S T U D I A G E O L O G I C A P O L O N I C A
Vol. 123, Kraków 2004, pp. 245–277.
Geology of the Pieniny Klippen Belt and the Tatra Mts, Carpathians
Edited by K. Birkenmajer
Part XVII

Krzysztof BIRKENMAJER[1] and Przemysław GEDL[2]

Dinocyst ages of some Jurassic strata, Grajcarek Unit at Sztolnia Creek, Pieniny Klippen Belt (Poland)[3]

(Figs 1–14; Tabs 1, 2)

Abstract. Dinocyst assemblages recovered from Jurassic strata of the Grajcarek Unit, Pieniny Klippen Belt, Poland, add new important data on their stratigraphic ages. The Jurassic ages of the Szlachtowa Formation flysch strata (Toarcian–Aalenian) and the Opaleniec Formation (Bajocian), already based on age-diagnostic macro-, micro- and nannofossils, have been confirmed. A critical evaluation of the age and field data presented in a recent paper by Oszczypko *et al.* (2004), who tried to prove a Cretaceous age of the Szlachtowa Formation ("black flysch") and the Opaleniec Formation, is given.

Key words: Dinocysts, Jurassic, Cretaceous, Grajcarek Unit, Pieniny Klippen Belt, West Carpathians.

INTRODUCTION

Samples for dinocyst investigation have been collected by the authors in 2000, in the company of Dr Elżbieta Gedl, from Jurassic and, partly, Cretaceous strata of the Grajcarek Unit (Magura Succession) exposed at Sztolnia Creek near Jaworki, Pieniny Klippen Belt, West Carpathians, Poland (Figs 1–3). Preliminary information on occurrence of dinocysts in these strata has been given by P. Gedl and E. Gedl (2001). The aim of the present paper is to add new data on fossil content and stratigraphic ages of the Jurassic strata of this unit, represented by the Szlachtowa Formation (Toarcian–Aalenian) and the Opaleniec Formation (Bajocian).

1 Institute of Geological Sciences, Polish Academy of Sciences, Cracow Research Centre, ul. Senacka 1, 31-002 Kraków, Poland. E-mail: ndbirken@cyf-kr.edu.pl
2 Institute of Geological Sciences, Polish Academy of Sciences, Cracow Research Centre, ul. Senacka 1, 31-002 Kraków, Poland. E-mail: ndgedl@cyf-kr.edu.pl
3 Manuscript accepted for publication, October 30, 2004.

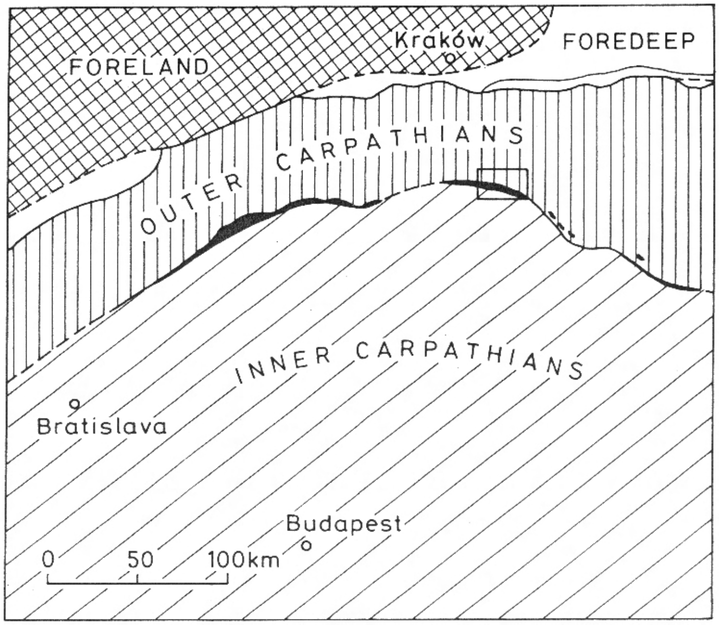

Fig. 1. Position of the Pieniny Klippen Belt (in black) in the West Carpathians. Box – see Fig. 2

The age of the "black flysch" lithostratigraphic unit, formalized as the Szlachtowa Formation by Birkenmajer (1977), became a matter of controversy some time ago, when Sikora (1962a, b) reported finds of single Cenomanian (resp. Albian–Cenomanian) planktonic foraminifers from shales of the "black flysch" exposed at Sztolnia Creek ("Sztolnia beds" *sensu* Sikora, *op. cit.*). At that time, finds of several *Cornaptychus* species, numerous foraminifer taxa, and bivalve "*Posidonia alpina* Gras" = *Bositra buchi* (Roemer), all indicated a Jurassic (resp. Aalenian) age of this formation (Gąsiorowski, 1962; Birkenmajer & Pazdro, 1963a, b; see also a summary in Birkenmajer, 1965).

Detailed geological and microfaunal investigation of the "black flysch" strata at Sztolnia Creek (Sikora's section at small waterfall), undertaken by Birkenmajer and Pazdro (1968), involved, i.a., careful washing of collected shale fragments prior to their processing for microfauna in glauber salt. It was found that single Cretaceous planktonic foraminifers with green and red tests occurred *only at the surface but not inside* the shale fragments. The grey/white-coloured benthic calcareous foraminifer assemblages recovered from cleaned shale fragments, determined and illustrated by Pazdro (in Birkenmajer & Pazdro, 1968; Pazdro, 1979), clearly showed their Jurassic (resp. Middle Jurassic) affinities. This was a decisive proof that Sikora's shale samples *were contaminated* by planktonic foraminifer tests which apparently had been washed out by stream waters from Cretaceous marls exposed higher upstream, and subsequently deposited in opened cracks and/or glued to weathered surfaces of the Jurassic ("black flysch") shales exposed lower downstream (*op. cit.*).

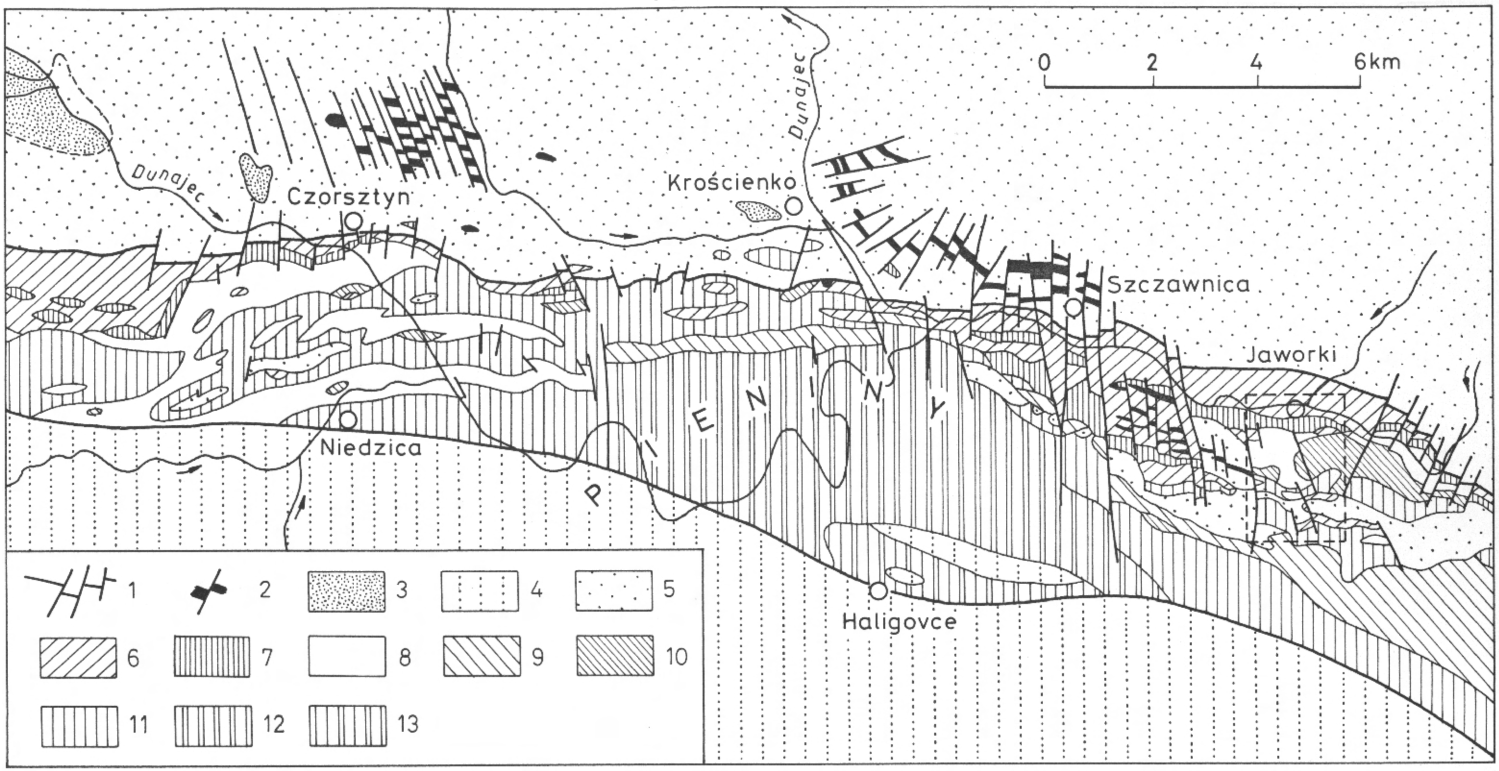

Fig. 2. Geological sketch of the Pieniny Klippen Belt (PKB), central sector. *1* – Miocene faults; *2* – Miocene andesite intrusions; *3* – Neogene fresh-water deposits; *4* – Podhale Palaeogene (autochthonous); *5* – Magura Palaeogene (Magura Nappe and autochthonous Palaeogene in the PKB); *6* – Jarmuta Fm. (Maastrichtian): Grajcarek Unit and autochthonous molasse in the PKB; *7* – Jurassic–Campanian of the Grajcarek Unit; *8–13* – Klippen successions (*8* – Czorsztyn; *9* – Czertezik; *10* – Niedzica; *11* – Branisko; *12* – Pieniny; *13* – Haligovce). Box – see Fig. 3

However obvious, this explanation had not been accepted by Sikora (1969, 1971a, b) and by Blaicher & Sikora (1969). Curiously enough, their views persisted, despite no new fossil age-evidence for a Cretaceous age of the "black flysch", in publications by Książkiewicz (1972, 1977), Golonka and Sikora (1981) and Golonka and Rączkowski (1984a, b).

Meanwhile, the Jurassic (Aalenian) age of the "black flysch" unit (= Szlachtowa Formation – Birkenmajer, 1977) has been confirmed at Sztolnia Creek by age-diagnostic Jurassic macrofauna: new finds of shells of the pelagic bivalve *Bositra buchi* (Roemer), whose stratigraphic range is Toarcian–Oxfordian, and of the ammonites *Leioceras opalinum* (Reinecke) and *L.* cf. *comptum* (Reinecke) – both zonal indices for Early Aalenian (Birkenmajer & Myczyński, 1977, figs 5–7, pls 1, 2). The finds of complete or nearly complete, thin and delicate *Bositra* shells collected from the shales, and of thin-shelled ammonite imprints collected from a limestone intercalation in the shales, excluded the possibility of their recycling from some unknown older strata. Their mode of occurrence in pelitic shales and micritic limestone, respectively, is the same as that of ammonite and bivalve shells *in situ* in analogous Jurassic rocks of the Czorsztyn-, Czertezik-, Niedzica-, Branisko- and Pieniny successions of the Pieniny Klippen Belt (cf. Myczyński, 1973, 2004; Birkenmajer & Myczyński, 2000).

Since 1977, the Jurassic age of the Szlachtowa Formation at its type locality in Sztolnia Creek, and elsewhere in the Pieniny Klippen Belt, has been firmly established, as further Jurassic *in situ* fossils have been found, determined and illustrated. These included, i.a.: ostracods (Błaszyk, 1968); foraminifers (Pazdro, 1979, tab. 1; Birkenmajer & Tyszka, 1996); isocrinids (Głuchowski *et al.*, 1983; Głuchowski, 1987); calcareous nannoplankton (Dudziak, 1986); gryphaeids (determined by Pugaczewska, 1971; for stratigraphic position of gryphaeid-bearing strata – see Birkenmajer, 1977, and Birkenmajer & Tyszka, 1996), and belemnites (Krawczyk *et al.*, 1992).

All at once, like *"the devil springing out of the box"*, the problem has been reanimated by Oszczypko *et al.* (2004) who have returned to the old-abandoned question of "redeposition" of Jurassic fossils in the "black flysch" (= Szlachtowa Formation) shales, and again tried to prove its Cretaceous and not Jurassic age. Their arguments will be discussed later on in the present paper.

SAMPLING AT SZTOLNIA CREEK

27 samples for palynological study were collected from deposits of the Grajcarek Unit exposed between lower (small) and upper (big) waterfalls at Sztolnia Creek (Fig. 4). The Lower-Middle Jurassic lithostratigraphic units sampled were: the Szlachtowa Formation flysch beds (Toarcian–Aalenian) and the Opaleniec Formation (Bajocian). Samples were also taken from some Cretaceous strata of the Grajcarek Unit: the Pieniny Limestone Formation (Tithonian–Barremian) and the Hulina Formation (Albian–Cenomanian) [For definition and ages of these lithostratigraphic units see Birkenmajer, 1977]. Dinocysts from the above Cretaceous

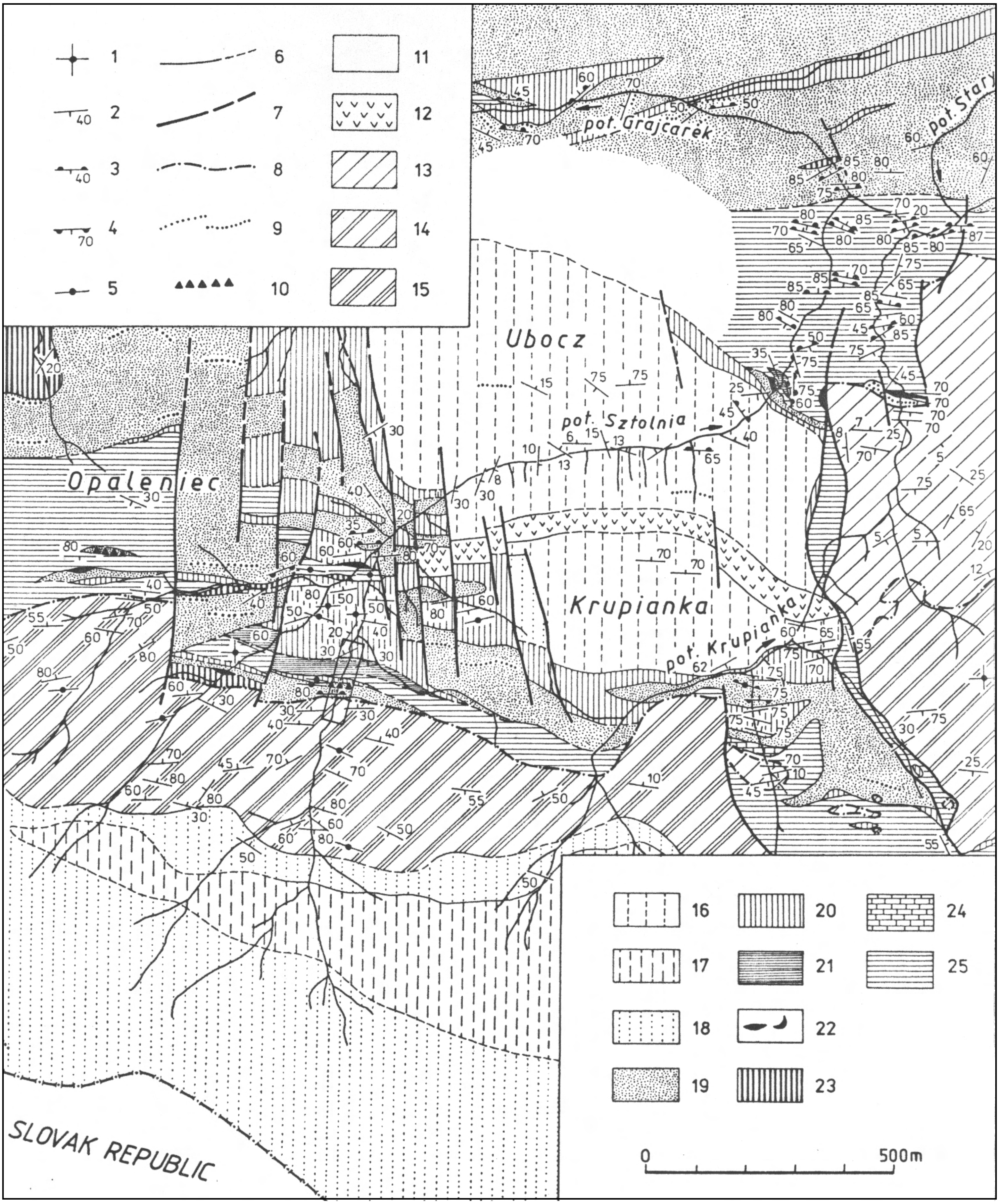

Fig. 3. Detailed geological map of the Sztolnia Creek and its vicinity. *1* – horizontal strata; *2* – strike and dip; *3* – normally dipping strata (as based on sole markings); *4* – tectonically overturned strata (as based on sole markings); *5* – vertical strata; *6* – normal contacts; *7* – tectonic contacts; *8* – overthrusts; *9* – conglomerate intercalations; *10* – sedimentary breccia intercalations; *11* – covered; *12* – andesite intrusion (Miocene); *13* – Czorsztyn Succession/Unit; *14* – Niedzica Succession/Nappe; *15* – Branisko Succession/Nappe; *16* – Magura Fm., Piwniczna Sandstone Mbr (Lower-Middle Eocene); *17* – Zarzecze Fm. (Lower Eocene); *18* – Szczawnica Fm. (Paleocene–Lower Eocene); *19–25* – **Grajcarek Unit:** *19* – Jarmuta Fm. (Maastrichtian– Paleocene) and Hałuszowa Fm. (Campanian); *20* – Malinowa Shale Fm. (Cenomanian–Campanian); *21* – Hulina Fm. (Albian–Cenomanian) and Kapuśnica Fm. (Aptian–Albian); *22* – Pieniny Limestone Fm. (Tithonian–Barremian); *23* – Czorsztyn Limestone Fm. (Kimmeridgian) and Czajakowa Radiolarite Fm. (Oxfordian); *24* – Opaleniec Fm. (Bajocian); *25* – Szlachtowa Fm. (Toarcian–Aalenian). Rectangular box – Sztolnia Creek, upper waterfall area (see Fig. 4)

