphic units such as the Hulina, Wronine or Malinowa Shale formations (the Szlachtowa Formation does not consist of red shale or green radiolarite). Productive samples are almost always collected from contact zones with Cretaceous units, whereas samples from typical Szlachtowa and Opaleniec formations are barren or contain assemblages non-diagnostic of age. Foraminifera assemblages from many samples show contamination, which is treated by Oszczypko et al. (2012) highly arbitrarily: when highlighted by their opponents as an indication of age-misunderstanding (e.g., Birkenmajer and Pazdro, 1968; Birkenmajer et al., 2008) – this is rejected; when referred to by themselves, even in such evident case as an admixture of Paleogene species – it is suppressed.

CONCLUSIONS

The Grajcarek Succession exposed above the Pieniny Limestone Formation on the NE bank of the Jarmucki Potok (Zabaniszcze Creek) at Szczawnica-Zabaniszcze consists of the following lithostratigraphic units: the Kapuśnica, Wronine, Opaleniec and Szlachtowa formations. The first two units remain in stratigraphical succession above the Pieniny Limestone Formation. Their dinoflagellate cysts are of Cretaceous age, particularly: Late Barremian–earliest Aptian (top of the Pieniny Limestone Formation), earliest Aptian (Kapuśnica Formation) and Albian? (Wronine Formation). The latter unit contacts tectonically with the superficially very similar Opaleniec Formation. The main difference that allows their distinction is the high carbonate content of the latter (the Wronine Formation consists predominantly of non- or poorly-calcareous shale); this makes the Wronine and Opaleniec formations barely distinguishable in field. But the dinoflagellate cyst content leaves no doubt that the Opaleniec Formation is of Jurassic age: its strata at Szczawnica-Zabaniszcze yielded very rich and well-preserved Late Bathonian assemblages. The Szlachtowa Formation yielded Jurassic assemblages: from Early Aalenian (Late Toarcian?) through Late Aalenian to Early Bajocian. Neither the Szlachtowa Formation nor Opaleniec Formation yielded Cretaceous dinoflagellate cysts that would justify suggesting a Cretaceous age for them.

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