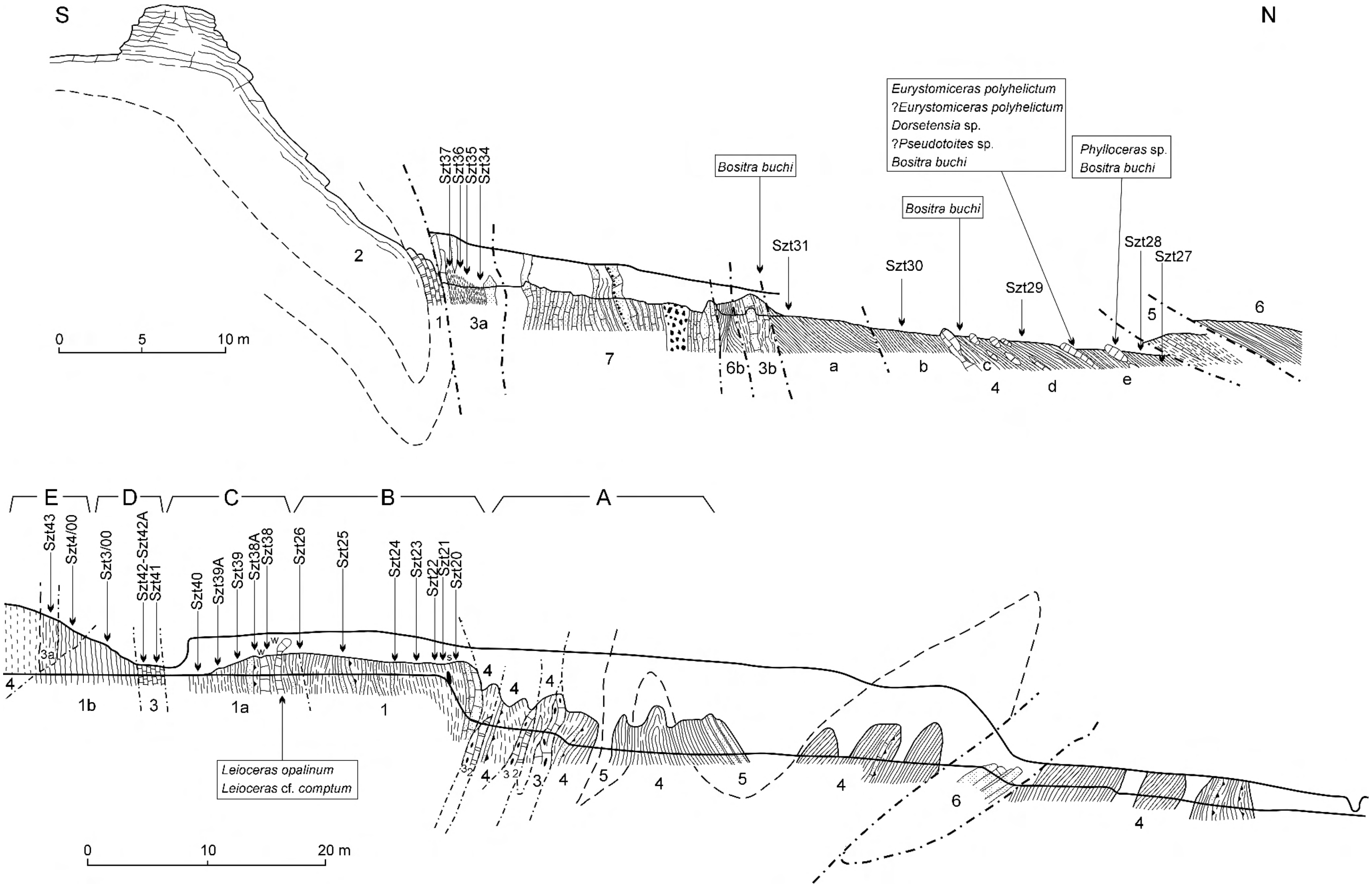

Fig. 4. Location of dinocyst samples in geological sections between the lower (small) and upper (big) waterfalls, Sztolnia Creek, with location of macrofauna (after Birkenmajer & Myczyński, 1977). Geology after Birkenmajer & Pazdro (1968), supplemented, explanations modified. **Lower section, Grajcarek Unit:** 1, 1a – Szlachtowa Fm. (Toarcian–Aalenian; 1a – limestone intercalation with ammonites *Leioceras opalinum* and *L.* cf. *comptum*; position of sole markings shown); 1b – Opaleniec Fm., lower part ("Sprzycne beds" of Sikora, 1971b; Opaleniec Fm., lower part of Birkenmajer & Myczyński, 1977); 2 – Czajakowa Radiolarite Fm. (Oxfordian); 3 – Pieniny Limestone Fm. (Tithonian–Barremian); 3a – Hulina Fm. (Albian–Cenomanian); 4 – Malinowa Shale Fm. (Cenomanian–Campanian: position of sole markings shown); 5 – Hałuszowa Fm. (Campanian); 6 – Jarmuta Fm. (Maastrichtian). A–E – sections with dinocyst samples (see Tabs 1–3); thicker dash-dot lines – tectonic contacts. **Upper section, Branisko Nappe:** 1 – Czajakowa Radiolarite Fm. (Oxfordian); 2 – Czorsztyn Limestone Fm. (Kimmeridgian). **Grajcarek Unit:** 3a, b – Szlachtowa Fm. (Toarcian–Aalenian); 4a–e Opaleniec Fm. (Bajocian), limestone intercalations/concretions marked (for location of macrofauna – see Fig. 5); 5 – Hulina Fm. (Albian–Cenomanian); 6a, b – Malinowa Shale Fm. (Cenomanian–Campanian); 7 – Jarmuta Fm. (Maastrichtian). Thicker dash-dot lines – tectonic contacts

lithostratigraphic units are under elaboration by Dr Elżbieta Gedl (Institute of Geological Sciences, Jagiellonian Uniersity, ul. Oleandry 2a, 30-063 Kraków).

Sztolnia Creek: lower waterfall and vicinity

Section A

Pieniny Limestone and Czajakowa Radiolarite formations. Small tectonic scales consisting of the Pieniny Limestone Formation (Tithonian–Barremian) and the Czajakowa Radiolarite Formation (Oxfordian), strongly folded together with Upper Cretaceous strata (Malinowa Shale, Hałuszowa and Jarmuta formations – see Fig. 4) were well exposed some 40–30 years ago at Sztolnia Creek below the small waterfall (see Birkenmajer & Pazdro, 1968, Fig. 4B; Birkenmajer & Myczyński, 1977, fig. 2B). They had been partly destroyed at the end of the 20th century by construction works for a new forest road. Consequently, no samples from the Jurassic strata were taken by us for dinocyst investigation.

Sections B and C

B. Szlachtowa Formation. Six samples (Szt20–26) were collected from dark-greyish shales with thin micaceous sandstone intercalations, well exposed between the small waterfall in the north, and the Early Aalenian ammonite-bearing limestone intercalation in the south (see Birkenmajer & Myczyński, 1977, fig.2B) – see Fig. 4: *1*. The unit is 15 m thick.

C. Szlachtowa Formation. Five samples (Szt38, 38A, 39, 39A and 40) were collected slightly higher upstream from olive-greenish shales which contain several thin intercalations of strongly micaceous sandstone, and two intercalations of grey-bluish pyritic limestones; the latter yielded Early Aalenian ammonites *Leioceras opalinum* (Reinecke) and *L.* cf. *comptum* (Reinecke) – see Birkenmajer & Myczyński (1977, p. 390, fig. 2B). The unit is about 8 m thick (Fig. 4: *1a*).

In the sections (A) – (C), the beds dip vertical to subvertical, with sole markings in strongly micaceous sandstone intercalations facing north (downstream) – Fig. 4. The set of strata is thus the oldest in the north and younging towards the south (cf. also Birkenmajer & Pazdro, 1968, fig. 4B; Birkenmajer & Myczyński, 1977, fig. 2B).

Section D

Pieniny Limestone Formation. This is a new exposure located immediately south of exposures of the Szlachtowa Formation shown in section C (see Fig. 4: *3*), where a new forest road crosses the stream bed. It shows a small klippe (2.5–3 m thick only) of vertically dipping Pieniny Limestone Formation. Two samples (Szt41 and 42) were collected from greyish and blackish limestone layers, 90 and 145 cm south from the northern margin of the klippe, respectively. The third sample (Szt42A) was taken from shaly part of the Szt42 bed. Dinocysts from these samples are under elaboration by Dr Elżbieta Gedl and will be published separately.

Section E

Section E, once well exposed in right scarp of the Sztolnia Creek (see Sikora, 1971b; Birkenmajer & Myczyński, 1977, fig. 3) was not available for study in 2000. Since 1977, the stream changed its course and rock exposures in the scarp became covered by solifluction and scree. Poor exposures were available for study in the stream bed only (see below).

Opaleniec Formation, lower part (= "Sprzycne beds" of Sikora, 1971b; Opaleniec Formation, lower part, of Birkenmajer & Myczyński, 1977, figs 3, 4). Two samples (Szt3/00 and Szt4/00) were collected from greyish-green spotty

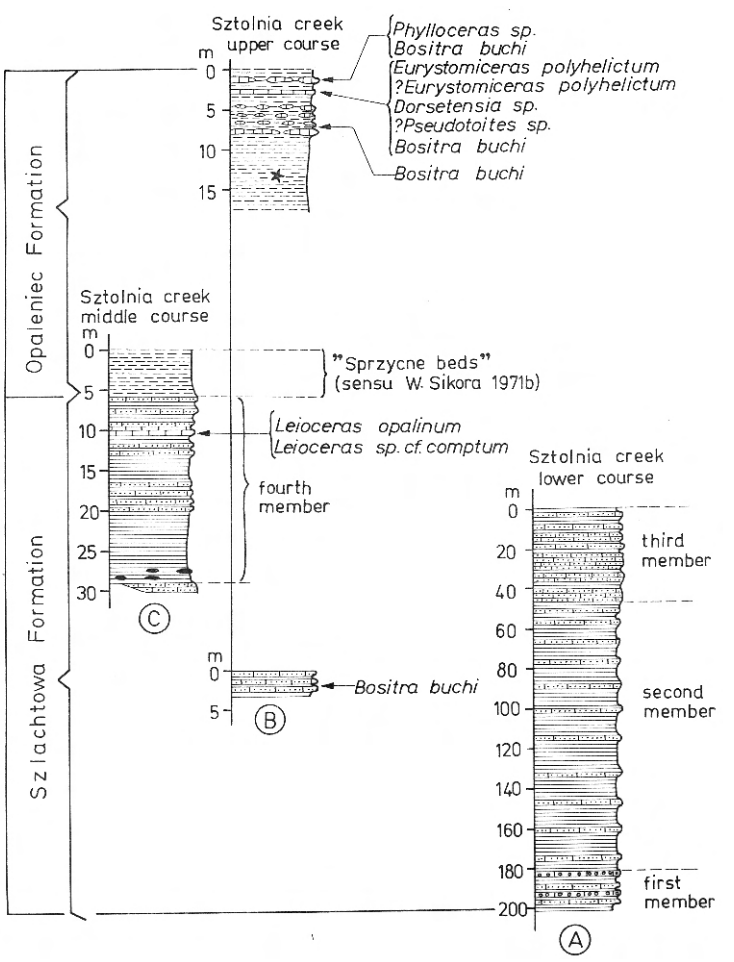

Fig. 5. Lithostratigraphic columns, relative stratigraphic position of field sections, and location of macrofauna within the Grajcarek Unit at Sztolnia Creek (after Birkenmajer & Myczyński, 1977; for lithology – see Figs 3, 4; for detailed characteristics of informal members in the Szlachtowa Fm. – see Birkenmajer, 1977)

shales upstream from the Pieniny Limestone Formation exposure (see: section D), at 6 and 6.5 m south of the northern margin of the limestone outcrop.

Hulina Formation. One sample (Szt43) was collected from grey-greenish spotty shales attributable to the Hulina Formation (Albian–Cenomanian – see Birkenmajer, 1977; Birkenmajer & Myczyński, 1977), c. 8 m south of the southern margin of the Pieniny Limestone outcrop (Fig. 4: *4a*). [Dinocysts from this sample are under elaboration by Dr Elżbieta Gedl]. Still more southward, there was a poor exposure of the Malinowa Shale Formation (Cenomanian–Campanian: Fig. 4: *4*).

Sztolnia Creek: upper waterfall and vicinity

In the Sztolnia Creek stream bed below the upper (big) waterfall, there occur two tectonic units of the Pieniny Klippen Belt separated by a major fault: (1) the Branisko Succession/Nappe in the south, consisting of a tectonically overturned syncline, with the Czorsztyn Limestone Formation (Kimmeridgian) at its core, and the Czajakowa Radiolarite Formation (Oxfordian) at its flanks; (2) the Grajcarek Unit in the north, showing overfolded vertical strata (Szlachtowa Formation and the Jarmuta Formation) near tectonic contact with the Branisko Nappe, and a complex of north-dipping strata (Opaleniec, Hulina and Malinowa Shale formations) farther downstream (Birkenmajer & Pazdro, 1968, Fig. 4C; formal lithostratigraphic terminology after Birkenmajer, 1977, and Birkenmajer & Myczyński, 1977, fig. 2A) – Fig. 4.

Szlachtowa Formation. The Szlachtowa Formation occurs as two small tectonic scales folded together with conglomerates and sandstones of the Jarmuta Formation (Maastrichtian), and red shales of the Malinowa Shale Formation (Cenomanian–Campanian). Samples Szt34–37 were collected from a small southern exposure (3-m thick) of vertical, unfossiliferous, dark-grey to black shales with strongly micaceous sandstone intercalations. The northern tectonic scale of the Szlachtowa Formation yielded shells of *Bositra buchi* (Roemer) – see Birkenmajer & Myczyński (1977, fig. 2A, 7, pl. 2) – Fig. 4.

Opaleniec Formation. Samples Szt27–31 were collected from a complex of olive-greenish spotty shales with limestone intercalations (see Fig. 4). This formation yielded a bivalve and ammonite fauna (Birkenmajer & Myczyński, 1977, figs 2, 4) diagnostic for the Bajocian age of the formation, moreover Middle Jurassic foraminifers (Pazdro, 1979).

METHODS APPLIED IN DINOCYST STUDY

The samples were processed by the junior author in the Micropalaeontological Laboratory of the Cracow Research Centre, Institute of Geological Sciences, Polish Academy of Sciences. The following procedure was applied:

20–30 G of carefully cleaned and crushed rock fragments were treated with 38% HCl to remove carbonates, sieved on 15 μm sieve (with ultrasonic treatment), treated with 40% HF to remove silicates, neutralized and sieved again on 15μm sieve (again 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.

The slides were examined under transmitted light microscope CARL ZEISS Axiolab. Photomicrographs were taken with the use of CARL ZEISS Axiolab microscope, Sony DSC-S75 camera and ZEISS Plan-NEOFLUAR 100x/1.30 Oil Pol and ZEISS Plan-NEOFLUAR 40x/0.85 Pol objectives.

The rock samples, palynological residuum and slides are stored in the collection of the Institute of Geological Sciences, Polish Academy of Sciences (Cracow Research Centre).

RESULTS OF DINOCYST EXAMINATION

Szlachtowa Formation

Section B: samples Szt20–26 (Tab. 1; Figs 7, 8). These samples yielded a rich dinocyst assemblage dominated by representatives of three genera: *Nannoceratopsis, Dissiliodinium* and *Kallosphaeridium*; the dinocyst assemblages differ by the ratio of the *Nannoceratopsis* specimens to the *Dissiliodinium* and *Kallosphaeridium* ones. A characteristic feature of these assemblages is various state of preservation of dinocysts in the same samples: *Nannoceratopsis* specimens are much poorer preserved compared to those of *Dissiliodinium* and *Kallosphaeridium*. This might be a result of various palaeoenvironmental preferences of these taxa: *Nannoceratopsis* dominates in palynofacies richer in land plant remains, becoming infrequent in palynofacies dominated by black opaque phytoclasts.

Sample **Szt20** contains numerous specimens of poorly preserved *Nannoceratopsis* (e.g., *N. gracilis, N. deflandrei senex*), and infrequent *Dissiliodinium* and *Kallosphaeridium*.

Sample **Szt21** yielded a rich assemblage composed exclusively of representatives of the genus *Nannoceratopsis*, the most common being *N. gracilis*.

Sample **Szt22**. In this sample, representatives of the genus *Nannoceratopsis* are less common, while *Kallosphaeridium* and *Dissilodinium* are the most frequent. A similar assemblage was found in samples **Szt24** (very rare dinocysts) and **Szt25**, whereas the *Nannoceratopsis*-dominated assemblages were found in samples **Szt23** and **Szt26**. The latter sample is characterized by the lack of *Dissilodinium* and *Kallosphaeridium*.

Section C: samples Szt38–40 (Tab. 1; Figs 9, 10). These samples were collected from flyschoid beds which yielded Early Aalenian ammonites *Leioceras opalinum* (Reinecke), and *L.* cf. *comptum* (Reinecke) found in a thin sedimentary intercalation of limestone (Birkenmajer & Myczyński, 1977).

Dinocysts from this section differ from those of the previus one (i.e., section B). No dinocysts were found in sample **Szt38**, while very poorly preserved specimens of the genus *Nannoceratopsis* occurred in sample **Szt39**.

Much richer dinocyst assemblages were found in samples **Szt38A**, **Szt39A**, and **Szt40**. They are dominated by new taxa unknown from section B: *Moendicodinium* spp. and *Ctenidodinium* spp. Representatives of the latter genus (*C. cornigerum*, *C. continuum*, *C. combazii* and *C. ornatum*) occur most frequently in sample **Szt39A**, whereas *Moendicodinium* spp. constitute as much as 98% of the assemblage in sample **Szt40**.

Section below upper (big) waterfall: samples Szt35–37. (Tab. 2; Fig. 6). Dinocyst assemblages recovered from three samples collected close to the big waterfall (Fig. 4: *Szt35–37*) are similar to those found in samples taken from the small waterfall section (see Fig. 4: *Szt20–26*). They consist of very poorly preserved specimens of *Nannoceratopsis* and much better preserved specimens of *Dissilodinium* and *Kallosphaeridium praussii*.

?Hulina Formation

Section below upper (big) waterfall: sample Szt34 (Fig. 4 *Szt34*, Fig. 14, Tab. 2). A different palynofacies and dinocyst assemblage characterizes sample **Szt34**: its palynofacies consists of black, opaque, small-size phytoclasts; the dinocysts are very rare and very poorly preserved, being in most cases undeterminable. *Spiniferites* sp. and, presumably, *Palaeohystrichophora infusorioides*, have been determined, pointing to a Late Cretaceous age of this sample. Taking into account strong tectonic disturbances/repetition of the strata in this section close to a major fault separating the Grajcarek Unit from the Branisko Nappe (Fig. 4, upper section), a small tectonic lense of some Upper Cretaceous shale (?Hulina Fm.) wedged into the Aalenian Szlachtowa Formation could be a plausible explanation; this lense was not exposed during the previous study by Birkenmajer & Pazdro (1968) and Birkenmajer and Myczyński (1977).

Opaleniec Formation

Section below upper (big) waterfall: samples Szt27–31 (Fig. 4, Tab. 2; Figs 11–13). This exposure of the Opaleniec Formation (type locality) yielded a good Bajocian diagnostic fauna of ammonites and pelagic bivalves (Birkenmajer & Myczyński, 1977 – see Figs 5, 6). Our dinocyst samples showed a common occurrence of the *Ctenidodinium* and *Endoscrinium* species.

Sample **Szt27** contained a rich dinocyst assemblage composed mainly of *Ctenidodinium combazii* and *C. ornatum*.

Sample **Szt31** yielded *C. combazii* and *C. cornigerum*. More diversified, although less rich dinocyst assemblages, with representatives of the genera *Epiplosphaera, Ctenidodinium, Endoscrinium* and *Gonyaulacysta*, were found in samples **Szt28** and **Szt30**. A different palynofacies, with very infrequent and poorly preserved dinocysts, with dominating black opaque phytoclasts was found in sample **Szt29**.

Section E: samples Szt3/00, Szt4/00 (Tab. 2): "Sprzycne beds" of Sikora (1971b) = Opaleniec Formation, lower part of Birkenmajer & Myczyński (1977).

The samples were barren of dinocysts. However, these beds previously yielded a poor foraminiferal-ostracod assemblage indicative of Middle Jurassic age (Pazdro, 1979, tab. 1).

STRATIGRAPHIC AGES AS BASED ON DINOCYSTS AND OTHER FOSSIL GROUPS

Szlachtowa Formation

Dominant dinocyst assemblages

The dinocysts recovered from dark-grey to black shales of this formation in the Sztolnia Creek, middle course (sections B, C), *show no traces of recycling* and may safely be treated as a primary assemblage of palynomorphs. Thus, they are reliable for age determination of these flysch-type rocks. Two dinocyst assemblages have been distinguished:

(i) The assemblage dominated by the genera *Dissiliodinium*, *Nannoceratopsis* and *Kallosphaeridium* occurs in stratigraphically lower part of the Szlachtowa Formation (Fig. 4: section B) at the small waterfall (this is the fourth and stratigraphically youngest informal member of the Szlachtowa Formation in Birkenmajer's, 1977, classification – see Fig. 5);

(ii) The assemblage with *Ctenidodinium* and other, frequently occurring genera, such as: *Endoscrinium*, *Moendicodinium*, *Lithodinia* and *Epiplosphaera*, occurs in stratigraphically highest part of the Szlachtowa Formation (Fig. 4: section C), just above the strata which yielded Early Aalenian ammonites *Leioceras opalinum* (Reinecke) and *L.* cf. *comptum* (Reinecke) – see Birkenmajer and Myczyński (1977). This dinocyst assemblage continues in the Opaleniec Formation (Bajocian – see below).

Age of the Szlachtowa Formation as based on dinocysts

Samples Szt20–26 and Szt35–37 (Tab. 1).The genus *Dissiliodinium*, often dominating in the assemblages, was described by Prauss (1989) from Middle Bajocian–Upper Bathonian strata of NW Germany. A Late Aalenian first appearance of this genus was reported by Feist-Burkhardt and Wille (1992) from the Swabian Alb (SW Germany).

Dissiliodinium psilatum, the species found in sample **Szt20** (tectonic base of the Szlachtowa Formation, Sztolnia Creek, lower section in Fig. 4), according to Prauss (1989) appears in Early Bajocian. Other *Dissiliodinium* species, such as *D. giganteum* and *D.* sp. A of Feist-Burkhardt (1990), which have been found in stratigraphically lower part of this section, were so far reported from uppermost Aalenian–Early Bajocian, and Late Aalenian–Early Bajocian strata of SW Germany, respectively (Feist-Burkhardt, 1990). A sighty different, Early Bajocian stratigraphic position, for the species *Dissiliodinium giganteum* was given by Feist-Burkhardt and Wille (1992).

Table 1

Grajcarek Unit at Sztolnia Creek, lower waterfall (see Fig. 4): distribution of dinocysts in the Szlachtowa Formation in section B (samples Szt20–26) and section C (samples Szt38–40)

Lithostratigraphy	Szlachtowa Formation											
									passage beds to Opaleniec Fm.?			
Taxon (in alphabetical order) / Sample	Szt20	Szt21	Szt22	Szt23	Szt24	Szt25	Szt26	Szt38	Szt38A	Szt39	Szt39A	Szt40
Aldorfia aldorfensis									X			
Ctenidodinium combazii											X	X
Ctenidodinium continuum											X	
Ctenidodinium cornigerum											X	
Ctenidodinium ornatum											X	
Ctenidodinium sp.											X	X
Dissiliodinium giganteum	X			X	X	X						
Dissiliodinium psilatum	X		X									
Dissiliodinium sp. A	X			X	X							
Dissiliodinium sp.			X			X						
Ellipsoidictyum cinctum											X	
Endoscrinium sp.												
Epiplosphaera reticulata											X	
Kallosphaeridium praussii	X		X			X						
Kallosphaeridium sp.	X		X			X						
Lithodinia reticulata											X	
Lithodinia sp.											X	
Moendicodinium sp.									X			X
Nannoceratopsis ambonis							X					
Nannoceratopsis deflandrei		X										
Nannoceratopsis gracilis	X	X	X	X	X	X						
Nannoceratopsis pellucida											X	
Nannoceratopsis plegas		X										
Nannoceratopsis raunsgaardii		X										
Nannoceratopsis ridingii				X								
Nannoceratopsis deflandrei senex	X	X				X					X	
Nannoceratopsis spiculata			X	X								
Nannoceratopsis sp.	X	X	X	X			X		X	X	X	
?*Rhynchodiniopsis*? *regalis*									X			
Valensiella ovula											X	

Stratigraphic ranges of other dinocyst species from the discussed assemblage are known less precisely. The representatives of the genus *Nannoceratopsis: N. ambonis, N. gracilis, N. plegas, N. raunsgaardii, N. deflandrei senex* and *N. spiculata* range mainly from Pliensbachian through Bajocian, even to post-Bajocian times (e.g., Bucefalo Palliani & Riding, 1977).

Basing on the above dinocyst assemblage data, a Late Aalenian–?Early Bajocian age may be assigned to the Szlachtowa Formation, as represented by samples Szt20–26 and Szt35–37.

Samples Szt38–40. Sample **Szt38** collected just above the limestone intercalation (lower intercalation – see Birkenmajer & Myczyński, 1977, fig. 2B) which yielded Early Aalenian ammonites (see Fig. 4, lower section: *38*) was barren of dinocysts. Sample **Szt38** yielded a poor assemblage of dinocysts with poorly preserved specimens of the genus *Nannoceratopsis* and the species ?*Rhynchodiniopsis regalis*?, and better preserved representatives of the genus *Moendicodinium* and the species *Aldorfia aldorfensis*.

Based on known age ranges of *A. aldorfensis* and *R. regalis*, and on the lack of younger forms, a Late Bajocian–Bathonian age (see Prauss, 1989; Riding & Thomas, 1992; Poulsen, 1998; Huault, 1999) may be accepted.

A similar, Upper Bajocian (or younger) age may be suggested for the samples **Szt39A** and **Szt40** (but not for sample **39** which yielded poorly preserved specimens of the genus *Nannoceratopsis* only). The species of the genus *Ctenidodinium* (e.g., *C. combazii*), present in samples Szt39A and 40, and the species *Ellipsoidictyum cinctum, Epiplosphaera reticulata* and *Nannoceratopsis pellucida*, appear in Europe for the first time in Late Bajocian (e.g., Prauss, 1989; Dodekova, 1990; Riding & Thomas, 1992; Bucefalo Palliani & Riding, 1997; Poulsen, 1998; Huault, 1999). Similarly, the species *Lithodinia reticulata* found in sample Szt39A, is reported from Late Bajocian of Europe (e.g., Herngreen & de Boer, 1974; Dodekova, 1975).

Age of the Szlachtowa Formation as based on other fossil groups

Based on fossil evidence published before 2004, the Szlachtowa Formation in the Pieniny Klippen Belt of Poland, which occurs mainly in the Grajcarek Unit, and less frequently in the Klippen Successions (Czertezik-, Niedzica- and Branisko successions – see Birkenmajer, 1977), covers the Early or Late Toarcian to Early Aalenian time span (Birkenmajer 1977; Birkenmajer & Myczyński, 1977; Birkenmajer & Tyszka, 1996). The most important age-indicative faunas of the Szlachtowa Formation ("black flysch") are:

(1) Aptychi: *Cornaptychus* gr. A *lythensis* (Quenstedt) Trauth var. aff. *sigmopleura* Trauth, and *Cornaptychus* sp. gr. A, were found at the base of the formation (see Gąsiorowski, 1962; Birkenmajer, 1977, fig. 12; Birkenmajer and Myczyński, 1977, p. 391). Stratigraphic age of these aptychi is Late Toarcian or Early Aalenian (Gąsiorowski, 1962);

(2) The pelagic bivalve *Bositra buchi* (Roemer) – appears already at the base of the formation, and continues higher up its stratigraphic column (see Figs 4, 5) – Birkenmajer and Pazdro (1963); Birkenmajer (1977, figs 9–12); Birkenmajer and Myczyński (1977, p. 391); Birkenmajer and Tyszka (1996). Age range of this bivalve in the Pieniny Klippen Belt, as elsewhere in Europe, is Toarcian–Oxfordian (see Myczyński, 1973, 2004; Birkenmajer & Myczyński, 1977; 2000);

(3) The ammonites *Leioceras opalinum* (Reinecke) and *Leioceras* cf. *comptum* (Reinecke) were found in the uppermost part of the Szlachtowa Formation (Figs 4, 5) – see Birkenmajer & Myczyński (1977, figs 2B, 4); Birkenmajer (1977, fig. 9). They are zonal indices for the Early Aalenian *Leioceras opalinum* Zone, possibly also *Leioceras comptum* Subzone (cf. Myczyński, 2004);

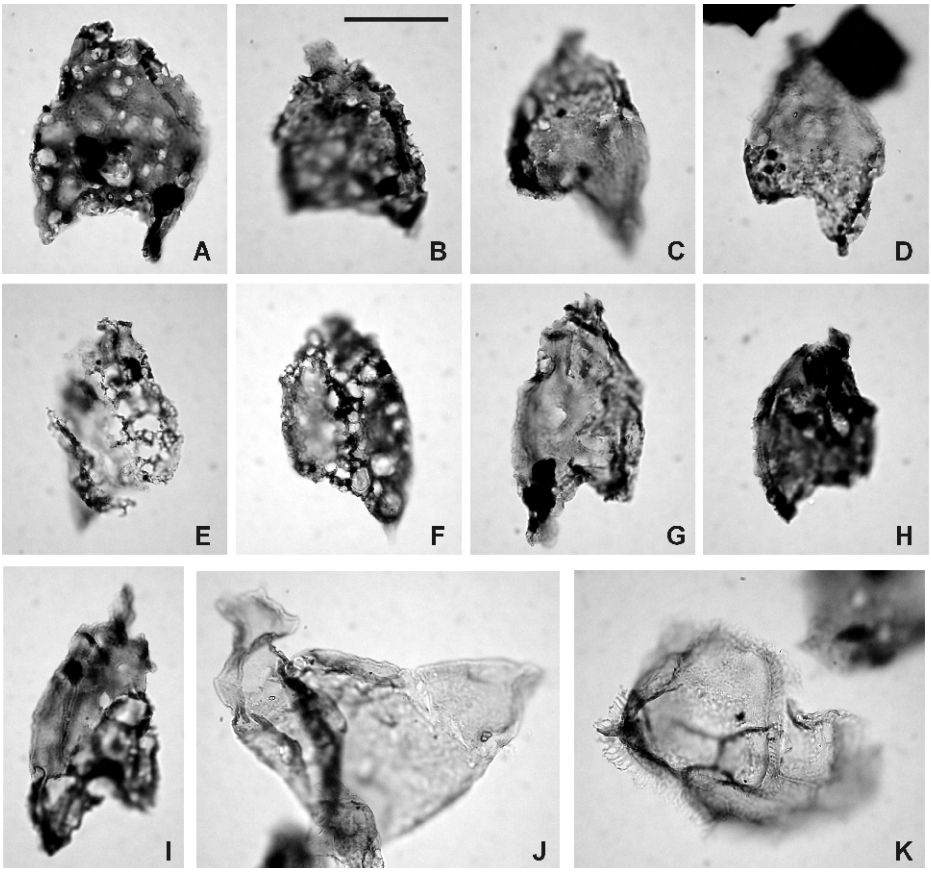

Fig. 6. Dinoflagellate cysts from the Szlachtowa Fm., Sztolnia Creek, section below upper (big) waterfall (see Fig. 4). Scale bar (in B) represents 25 μm and refers to all photomicrographs. Slide code given (*photo P. Gedl*). **A–I** – poorly preserved specimens of *Nannoceratopsis* sp., Szt36; **J** – *Dissiliodinium* sp., Szt36; **K** – ?*Rhynchodiniopsis* sp., Szt36

(4) Well preserved belemnite rostra determined as *Holcobelus blainvillei* (Voltz) and *Holcobelus* sp. were found in the Szlachtowa Formation by Krawczyk *et al.* (1992). *H. blainvillei* is known, i.a., from Aalenian and Bajocian of France and from basinal Upper Aalenian and Bajocian strata of the Branisko Succession in the Pieniny Klippen Belt (Myczyński, 1973);

(5) Foraminifer *Lingulina* gr. *tenera* (Bornemann) was found in flysch beds of the Szlachtowa Formation which underlie the Aalenian *Gryphaea*-bearing Krzonowe Formation (Birkenmajer & Tyszka, 1996). Its age range is Early Pliensbachian–Early Toarcian: *Lingulina* gr. *tenera* Zone of Tyszka (1999);

(6) A rich and well preserved assemblage of gryphaeid shells was collected by K. Birkenmajer from the Krzonowe Formation of the Grajcarek Unit. The latter, most probably, is an intercalation within the Szlachtowa Formation flysch (Birkenmajer & Tyszka, 1996). The following gryphaeids were determined by Pugaczewska (1971):

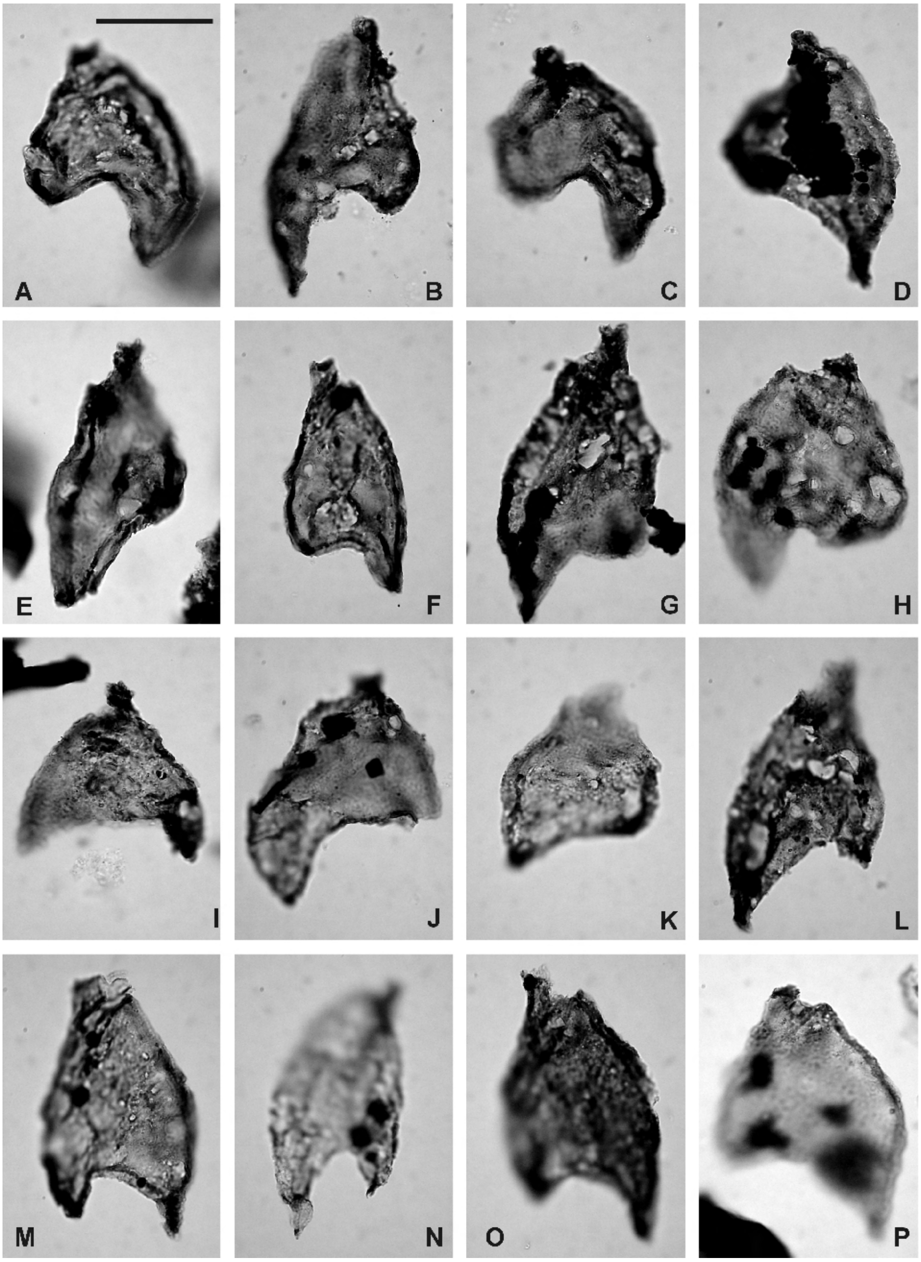

Fig. 7. Dinoflagellate cysts from the Szlachtowa Fm., Sztolnia Creek, section B above lower (small) waterfall (see Fig. 4). Scale bar (in A) represents 25 µm and refers to all photomicrographs. Slide code and England Finder references given (*photo P. Gedl*). **A** – *Nannoceratopsis gracilis*, Szt20: M41; **B** – *N. gracilis*, Szt21:L47.3/4; **C** – *N. gracilis,* Szt21: P28; **D** – *N. gracilis*, Szt22:E33; **E** – *N. deflandrei senex,* Szt20:M36; **F** – *N. deflandrei senex*, Szt20:W40.4; **G** – *N. gracilis,* Szt22:E33.3; **H** – *N. gracilis*, Szt23:D34; **I** – *N. raunsgaardii*, Szt21:K40; **J** – *N. plegas*, Szt21:P38; **K** – *N. ambonis*, Szt26:Y37.1/2; **L** – *N. deflandrei*, Szt21:K34; **M** – *N. spiculata*, Szt22:D48.2; **N** – *N. spiculata*, Szt23:K45; **O** – *N. ridingii*, Szt23:E37; **P** – *N. ridingii*, Szt22:U51

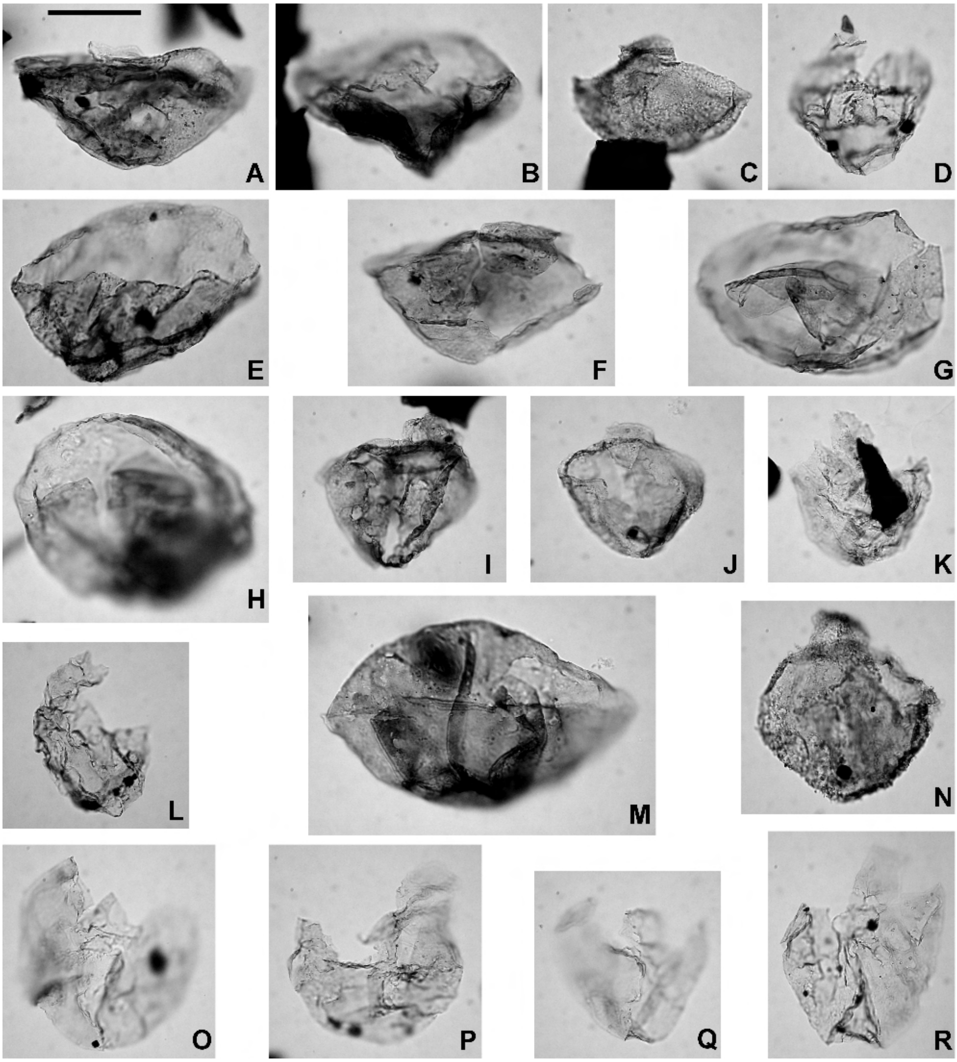

Fig. 8. Dinoflagellate cysts from the Szlachtowa Formation, Sztolnia Creek, section B above lower (small) waterfall (see Fig. 4). Scale bar (in A) represents 25 µm and refers to all photomicrographs. Slide code and England Finder references given (*photo P. Gedl*). **A** – *Dissiliodinium giganteum*, Szt20:M41.2; **B** – *D. giganteum*, Szt20:H48.2; **C** – *D.* sp. A, Szt20:E39; **D** – *Kallosphaeridium praussii*, Szt22:Q36.1; **E** – *Dissiliodinium giganteum*, Szt23:W35.4; **F** – *D. giganteum*, Szt23:N42; **G** – *D. giganteum*, Szt25:S49; **H** – *D. giganteum*, Szt25:M40; **I** – *D.* sp. A, Szt24:X42; **J** – *D.* sp. A, Szt20:H50.3/4; **K** – *Kallosphaeridium praussii*, Szt26:K26; **L** – *K. praussii*, Szt22:L39.1/2; **M** – *Dissiliodinium giganteum*, Szt25:S42; **N** – *D.* sp. A, Szt23:V36.1; **O** – *Kallosphaeridium praussii,* Szt22:E37; **P** – *K. praussii*, Szt22:O48.3; **Q** – *K. praussii*, Szt25:S40.4; **R** – *K. praussii*, Szt22:L35.1

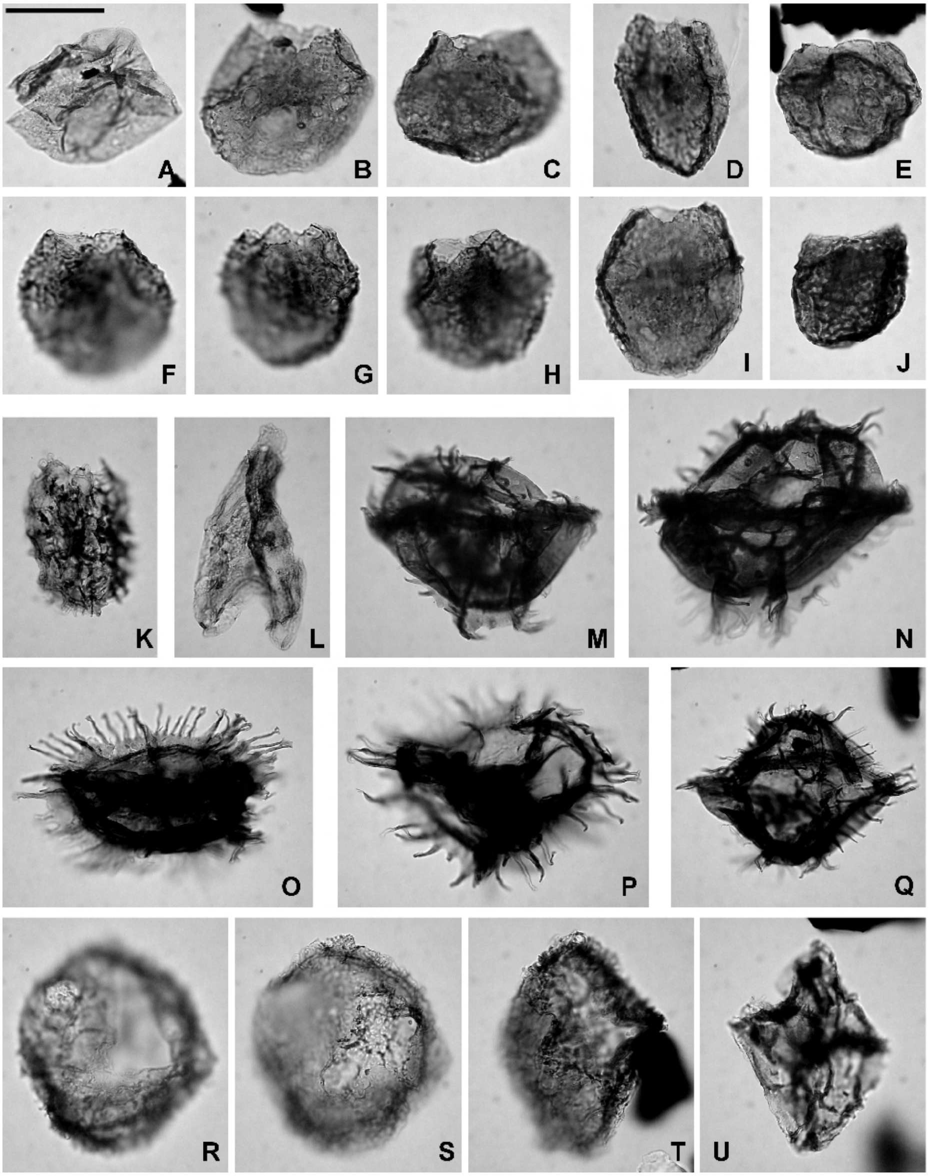

Fig. 9. Dinoflagellate cysts from the Szlachtowa Fm., Sztolnia Creek, section C above lower (small) waterfall (see Fig. 4). Scale bar (in A) represents 25 µm and refers to all photomicrographs. Slide code and England Finder references given (*photo P. Gedl*). **A** – *Moendicodinium* sp., Szt38A:M31.3/4; **B** – *Lithodinia reticulata*, Szt39A:G40.3; **C** – *L. reticulata*, Szt39A:Q34.4; **D** – *L. reticulata*, Szt39A:F34.3; **E** – *L.* sp., Szt39A:D47.3/4; **F** – *L. reticulata*, Szt39A:S44; **G** – *L. reticulata*, Szt39A:D39; **H** – *L. reticulata*, Szt39A:N30; **I** – *L.* sp., Szt39A:U39.4; **J** – *L. reticulata*, Szt39A:H44; **K** – *Ellipsoidictyum cinctum*, Szt39A:D35.1; **L** – *Nannoceratopsis pellucida*, Szt39A:M32.3; **M** – *Ctenidodinium ornatum*, Szt39A:C50.4; **N** – *C. ornatum*, Szt39A:V30.4; **O** – *C. combazii*, Szt39A:K32.3; **P** – *C. combazii*, Szt39A:P46; **Q** – *C. cornigerum*, Szt39A:E41.3; **R, S** – *Aldorfia aldorfensis*, same specimen, various foci (R – dorsal side; S – ventral side), Szt38A:Y39.1; **T** – *Aldorfia aldorfensis*, Szt38A:D39.4; **U** – *Endoscrinium* sp., Szt38A:R40

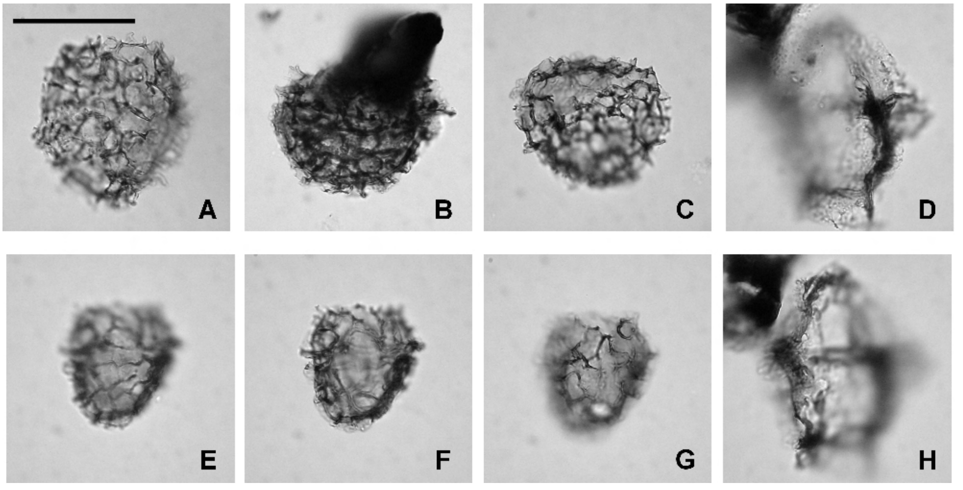

Fig. 10. Dinoflagellate cysts from the Szlachtowa Fm., Sztolnia Creek, section C above lower (small) waterfall (see Fig. 4). Scale bar (in A) represents 25 µm and refers to all photomicrographs. Slide code and England Finder references given (*photo P. Gedl*). **A** – *Epiplosphaera reticulata*, Szt39A:R42.4; **B** – *E. reticulata*, Szt39A:D34.3; **C** – *E. reticulata*, Szt39A:E31.4; **D, H** – ?*Rhynchodiniopsis*? *regalis*, Szt38A:V33.3; **E–G** – *Valensiella ovula*, same specimen, different foci, Szt39A:G30.1

Gryphaea dewalquei Rollier. Age-range: Late Toarcian (*Dumortieria levesquei* Zone) to Early Bajocian (*Sonninia sowerbyi* Zone);

Gryphaea ferruginea-champigneullensis Charles et Maubeuge. Age range: Early Aalenian (*Leioceras opalinum* Zone) to Late Aalenian (*Graphoceras concavum* Zone);

Gryphaea sublobata Deshayes. Age range: Early Aalenian (*Leioceras opalinum* Zone) to Early Bajocian (*Sonninia sowerbyi* Zone);

Gryphaea lampada Rollier. Age range: Middle Aalenian (*Ludwigia murchisonae* Zone) to Early Bajocian (*Stephanoceras humphriesianum* Zone);

(7) The assemblages of Foraminifera (*in:* Birkenmajer & Pazdro, 1963a, b; Birkenmajer & Pazdro, 1968; Pazdro, 1979, tab. 1: *III, IV*), according to Pazdro, predominantly show a Middle Jurassic character, some taxa being reported elsewhere exclusively from the Aalenian and/or the Toarcian (resp. Liassic) deposits;

(8) The ostracods predominantly show Jurassic character (Błaszyk, 1968);

(9) Well preserved skeletal elements of Jurassic isocrinids, *Pentacrinites dargniesi* Terquem et Jourdy and *Chariocrinus andreae* (Desor), were found in limestone (calcarenite) intercalations in lower part of the Szlachtowa Formation flysch (Głuchowski *et al.*, 1983; Głuchowski, 1987);

(10) Calcareous nannoplankton is represented by taxa ranging mainly from Liassic to Oxfordian (Birkenmajer *et al.*, 1979; Dudziak, 1986):

Crepidolithus crassus (Deflandre) Noël. Age range: Pliensbachian to Bajocian;

Shizosphaerella punctata Deflandre et Dangeard. Age range: Hettangian to Oxfordian;

Podorhabdus cylindratus Noël. Age range: Pliensbachian–Late Oxfordian;

(11) Trace fossils *Paleodictyon maximum* (Eichwald) and *P. hexagonum* (Marck) resemble most the taxa described from Triassic and Lower Jurassic deposits of Crimea (Krawczyk & Słomka, 1981; Krawczyk *et al.*, 1995).

Stratigraphic age. The above fossil assemblages give *a strong evidence for the Toarcian–Aalenian age of the Szlachtowa Formation* in the Grajcarek Unit in Poland.

Remarks. Curiously enough, no reference is to be found in Oszczypko *et al.* (2004), to the above cited important papers by Gąsiorowski (1962), Pugaczewska (1971), Pazdro (1979), Głuchowski (1987), Dudziak (1986), Krawczyk *et al.* (1992), Birkenmajer & Tyszka (1996), and Tyszka (1999), in which age-diagnostic Jurassic mega-, micro- and nannofossils have been described and illustrated from the Szlachtowa Formation.

Opaleniec Formation

Dinocyst assemblages

The dinocyst assemblage (ii) with *Ctenidodinium*, associated with the genera *Endoscrinium*, *Moendicodinium*, *Lithodinia* and *Epiplosphaera*, continues from the topmost flysch strata of the Szlachtowa Formation (Fig. 4: section C) to the Opaleniec Formation (Fig. 4: upper section), inclusively:

Ctenidodinium ornatum and *C. combazii*, have been reported by Feist-Burkhardt and Wille (1992) from SW Germany to appear in the Late Bajocian *Strenoceras niortense* and *Parkinsonia parkinsoni* zones, respectively;

Huault (1999) reported the first appearance of *Ctenidodinium continuum* and *C. combazii* from Late Bajocian of the Paris Basin, *Strenoceras subfurcatum* and *Garantiana garantiana* zones, respectively;

Late Bajocian first appearances of most species which occur in our assemblage were given by Prauss (1989) from NW Germany.

Age as based on dinocysts

Samples Szt27–31. The whole dinocyst assemblage (ii) from the Opaleniec Formation, when compared with dinocyst zonation for NW Europe, is most similar to the Late Bajocian *Acanthaulax crispa* Zone *sensu* Woolam and Riding (1983: *Garantiana garantiana* and *Parkinsonia parkinsoni* zones), and to upper part of its subzone "b" *sensu* Riding and Thomas (1992: *Garantiana garantiana-Parkinsonia parkinsoni* zones). This conclusion is based on the presence in our assemblage of the following characteristic taxa: *Aldorfia aldorfensis*, *Ctenidodinium continuum*, *C. asymmetricum* and *C. combazii.*

Remarks. A part of the dinocysts found in samples Szt27–31 occurs also in samples Szt38–40. This may suggest their at least Late Bajocian age (the taxa *Ctenidodinium* spp., *Nannoceratopsis pellucida* and *Epiplosphaera reticulata*). The remaining taxa, which were recovered from a part of the section below the big

Table 2

Grajcarek Unit at Sztolnia Creek, below upper waterfall (see Fig. 4): distribution of dinocysts in samples from the Szlachtowa Formation (Szt35–37) and the Opaleniec Formation (Szt27–31)

Lithostratigraphy	Opaleniec Formation					?	Szlach-towa Formation		
Taxon (in alphabetical order) / Sample	Szt27	Szt28	Szt29	Szt30	Szt31	Szt34	Szt35	Szt36	Szt37
Adnatosphaeridium caulleryi	X								
Aldorfia sp.				X					
Atopodinium prostatum		X							
Chytroeisphaeridia chytroeides		X			X				
Ctenidodinium combazii	X				X				
Ctenidodinium continuum					X				
Ctenidodinium cornigerum		X			X				
Ctenidodinium ornatum	X								
Ctenidodinium sp.			X						
Dingodinium minutum		X							
Dissiliodinium giganteum								X	X
Dissiliodinium sp.							X	X	X
Endoscrinium asymmetricum	X	X							
Endoscrinium luridum		X		X					
Endoscrinium sp.		X							
Epiplosphaera bireticulata	X	X							
Epiplosphaera gochtii		X							
Epiplosphaera reticulata	X	X							
Epiplosphaera reticulospinosa		X							
Epiplosphaera sp.		X							
Gonyaulacysta jurassica adecta		X							
Gonyaulacysta sp.		X							
Impletosphaeridium varispinosum					X				
Kallosphaeridium praussii							X	X	
Leptodinium sp.				X					
Nannoceratopsis deflandrei									X
Nannoceratopsis gracilis								X	X
Nannoceratopsis pellucida		X		X	X				
Nannoceratopsis raunsgaardii								X	
Nannoceratopsis deflandrei senex								X	X
Nannoceratopsis spiculata			X	X					X
Nannoceratopsis sp.							X	X	X
Palaeohystrichophora infusorioides						X			
?*Rhynchodiniopsis* sp.				X				X	
Sentusidinium sp.		X							
Spiniferites sp.						X			
Surculosphaeridium sp.		X							
Surculosphaeridium? *vestitum*					X				
?*Systematophora* sp.		X							
?*Taeniophora iunctispina*		X							

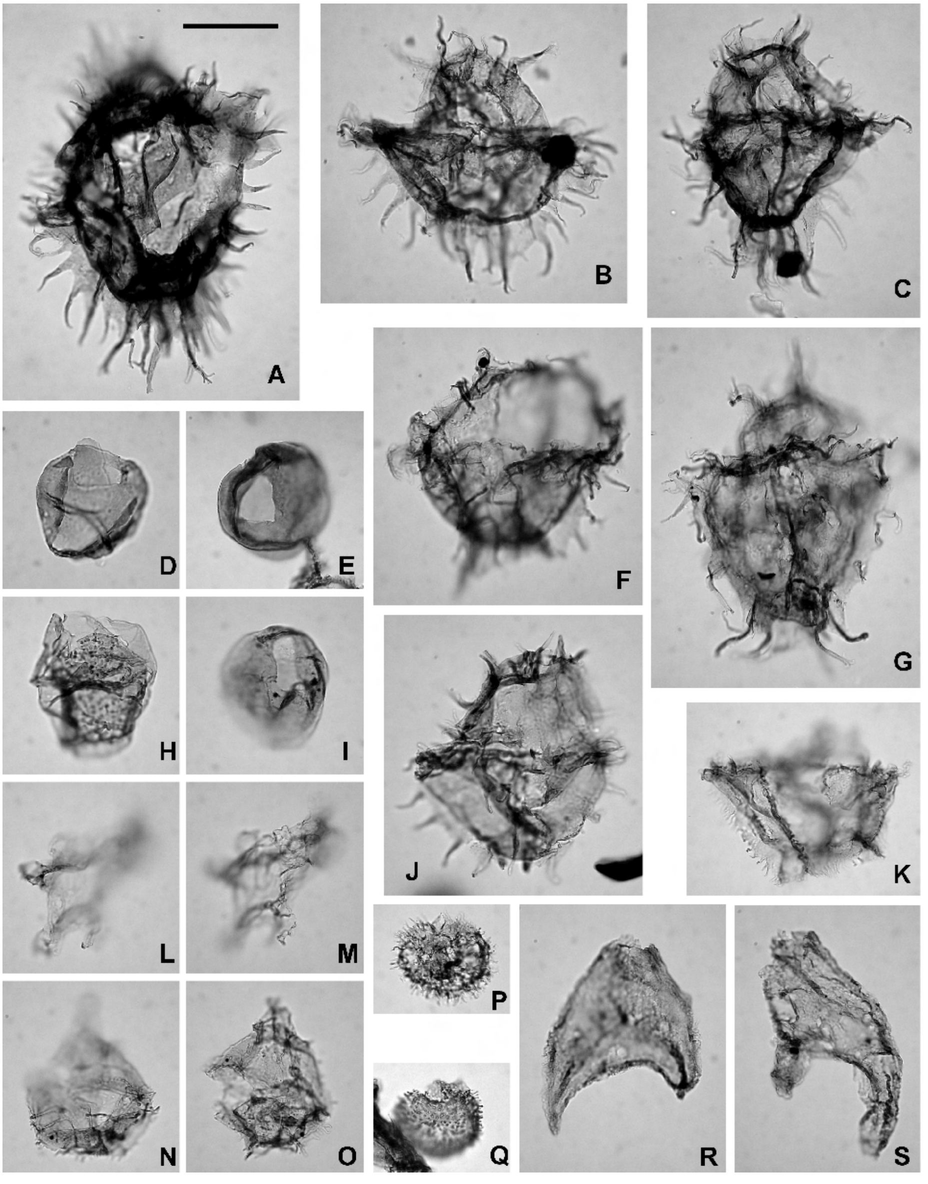

Fig. 11. Dinoflagellate cysts from the Opaleniec Fm., Sztolnia Creek, section below upper (big) waterfall (see Fig. 4). Scale bar (in A) represents 25 µm and refers to all photomicrographs. Slide code and England Finder references given (*photo P. Gedl*). **A** – *Ctenidodinium combazii*, Szt27:M45; **B** – *C. combazii*, Szt27:G34; **C** – *C. combazii*, Szt27:E30.2; **D** – *Chytroeisphaeridia chytroeides*, Szt28a:S37.4; **E** – *Ch. chytroeides*, Szt31:R34.3; **F** – *Ctenidodinium combazii*, Szt27:G41.4; **G** – *C. combazii*, Szt27:D37; **H** – *Dingodinium minutum*, Szt28bM33.1/2; **I** – *Chytroeisphaeridia chytreo-ides,* Szt28a:K53.1; **J** – *Ctenidodinium ornatum*, Szt31:P41.3; **K** – *C. continuum*, Szt31:R34.4; **L, M** – *Atopodinium prostatum*, same specimen, various foci, Szt28a:O42.4; **N** – *Gonyaulacysta jurassica adecta*, Szt28a:W32.1/3; **O** – *G. jurassica adecta*, Szt28a:Q30.2/4; **P** – *Sentusidinium* sp., Szt27:K36.2; **Q** – *Sentusidinium* sp., Szt28a:D40.1; **R** – *Nannoceratopsis spiculata*, Szt30:O44; **S** – *N. pellucida*, Szt28b:W31

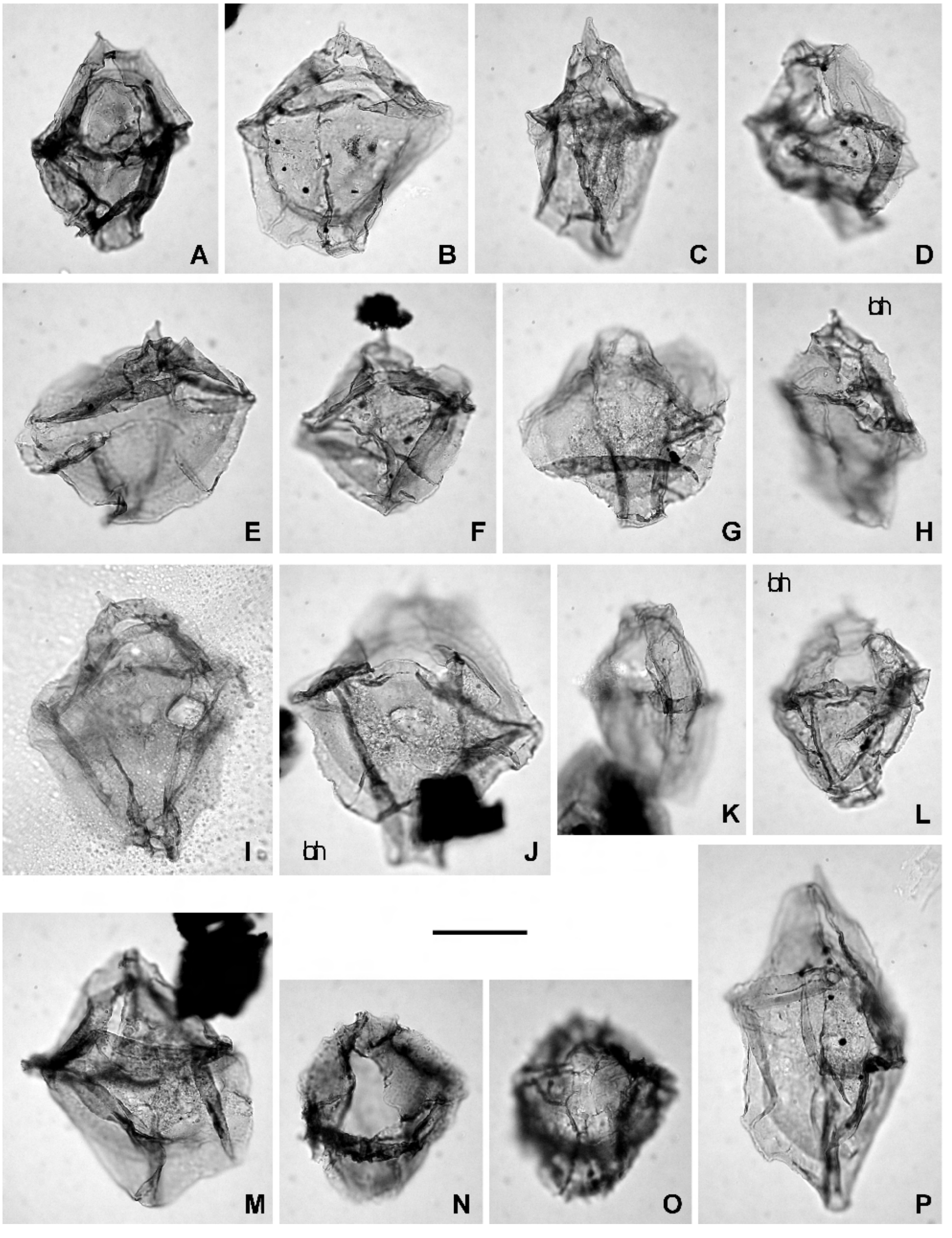

Fig. 12. Dinoflagellate cysts from the Opaleniec Fm., Sztolnia Creek, section below upper (big) waterfall (see Fig. 4). Scale bar represents 25 µm and refers to all photomicrographs. Slide code and England Finder references given (*photo P. Gedl*). **A** – *Endoscrinium asymmetricum*, Szt27:Y35.3; **B** – *E. asymmetricum*, Szt28b:S33.1/3; **C** – *E. asymmetricum*, Szt28a:O50.2; **D** – *E. asymmetricum*, Szt28a:N47.3; **E** – *E. asymmetricum*, Szt28a:U32.1/2; **F** – *E. asymmetricum*, Szt28a:Y39.2/4; **G** – *E. asymmetricum*, Szt28a:U41.1; **H** – *E. luridum*, Szt28b:T39.1; **I** – *E. asymmetricum*, Szt28a:N53; **J** – *E. luridum*, Szt28b:R35.4; **K** – *E.* sp., Szt28a:U52.1/3; **L** – *E. luridum*, Szt28b:N41.3; **M** – *E. asymmetricum*, Szt28a:X32; **N, O** – *Leptodinium* sp., same specimen, various foci (N – dorsal side; O – ventral side), Szt30:N33.1/3; **P** – *Endoscrinium asymmetricum*, Szt28b:S41.4

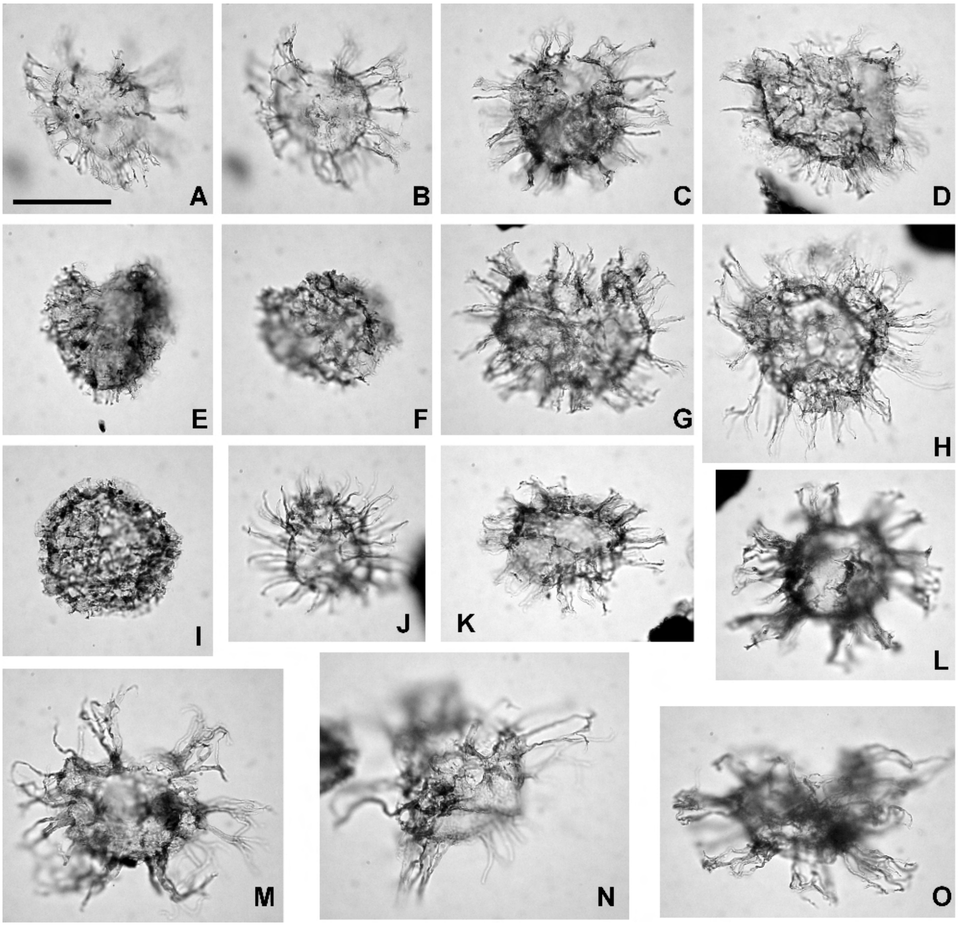

Fig. 13. Dinoflagellate cysts from the Opaleniec Fm., Sztolnia Creek, section below upper (big) waterfall (see Fig. 4). Scale bar (in A) represents 25 µm and refers to all photomicrographs. Slide code and England Finder references given (*photo P. Gedl*). **A, B** – *Adnatosphaeridium caulleryi*, same specimen, various foci, Szt27:L36; **C** – *Epiplosphaera reticulospinosa*, Szt28a:O49.2; **D** – *E. reticulospinosa*, Szt28a:F41; **E** – *E. gochtii*, Szt28a:W34.1; **F** – *E. reticulata*, Szt28a:M39; **G** – *E. reticulospinosa*, Szt28a:U53; **H** – *E. reticulospinosa*, Szt28a:N51; **I** – *E. bireticulata*, Szt28b:P53.2; **J** – *Impletosphaeridium varispinosum*, Szt31:N46; **K** – *Epiplosphaera reticulospinosa*, Szt28a:F33.2; **L** – *Surculosphaeridium*? *vestitum*, Syt31:K32.4; **M** – *Surculosphaeridium* sp., Szt28a:W42.4; **N** – ?*Taeniophora iunctispina*, Szt28a:P43.4; **O** – ?*Systematophora* sp., Szt28a:K33.1

waterfall, have their first appearances in Late Bajocian: *Endoscrinium asymmetricum*, *Epiplosphaera gochtii*, *E. reticulospinosa* and *Gonyaulacysta jurassica adecta* (see Riding & Thomas, 1992; Poulsen, 1998; Huault, 1999). There are also some taxa which have their first appearance in the Bathonian: *Adnatosphaeridium caulleryi, Atopodinium prostatum, Dingodinium minutum* and *Impletosphaeridium varispinosum* (see Prauss, 1989; Dodekova, 1990; Riding & Thomas, 1992; Poulsen, 1998; Huault, 1999). Poorly preserved chorate species, most probably be-

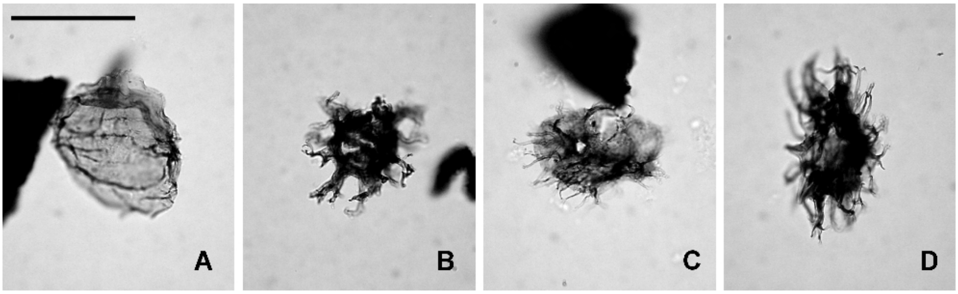

Fig. 14. Dinoflagellate cysts from sample Szt34 (Szlachtowa Fm.), Sztolnia Creek, below upper (big) waterfall (see Fig. 4). Scale bar (in A) represents 25 μm and refers to all photomicrographs (*photo P. Gedl*). **A** – undetermined peridinioid; **B** – poorly preserved dinocyst (?*Spiniferites* sp.); **C** – poorly preserved chorate dinocyst, with presumably apical archeopyle and thin, slender nontabular processes; **D** – *Spiniferites* sp.

longing to the genus *Systematophora* and the species *Surculosphaeridium*? *vestitum* and ?*Taeniophora iunctispina*, whose first appearance is usually given from a higher Bathonian and Callovian (see Prauss, 1989; Riding & Thomas, 1992; Huault, 1999) have also been found.

Age as based on macrofauna

Late Bajocian. The Opaleniec Formation at its type locality (see Fig. 4, upper section) yielded the following Late Bajocian macrofaunal assemblage (Birkenmajer & Myczyński, 1977): ammonites *Eurystomiceras polyhelictum* (Böckh), ?*E. polyhelictum* (Böckh), *Dorsetensia* sp., ?*Pseudotoites* sp., *Phylloceras* sp., and numerous shells of pelagic bivalve *Bositra buchi* (Roemer).

?Early Bajocian–Middle Aalenian. This period of time in the Grajcarek Unit is represented by the Harcygrund Shale Formation (previously "*Posidonia* shales") some 30 m thick, which locally occurs in this unit in the Homole Gorge area, to the east of the Sztolnia Creek (see Birkenmajer & Pazdro, 1968; Birkenmajer, 1970). South of the Petrylakowska Skała klippe, at left slope of the Kamionka Stream, it yielded Aalenian ammonites *Ptychophylloceras tatricum* (Pusch), *Lytoceras* spp., *Ludwigia* sp., and numerous specimens of bivalve *Inoceramus (Mytiloceramus)* aff. *polyplocus* Roemer (Myczyński, 2004, Site 11).

Remarks. Appearance of the dinocyst assemblage (ii) already in the uppermost strata of the Szlachtowa Formation (small waterfall, section C), which yielded ammonites of the Early Aalenian *Leioceras opalinum* Zone, probably also *Leioceras comptum* Subzone (Birkenmajer & Myczyński, 1977), suggests that this assemblage may in fact have a much wider stratigraphic range: Early Aalenian–Late Bajocian, contrary to a much narrower (Early-Late Bajocian) range as given by Prauss (1989), Feist-Burkhardt (1990), Feist-Burkhardt and Willie (1992), Riding and Thomas (1992) and Huault (1999) from NW and SE Germany and France (Paris Basin).

DISCUSSION

(1) **Age of the Szlachtowa Formation.** The occurrence of Jurassic nanno-, micro- and megafossil assemblages in the Szlachtowa Formation ("black flysch"), has been explained by Oszczypko *et al.* (2004) as a result of fossil recycling from some unknown Jurassic strata during mid-Cretaceous time. They conclude that "The biostratigraphic analysis presented herein proves without doubt an Albian–Cenomanian age of the black flysch deposits of the Pieniny Klippen Belt..." (*op. cit.*, p. 110).

In our opinion, this is an unfortunate return to the long-discredited views of Sikora (1962a, b, 1969, 1971a, b) and Blaicher and Sikora (1969, 1972), whose samples were *contaminated with single Cretaceous foraminifera* as proved by Birkenmajer & Pazdro (1968) and Pazdro (1979).

(2) **Problem of sample contamination**. In our study, we seriously considered the problem of possible sample contamination by foraminiferal tests which could have been washed out of marly/shaly Cretaceous strata well exposed above the upper waterfall at Sztolnia Creek (see Birkenmajer & Pazdro, 1968, fig. 2: *15* – Branisko Succession), then floated in muddy stream waters, eventually being deposited downstream in cracks and/or glued to weathered surfaces of Jurassic shales. A very strict laboratory procedure of *cleaning/washing of every shale fragment* before further processing for microfossil content was thus applied (cf. Birkenmajer & Pazdro, 1968; Pazdro, 1979). As a result, our dinocyst assemblages from the Szlachtowa and the Opaleniec formations are consistent in their Jurassic character and *do not show any* contamination by Cretaceous forms.

(3) **In situ megafossils.** The mode of occurrence of megafossils in both the Szlachtowa and the Opaleniec formations does also indicate that they occur *in situ* in their host strata. In these formations, delicate, often nearly complete, thin pelagic bivalve *Bositra buchi* shells occur in pelitic shales and in limestone/ferruginous dolostone which form intercalations/concretions in the shales. The ammonite shells (*Leioceras opalinum*, *L.* cf. *comptum*, *Eurystomiceras polyhelictum*, *Dorsetensia* sp., etc.) occur in the limestone/ferrugineous dolostone intercalations/concretions within shales (Birkenmajer & Myczyński, 1977, figs 2A, B: *w*). These delicate shells have *never been found in any coarser-grained clastics* (sandstones, conglomerates, sedimentary breccias) of the Upper Cretaceous age (Jarmuta Fm.) which occur in the same area (see Birkenmajer & Myczyński, 1977, fig. 2A, B).

The mode of occurrence of the *Bositra* and ammonite shells in the Szlachtowa and the Opaleniec formations at Sztolnia Creek is exactly the same as that in other Upper Liassic and Dogger shales, marls, layered limestones and calcareous/dolostone/sideritic concretions everywhere in the Pieniny Klippen Belt (e.g., Myczyński, 1973, 2004).

Jurassic belemnite rostra found at sole of some turbidite sandstone layers in the Szlachtowa Formation flysch beds are well preserved, long and not fragmented (Krawczyk *et al.*, 1992).

(4) **Redeposition of clasts of older rocks.** In psammitic rocks of the Szlachtowa Formation flysch (turbidites) occur small clasts of metamorphic (quartz-feldspar-mica schists, gneiss, meta-mudstone, meta-sandstone, quartzite), magmatic (da-

cite, rhyolite, tuffs, lamprophyre), and sedimentary rocks. The latter are represented by: fine-sparitic Triassic dolostones (especially frequent in crinoidal calcarenite intercalations), marls, sparitic-oolitic, sparitic-pellet and micritic-organodetrital limestone, arenaceous claystone and siliceous rocks (see Birkenmajer, 1958, 1970, 1979; Krawczyk & Słomka, 1986, 1987; Krawczyk *et al.* 1987). In a coarser exotics-bearing intercalation have been found: dolostone, limestone, sandstone and mudstone clasts (Krawczyk & Słomka, 1986). The clast spectrum obtained from both psammitic and psephitic rocks indicates a source composed of low-degree metamorphic, probably Early Palaeozoic, basement cut by small intrusive veins of acidic (dacitic-rhyolitic), sometimes also more basic (lamprophyric) composition, capped by lavas and tuffs of acidic (dacitic-rhyolitic) character. The sedimentary cover of this metamorphic basement included, i.a., carbonate (dolostone and limestone) and arenaceous strata, Triassic and probably late Palaeozoic in age (*op. cit.*). Occurrence of recycled Namurian miospores recovered from thin stratified allochthonous coal intercalations in the Szlachtowa Formation (Birkenmajer & Turnau, 1962; Birkenmajer, 1977, figs 10, 12B) indicates that some productive coal-bearing Upper Carboniferous strata were also source rocks for the Szlachtowa Formation flysch.

On the contrary, no clasts of such characteristic rocks as the deep-water manganese, green and red radiolarites (Sokolica Radiolarite and Czajakowa Radiolarite fms: Callovian–Oxfordian/Kimmeridgian), and the pelagic white cherty limestones (Pieniny Limestone Fm.: Tithonian–Barremian), have ever been found as recycled fragments in the basinal Szlachtowa Formation flysch and the pelagic shales of the Opaleniec Formation. Contamination by fragmented Middle-Upper Jurassic and Lower Cretaceous rocks would certainly be expected in case of emergence and reworking of older deposits during mid-Cretaceous time. It should be remembered that the Lower Jurassic (Upper Liassic) through the Campanian sedimentary column of the Grajcarek Unit (Magura Succession) is deep-water in character, continuous, devoid of any recognizable erosional hiatus, and lacking evidence of synsedimentary reworking (see, e.g., Birkenmajer, 1977, 1986).

(5) **Sample location.** Oszczypko *et al.* (2004) examined 59 samples collected from strongly tectonically disturbed Mesozoic sedimentary strata of the Pieniny Klippen Belt at Ujak (E Slovakia), and at the Sztolnia, Krupianka and Grajcarek creeks (Poland), 29 out of these attributed by them to the "black flysch". In Poland, 15 out of 44 samples collected by them from well-exposed, less tectonically disturbed sections were attributed to the "black flysch".

Location of some "black flysch" samples which apparently yielded Cretaceous foraminifers (*op. cit.*, figs 6, 7), as compared with detailed maps, field sections and columns presented by Birkenmajer & Pazdro (1968, figs 2–6), and Birkenmajer & Myczyński (1977, figs 2–4), raises *serious doubts* as to correct attribution of these samples to formal lithostratigraphic units of the Pieniny Klippen Belt (cf. Birkenmajer, 1977), e.g.:

In the **small waterfall** section, their samples 14 and 15 were most probably collected from the Upper Cretaceous Hałuszowa Formation (Campanian) and the Jarmuta Formation (Maastrichtian), but not from the Szlachtowa Formation (see Fig. 4: section A), the latter being represented by their sample 18 only.

In the **big waterfall** section, their sample 20 was taken at tectonic contact of the Opaleniec Formation (Bajocian) and the Hulina Formation (Albian–Cenomanian), while sample 30 – from tectonic contact of the Szlachtowa/Opaleniec formations. Other samples, obviously taken from the Jurassic lithostratigraphic units (Szlachtowa and Opaleniec formations), did not yield any age-diagnostic mid-Cretaceous planktonic foraminifers (see Oszczypko *et al.*, 2004, tab. 4).

(6) **Calcareous nannoplankton**. Oszczypko *et al.* (2004, p. 106), wrote: “The calcareous nannofossil assemblages indicate the following ages (Tables 1, 3, 5): black flysch, Aalenian–Bajocian, mainly Early Bajocian...”. In most of their samples, the coccolith assemblages are similar, often monospecific ones – with *Lotharingius contractus*. In sample 20, appears *Watznaueria britannica.* Only in one sample from the Krupianka stream (sample 2Kr), a Cretaceous form *Tranolithus ornatus* was found, however it was neither described nor illustrated.

(7) **Foraminifera.** “Black flysch” at Ujak (*op. cit.*): out of 6 samples investigated, only two (U2, U3) yielded infrequent, poorly preserved, and specifically little differentiated Foraminifera; they have not been illustrated. The remaining 4 samples yielded crinoid fragments, sponge spicules and echinoid spines and some “non-diagnostic” foraminifers.

Sztolnia Creek, upper course. Five out of eight samples which, according to Oszczypko *et al. (op. cit.)*, represent the “black flysch”, yielded Cretaceous foraminifers: samples 14, 15, 18 (= Szlachtowa Fm.), 20 and 30 (= ?Opaleniec Fm.):

Sample 18 contained Cretaceous foraminifers (illustrated); calcareous nannoplankton recovered from this sample was poor, its taxons were not age-diagnostic (Jurassic and Jurassic–Cretaceous);

Sample 20: tectonic contact of the Opaleniec Formation (Bajocian), and the Hulina Formation (Albian–Cenomanian) – see Discussion (5); and sample 30: tectonic contact of the Szlachtowa/Opaleniec fms – see Discussion (5) – yielded several Cretaceous foraminifers, besides Jurassic and Jurassic–Cretaceous calcareous nannoplankton;

No foraminiferal investigations have been applied to well-exposed and less tectonized exposures of the Szlachtowa Formation in lower course of the Sztolnia Creek (north of the small waterfall), the Krupianka Stream and the Grajcarek Stream;

Samples 14 and 15 most probably represent Cretaceous strata: the Hałuszowa and the Jarmuta formations, but not the Szlachtowa Formation – see Discussion (5).

(8) **Final remarks.** In our opinion, the paper by Oszczypko *et al.* (2004) has been prepared for, and published by, the journal “Cretaceous Research” in undue haste, without proper review by competent referees. This is shown by the above remarks (1–7) and, moreover, by the following obvious errors:

(i) Oszczypko *et al.* (2004) seem to be oblivious of most papers which give location, mode of occurrence and preservation of age-diagnostic Jurassic *in situ* megafossils so-far described from the Szlachtowa Formation (see Conclusions: 2);

(ii) Location of their samples (*op. cit.*, fig. 7) is so imprecise that it raises doubts as to attribution to proper lithostratigraphic units of the Grajcarek Unit;

(iii) In their fig. 6, the Eocene Piwniczna Sandstone Member of the Magura Sandstone Formation (formal unit as distinguished by Birkenmajer & Oszczypko, 1988, 1989, pp. 168-169, and references to previous papers herein) at Mt Ubocz and Mt Krupianka (see, e.g., Birkenmajer & Pazdro, 1968, fig. 2; Birkenmajer, 1970, pl. I; Fig. 3 – this paper) has been included to the Maastrichtian Jarmuta Formation (sic !);

(iv) Their fig. 2 gives a false presentation of palaeogeographic position of some stratigraphic successions in the Pieniny Klippen Basin and the Magura Basin. Contrary to this figure, the Branisko Succession/Nappe at Zawiasy, Krościenko (see Birkenmajer, 1958, IV, fig. 99; 1979, fig. 80) had not been deposited in the Magura Basin, but in the Pieniny Klippen Basin (see also Birkenmajer, 1977, 1986). The Czorsztyn-, Czertezik- and the Niedzica successions have also been improperly located in this figure;

(v) The units named "Zlatna" (sic ! – unit non existent in the Pieniny Klippen Belt – cf. Birkenmajer, 1977, 1986), and "Klapa" (? Klape) are curious misspellings;

(vi) "Lithostratigraphic logs" presented by Oszczypko *et al.* (2004, fig. 5) lack thickness scale and do not attempt to correlate the beds with the existing lithostratigraphic standard.

CONCLUSIONS

(1) The dinocyst assemblages here presented **confirm the Jurassic – Lower Aalenian through ?Early Bajocian age** of the "black flysch" beds = Szlachtowa Formation (Birkenmajer, 1977) at Sztolnia Creek. Here and elsewhere in the Pieniny Klippen Belt of Poland, this formation ranges down to the Toarcian, as evidenced by *in situ* fossils recovered mainly from deposits of the Grajcarek Unit. The Jurassic–Upper Cretaceous deposits of this unit were laid down in oceanic Magura Basin, to the north of the Czorsztyn Ridge. As a result of late Cretaceous subduction, they had been stripped off their presumably oceanic basement and piled up as an accretion prism (Grajcarek Unit) in front of the Pieniny Klippen Belt orogen during the Laramian folding (Cretaceous/Palaeogene boundary). The Grajcarek Unit was subsequently strongly refolded and faulted during the Miocene Savian and Styrian orogenies (cf. Birkenmajer, 1970, 1986).

The Szlachtowa Formation occurs also in the Czertezik-, Niedzica- and the Branisko succesions which were deposited in the Pieniny Klippen Basin, and not in the Magura Basin. There, its stratigraphical position is **always below** the Skrzypne Shale Fm. (Aalenian–Bajocian) and the Krempachy Marl Fm. (Toarcian–Aalenian) which are rich in age-diagnostic *in situ* megafossils, mainly ammonites – see Birkenmajer (1977, and references herein; Myczyński, 1973, 2004).

(2) Contrary to the views expressed by Oszczypko *et al.* (2004), there is **absolutely no geological evidence** that the Toarcian–Aalenian megafossils found in the

Szlachtowa Formation had been recycled/redeposited from some unknown Jurassic strata during (mid-)Cretaceous time.

These megafossils, including: aptychi, *Cornaptychus* gr. A *lythensis* var. aff. *sigmopleura* and *C.* gr. A (see Gąsiorowski, 1962); pelagic bivalves *Bositra buchi* (see Birkenmajer & Pazdro, 1963a; Birkenmajer & Myczyński, 1977; Birkenmajer & Tyszka, 1996); ammonites *Leioceras opalinum* and *L.* cf. *comptum* (see Birkenmajer & Myczyński, 1977); gryphaeids (Pugaczewska, 1971; Birkenmajer, 1977; Birkenmajer & Tyszka, 1996) and belemnite rostra *Holcobelus blainvillei* and *H.* sp. (see Krawczyk *et al.*, 1992), are preserved well enough for specific determination, being neither crushed nor fragmented. Delicate shells of pelagic bivalves *Bositra buchi* and thin-shelled ammonites of the genus *Leioceras* were collected either from pelitic shale or from limestone intercalations/concretions within the shale. Gryphaeid shells are preserved near perfect, many with both valves still attached to one another.

(3) The **only recycled fossils** which occur in the Szlachtowa Formation **are Late Carboniferous** (younger than Namurian A, older than Westphalian C) miospores which were recovered from thin coal intercalations found in stratigraphically higher part (third member) of this formation (Birkenmajer & Turnau, 1962; Birkenmajer, 1977, fig. 12A). They indicate that some productive Late Carboniferous rocks were the source for the Szlachtowa Formation (“black flysch”) turbidites, being exposed above the sea during the Toarcian–Aalenian times.

(4) The assemblages of foraminifers (see Birkenmajer & Pazdro, 1968; Pazdro, 1979; Birkenmajer & Tyszka, 1966; Tyszka, 1999), ostracods (see Błaszyk, 1968), isocrinids (see Głuchowski *et al.*, 1983; Głuchowski, 1987), calcareous nannoplankton (see Dudziak, 1986), and of dinocysts (this paper), all show Jurassic – **mainly Toarcian–Aalenian** – affinities. They all have been obtained from *carefully cleaned* samples and show *no admixture* of (mid)-Cretaceous taxa which would be expected in case of mixing Jurassic (recycled) with Cretaceous (*in situ*) fossils.

(5) The dinocyst assemblages here described, are well preserved and show no admixture of Cretaceous taxa. They support the Jurassic – **mainly Aalenian and Bajocian** – ages of the Szlachtowa Formation and the Opaleniec formations, respectively. The dinocysts certainly occur *in situ* within the investigated deposits, and had not been recycled from some undetermined older strata.

(6) In the Szlachtowa Formation turbidites (flysch beds), no redeposited clasts of such characteristic rocks as green and red radiolarites (Sokolica Radiolarite Fm. – Callovian; Czajakowa Radiolarite Fm. – Oxfordian/Kimmeridgian) or white cherty limestone (Pieniny Limestone Formation – Tithonian–Barremian) have ever been found, either in the turbidite sandstones or in very rare exotic-bearing conglomerate intercalations (see Birkenmajer, 1958, 1970, 1977, 1979; Krawczyk & Słomka, 1986, 1987; Krawczyk *et al.*, 1987). This fact gives another **strong argument against redeposition** in the Szlachtowa Formation of micro- and nannofossils which are believed by Oszczypko *et al.* (2004) to have been derived from some unknown Toarcian–Aalenian strata during mid-Cretaceous time.

(7) The Bajocian age of the Opaleniec Formation, so far based on ammonites, bivalves and foraminifers (Birkenmajer & Myczyński, 1977; Birkenmajer, 1977; Pazdro, 1979), by age evaluation of our dinocyst assemblages may probably be extended to the Bathonian.

(8) Taking into account **very strong tectonic disturbances** involving multiple tectonic repetition of strata in the Grajcarek Unit, which resembles a tectonic mélange produced by the process of obduction in a plate-tectonic setting, the field sampling and laboratory processing of its deposits for age-evaluation based on nanno- and microfossils, **should be carried out with utmost care**. In our opinion, this often was not the case with the samples collected by Oszczypko *et al.* (2004) in the area of Szlachtowa: it is shown, i.a., by frequent improper attribution of their samples to formal lithostratigraphic units.

Appendix – List of dinocysts

Adnatosphaeridium caulleryi (Deflandre 1939) Williams et Downie 1969 (Fig. 13: *A*, *B*)
Aldorfia aldorfensis (Gocht 1970) Stover et Evitt 1978 (Fig. 9: *R-T*)
Aldorfia sp.
Atopodinium prostatum Drugg 1978 (Fig. 11: *L*, *M*)
Chytroeisphaeridia chytroeides (Sarjeant 1962) Downie et Sarjeant 1965 (Fig. 11: *D*, *E*, *I*)
Ctenidodinium combazii Dupin 1968 (Fig. 9: *O*, *P*; Fig. 11: *A-C*, *F*, *G*)
Ctenidodinium continuum Gocht 1970 (Fig. 11: *K*)
Ctenidodinium cornigerum (Valensi 1953) Jan du Chęne, Fauconnier et Fenton 1985 (Fig. 9: *Q*)
Ctenidodinium ornatum (Eisenack 1935) Deflandre 1938 (Fig. 9: *M*, *N*; Fig. 11: *J*)
Ctenidodinium sp.
Dingodinium minutum Dodekova 1975 (Fig. 11: *H*)
Dissiliodinium giganteum Feist-Burkhardt 1990 (Fig. 8: *A*, *B*, *E-H*, *M*)
Dissiliodinium psilatum Prauss 1989
Dissiliodinium sp. A *sensu* Feist-Burkhardt 1990 (Fig. 8: *C*, *I*, *J*, *N*)
Dissiliodinium sp. (Fig. 6: *J*)
Ellipsoidictyum cinctum Klement 1960 (Fig. 9: *K*)
Endoscrinium asymmetricum Riding 1987 (Fig. 12: *A-G*, *I*, *M*, *P*)
Endoscrinium luridum (Deflandre 1938) Gocht 1970 (Fig. 12: *H*, *J*, *L*)
Endoscrinium sp. (Fig. 9: *U*; Fig. 12: *K*)
Epiplosphaera bireticulata Klement 1960 (Fig. 13: *I*)
Epiplosphaera gochtii (Fensome 1979) Brenner 1988 (Fig. 13: *E*)
Epiplosphaera reticulata (Valensi 1953) Courtinat 1989 (Fig. 10: *A-C*; Fig. 13: *F*)
Epiplosphaera reticulospinosa Klement 1960 (Fig. 13: *C*, *D*, *G*, *H*, *K*)
Epiplosphaera sp.
Gonyaulacysta jurassica adecta Sarjeant 1982 (Fig. 11: *N*, *O*)
Gonyaulacysta sp.
Impletosphaeridium varispinosum (Sarjeant 1959) Islam 1993 (Fig. 13: *J*)
Kallosphaeridium praussii Lentin et Williams 1993 (Fig. 8: *D*, *K*, *L*, *O-R*)
Kallosphaeridium sp.
Leptodinium sp. (Fig. 12: *N*, *O*)
Lithodinia reticulata (Dodekova 1975) Gocht 1976 (Fig. 9: *B-D*, *F-H*, *J*)
Lithodinia sp. (Fig. 9: *E*, *I*)
Moendicodinium sp. (Fig. 9: *A*)
Nannoceratopsis ambonis Drugg 1978 (Fig. 7: *K*)
Nannoceratopsis deflandrei Evitt 1961 (Fig. 7: *L*)
Nannoceratopsis gracilis Alberti 1961 (Fig. 7: *A-D*, *G*, *H*)

Nannoceratopsis pellucida Deflandre 1939 (Fig. 9: *L*; Fig. 11: *S*)
Nannoceratopsis plegas Drugg 1978 (Fig. 7: *J*)
Nannoceratopsis raunsgaardii Poulsen 1996 (Fig. 7: *I*)
Nannoceratopsis ridingii Poulsen 1992 (Fig. 7: *O*, *P*)
Nannoceratopsis deflandrei senex (Van Helden 1977) Ilyina 1994 (Fig. 7: *E*, *F*)
Nannoceratopsis spiculata Stover 1966 (Fig. 7: *M*, *N*; Fig. 11: *R*)
Nannoceratopsis sp. (Fig. 6: *A-I*)
Palaeohystrichophora infusorioides Deflandre 1935
?*Rhynchodiniopsis*? *regalis* (Gocht 1970) Jan du Chęne, Fauconnier et Fenton 1985 (Fig. 10: *D*, *H*)
?*Rhynchodiniopsis* sp. (Fig. 6: *K*)
Sentusidinium sp. (Fig. 11: *P*, *Q*)
Spiniferites sp. (Fig. 14: *D*)
Surculosphaeridium? *vestitum* (Deflandre 1939) Davey, Downie, Sarjeant et Williams 1966 (Fig. 13: *L*)
Surculosphaeridium sp. (Fig. 13: *M*)
?*Systematophora* sp. (Fig. 13: *O*)
?*Taeniophora iunctispina* Klement 1960 (Fig. 13: *N*)
Valensiella ovula (Deflandre 1947) Eisenack 1963 (Fig. 10: *E-G*)

REFERENCES

Birkenmajer, K., 1958. *Przewodnik geologiczny po pienińskim pasie skałkowym* (Pieniny Klippen Belt in Poland. Geological guide – in Polish), I-IV, Wydawnictwa Geologiczne, Warszawa.

Birkenmajer, K., 1965. Zarys budowy geologicznej pienińskiego pasa skałkowego Polski (Outlines of the geology of the Pieniny Klippen Belt of Poland). *Rocznik Polskiego Towarzystwa Geologicznego (Annales de la Société Géologique de Pologne)*, 35 (3): 327–356, 401–407.

Birkenmajer, K., 1970. Przedeoceńskie struktury fałdowe w pienińskim pasie skałkowym Polski (Pre-Eocene fold structures in the Pieniny Klippen Belt, Carpathians, of Poland). *Studia Geologica Polonica*, 31: 1–77.

Birkenmajer, K., 1977. Jurassic and Cretaceous lithostratigraphic units of the Pieniny Klippen Belt, Carpathians, Poland. *Studia Geologica Polonica*, 45: 1–159.

Birkenmajer, K., 1979. *Przewodnik geologiczny po pienińskim pasie skałkowym* (Pieniny Klippen Belt of Poland. Geological Guide – in Polish). Wydawnictwa Geologiczne, Warszawa: 1–236.

Birkenmajer, K., 1986. Stages of structural evolution of the Pieniny Klippen Belt, Carpathians. *Studia Geologica Polonica*, 88: 7–32.

Birkenmajer, K. & Myczyński, R., 1977. Middle Jurassic deposits and fauna of the Magura Succession, near Szlachtowa, Pieniny Klippen Belt (Carpathians). *Acta Geologica Polonica*, 27 (3): 387–400.

Birkenmajer, K. & Myczyński, R., 2000. Bajocian age of the Podzamcze Limestone Formation at Stare Bystre, Pieniny Klippen Belt (Carpathians, Poland), based on its macrofauna. *Studia Geologica Polonica*, 117: 49–68.

Birkenmajer, K. & Oszczypko, N., 1988. New lithostratigraphic standard for the Palaeogene of the Magura flysch basin (southern part), Carpathians. *Bulletin of the Polish Academy of Sciences:* Earth sci., 36 (3-4): 253–259).

Birkenmajer, K. & Oszczypko, N., 1989. Cretaceous and Palaeogene lithostratigraphic units in the Magura Nappe, Krynica Subunit, Carpathians. *Annales Societatis Geologorum Poloniae*, 59: 145–181.

Birkenmajer, K. & Pazdro, O., 1963a. Wiek i pozycja geologiczna tzw. "warstw podfliszowych" pienińskiego pasa skałkowego Polski (On the age and geological position of the so-called "Sub-Flysch Beds" of the Pieniny Klippen Belt of Poland). *Rocznik Polskiego Towarzystwa Geologicznego (Annales de la Société Géologique de Pologne)*, 33: 415–456.

Birkenmajer, K. & Pazdro, O., 1963b. Microfaunal reconnaissance of the Dogger of the Pieniny

Klippen Belt (Carpathians) in Poland. *Bulletin de l'Académie Polonaise des Sciences*: sér. sci. géol. et géogr., 11 (3): 127–132.

Birkenmajer, K. & Pazdro, O., 1968. W sprawie tzw. "warstw ze Sztolni" w pienińskim pasie skałkowym Polski (On the so-called "Sztolnia beds" in the Pieniny Klippen Belt of Poland). *Acta Geologica Polonica*, 18 (2): 325–365.

Birkenmajer, K. & Turnau, E., 1962. Carboniferous microspores as secondary deposit in the Aalenian Flysch of the Pieniny Klippen Belt (Carpathians). *Bulletin de l'Académie Polonaise des Sciences*, Sér. sci. géol., géogr., 10 (2): 92–103

Birkenmajer, K. & Tyszka, J., 1996. Palaeoenvironment and age of the Krzonowe Formation (marine Toarcian–Aalenian), Pieniny Klippen Belt, Carpathians. *Studia Geologica Polonica*, 109: 7–42.

Birkenmajer, K., Dudziak, J. & Jednorowska, A., 1970. Wgłębna budowa geologiczna północnej strefy dyslokacyjnej pienińskiego pasa skałkowego w Szczawnicy (Subsurface geological structure of the northern boundary fault zone of the Pieniny Klippen Belt at Szczawnica, Carpathians). *Studia Geologica Polonica*, 61: 7–36.

Blaicher, J. & Sikora, W., 1969. W sprawie wieku ogniwa zwanego aalenem fliszowym w pienińskim pasie skałkowym Polski (On the age of the so-called flysch Aalenian in the Pieniny Klippen Belt of Poland – in Polish). *Kwartalnik Geologiczny* (Warszawa), 13 (3): 716–717.

Blaicher, J. & Sikora, W., 1972. O nowej fliszowej facji albu w pienińskim pasie skałkowym Polski (On a new Albian flysch facies in the Pieniny Klippen Belt of Poland – in Polish). *Kwartalnik Geologiczny* (Warszawa), 16 (4): 1067–1068.

Błaszyk, J., 1968. Małżoraczki z profilu potoku Sztolnia w pienińskim pasie skałkowym Polski (Ostracods from the Sztolnia Creek profile in the Pieniny Klippen Belt of Poland). *Acta Geologica Polonica*, 18 (2): 367–373.

Dodekova, L., 1975. New Upper Bathonian dinoflagellate cysts from northeastern Bulgaria. *Bulgarian Academy of Sciences*: Palaeontology, Stratigraphy and Lithology, 2: 17–34.

Dudziak, K., 1986. Nannoplankton wapienny z formacji szlachtowskiej (jura) w potoku Sztolnia, pieniński pas skałkowy (Calcareous nannoplankton from the Szlachtowa Formation, Jurassic, of Sztolnia Creek, Pieniny Klippen Belt, Carpathians). *Studia Geologica Polonica*, 88: 135–141.

Feist-Burkhardt, S., 1990. Dinoflagellate cyst assemblages of the Hausen coreholes (Aalenian to early Bajocian), Southwest Germany. *Bulletin du Centre des Recherches, Exploration-Production, Elf-Aquitaine*, 22: 273–321.

Feist-Burkhardt, S. & Wille, W., 1992. Jurassic palynology in southwest Germany – state of the art. *Cahiers du Micropaléontologie*, 7: 141–164.

Gąsiorowski, S. M., 1962. Aptychi from the Dogger, Malm and Neocomian in the Western Carpathians, and their stratigraphical value. *Studia Geologica Polonica*, 10: 1–151.

Gedl, P. & Gedl, E., 2001. Wyniki badań palinologicznych jednostki Grajcarka w Potoku Sztolnia, pieniński pas skałkowy, polskie Karpaty Wewnętrzne (Results of palynological investigations of the Grajcarek Unit at Sztolnia Creek, Pieniny Klippen Belt, Polish Inner Carpathians – in Polish). *Jurassica II* (Polish Geological Society, Kraków): 10.

Głuchowski, E. A., 1987. Jurassic and Early Cretaceous Articulate Crinoidea from the Pieniny Klippen Belt and the Tatra Mts, Poland. *Studia Geologica Polonica*, 94: 1–100.

Głuchowski, E. A., Krawczyk, A. J. & Słomka, T., 1983. Isocrinida from the Szlachtowa Formation (Jurassic) of the Pieniny Klippen Belt, Carpathians, Poland. *Studia Geologica Polonica*, 77: 83–88.

Golonka, J. & Rączkowski, W., 1984a. Objaśnienia do Szczegółowej Mapy Geologiczej Polski, 1:50.000, ark. Piwniczna (Explanations to the Geological Map of Poland, sheet Piwniczna, 1:50,000 – in Polish). Instytut Geologiczny & Wydawnictwa Geologiczne, Warszawa.

Golonka, J. & Rączkowski, W., 1984b. Szczegółowa Mapa Geologiczna Polski, 1:50.000, ark. Piwniczna (Detailed Geological Map of Poland, sheet Piwniczna, 1:50,000 – in Polish). Instytut Geologiczny & Wydawnictwa Geologiczne, Warszawa.

Golonka, J. & Sikora, W., 1981. Mikrofacje ścienionych sedymentacyjnie utworów jury i kredy dolnej pienińskiego pasa skałkowego w Polsce (Microfacies of the Jurassic and Lower Cretaceous sedimentarily thinned deposits in the Pieniny Klippen Belt in Poland). *Biuletyn Instytutu*

Geologicznego (Warszawa), 331: 7–37.

Herngreen, G. F. W. & de Boer, K. F., 1974. Palynology of Rhaetian, Liassic and Dogger strata in the eastern Netherlands. *Geologie en Mijnbouw*, 53: 343–368.

Huault, V., 1999. Zones de kystes de dinoflagellés de l'intervalle Aalénien – Oxfordien sur la bordure méridionale du bassin de Paris. *Review of Palaeobotany and Palynology*, 107: 145–190.

Krawczyk, A. & Słomka, T., 1981. *Paleodictyon* z formacji szlachtowskiej pienińskiego pasa skałkowego (*Palaeodictyon* from the Szlachtowa Formation, ?Upper Toarcian–Lower Aalenian, of the Pieniny Klippen Belt of Poland). *Studia Geologica Polonica*, 70: 67–71.

Krawczyk, A. J. & Słomka, T., 1986. Wykształcenie i sedymentacja formacji szlachtowskiej (jura) na wschód od Szczawnicy; jednostka Grajcarka, pieniński pas skałkowy (Development and sedimentation of the Szlachtowa Formation, Jurassic flysch, east of Szczawnica; Grajcarek Unit, Pieniny Klippen Belt, Carpathians. *Studia Geologica Polonica*, 88: 129–134.

Krawczyk, A. J. & Słomka, T., 1987. Egzotyki z formacji szlachtowskiej pienińskiego pasa skałkowego (Exotic rocks from the Szlachtowa Formation (Jurassic flysch) of the Pieniny Klippen Belt, Carpathians). *Studia Geologica Polonica*, 92: 69–74.

Krawczyk, A. J., Muszyński, M. & Słomka, T., 1987. Okruchy skał w psamitach formacji szlachtowskiej pienińskiego pasa skałkowego (Exotic rock fragments from psammitic rocks of the Szlachtowa Formation, Jurassic flysch, of the Pieniny Klippen Belt, Carpathians). *Studia Geologica Polonica*, 92: 75–86.

Krawczyk, A. J., Krobicki, M. & Słomka, T., 1992. Belemnites from the Szlachtowa Formation (Middle Jurassic), Pieniny Klippen Belt, Carpathians. *Bulletin of the Polish Academy of Sciences:* Earth sci., 40 (1): 1–7.

Krawczyk, A. J., Krobicki, M. & Słomka, T., 1995. Palaeoecological significance of trace fossils within Middle Jurassic black flysch (Pieniny Klippen Belt, Carpathians). *Geological Society of Greece, Special Publication (Proceedings, XVth Congress of the Carpatho-Balcan Geological Association*, Sep. 1995, Athens, Greece), 4: 204–208.

Książkiewicz, M., 1972. *Budowa Geologiczna Polski*. IV (Tektonika), 3 (Karpaty). Wydawnictwa Geologiczne, Warszawa: 1–228.

Książkiewicz, M., 1977. Geology of Poland. IV (Tectonics), 3 (The tectonics of the Carpathians). Wydawnictwa Geologiczne, Warszawa: 476–620.

Myczyński, R., 1973. Stratygrafia jury środkowej serii braniskiej okolic Czorsztyna, pieniński pas skałkowy (Middle Jurassic stratigraphy of the Branisko Succession in the vicinity of Czorsztyn, Pieniny Klippen Belt, Carpathians). *Studia Geologica Polonica*, 42: 1–122.

Myczyński, R., 2004. Toarcian, Aalenian and Early Bajocian (Jurassic) ammonite faunas and biostratigraphy in the Pieniny Klippen Balt and the Tatra Mts, West Carpathians. *Studia Geologica Polonica*, 123: 7–131.

Oszczypko, N., Malata, E., Švábenická, L., Golonka, J. & Marko, F., 2004. Jurassic–Cretaceous controversies in the Western Carpathian Flysch: the "black flysch" case study. *Cretaceous Research*, 25: 89–113.

Pazdro, O., 1979. Mikrofauna formacji z Opaleńca (jura środkowa) pienińskiego pasa skałkowego Polski (Microfauna from the Opaleniec Formation, Middle Jurassic, Pieniny Klippen Belt of Poland, Carpathians). *Studia Geologica Polonica*, 61: 105–128.

Prauss, M., 1989. Dinozysten-Stratigraphie und Palynofazies im Oberen Lias und Dogger von NW-Deutschland. *Palaeontographica*, Abt. B, 214: 1–124.

Pugaczewska, H., 1971. Aalenian Gryphaeinae from the Pieniny Klippen Belt of Poland. *Acta Palaeontologica Polonica*, 16 (4): 389–399.

Riding, J. B. & Thomas, J. E., 1992. Dinoflagellate cysts of the Jurassic system. *In:* Powell, A. J. (ed.), *A Stratigraphic Index of Dinoflagellate Cysts*. Chapman & Hall, London: 7–97.

Sikora, W., 1962a. Nowe dane o stratygrafii serii magurskiej w okolicy Szczawnicy (New data on stratigraphy of the Magura succession near Szczawnica – in Polish). *Kwartalnik Geologiczny* (Warszawa), 6 (4): 805–806.

Sikora, W., 1962b. New data on the geology of the Pieniny Klippen Belt. *Bulletin de l'Académie Polonaise des Sciences:* sci. géol., géogr., 10 (4): 203–211.

Sikora, W., 1969. Peninskaja utesova zona. *Putevoditel ekskursji dla očastnikov 14 zasedanija Postojannoj Komisii SEV po geologii.* Geologičeskoe Izdatelstvo, Varšava: 1–38.

Sikora, W., 1971a. Očerk tektogeneza peninskoj utjosovoj zony v Polše v svete novych geologičeskich dannych (Esquisse de la tectogénčse de la zone des Klippes des Pieniny en Pologne d'aprčs de nouvelles données géologiques). *Rocznik Polskiego Towarzystwa Geologicznego (Annales de la Société Géologique de Pologne).* 41 (1): 221–239.

Sikora, W., 1971b. Wycieczka D-2, Karpaty (Excursion D-2, Carpathians – in Polish). *Przewodnik 43. Zjazdu Polskiego Towarzystwa Geologicznego* (Kraków 12-14 IX 1971). Instytut Geologiczny (Warszawa): 222–223.

Tyszka, J., 1999. Foraminiferal biozonation of the Early and Middle Jurassic in the Pieniny Klippen Belt (Carpathians). *Bulletin of the Polish Academy of Sciences*: Earth sci., 47 (1): 27–45.

Woolam, R. & Riding, J. B., 1983. Dinoflagellate cyst zonation of the English Jurassic. *Institute of Geological Sciences*, *Report*, 83/2: 1–41.