Annales Societatis Geologorum Poloniae (2001), vol. 71: 75–103.

BARNASIÓWKA RADIOLARIAN SHALE FORMATION – A NEW LITHOSTRATIGRAPHIC UNIT IN THE UPPER CENOMANIAN–LOWERMOST TURONIAN OF THE POLISH OUTER CARPATHIANS (SILESIAN SERIES)

Krzysztof BĄK[1], Marta BĄK[2] & Zbigniew PAUL[3]

[1] *Institute of Geography, Cracow Pedagogical University, Podchorążych 2, 30-084 Kraków, Poland; e-mail: sgbak@cyf-kr.edu.pl*

[2] *Institute of Geological Sciences, Jagiellonian University, Oleandry 2a, 30-063 Kraków, Poland; e-mail: bak@ing.uj.edu.pl*

[3] *Polish Geological Institute, Carpathian Branch, Skrzatów 1, 31-560 Kraków, Poland; e-mail: pigok@pig.com.pl*

Bąk, K., Bąk, M. & Paul, Z., 2001. Barnasiówka Radiolarian Shale Formation – a new lithostratigraphic unit in the Upper Cenomanian–lowermost Turonian of the Polish Outer Carpathians (Silesian Series). *Annales Societatis Geologorum Poloniae*, 71: 75–103.

Abstract: A new lithostratigraphic unit – the Barnasiówka Radiolarian Shale Formation – is herein defined. It belongs to the Silesian Series of the Outer Carpathians. The formation consists of biosiliceous deposits rich in organic matter, laid down around the Cenomanian–Turonian boundary.

The formation includes, from bottom to top: (1) a series of green to black, calcareous and siliceous shales, alternating with layers of chert, siliceous siltstone and sandstone (up to 10 m thick); (2) a series of green to black, argillaceous to siliceous shales, intercalated with tuffites, bentonites, and a ferromanganese layer (up to 9 cm thick) in its middle part (up to 3.2 m thick); (3) a series of green and red, siliceous siltstones and cherts with intercalations of non-calcareous green shales and benthonites (up to 2 m thick). The total thickness of the formation ranges from 0.5 m in the eastern part (reduced tectonically?) up to about 14–15 m in the middle and the western parts of the Silesian Nappe, due to the increase in the number and thickness of turbidite intercalations.

The formation represents the *Holocryptocanium barbui* – *Holocryptocanium tuberculatum* through the *Alievium superbum* radiolarian zones and the *Uvigerinammina praejankoi*–*Uvigerinammina jankoi* foraminiferal zones, which correspond to the Upper Cenomanian through the lowermost Turonian.

Microfacies and geochemical characteristics of the distinguished lithological types are presented in this paper, based on recent studies and published data.

The described formation has been compared and correlated with deposits of similar age from other tectonic-facies units of the Outer Carpathians in Poland and Ukraine.

Key words: lithostratigraphy, biostratigraphy, Cenomanian, Turonian, Silesian Nappe, Outer Carpathians.

Manuscript received 4 January 2001, accepted 18 June 2001

INTRODUCTION

The Cenomanian–Turonian biosiliceous and organic-rich deposits are widespread in the ancient Mediterranean Tethys area and the Atlantic Ocean. Their detailed local descriptions have included the geochemical, sedimentological and biostratigraphical features (e.g., Schlanger & Jenkyns, 1976; Brumsack & Thurrow, 1986; Herbin *et al.*, 1986a, b; Kuhnt *et al.*, 1986; Arthur *et al.*, 1987).

Similar organic-rich sediments, with abundant radiolarians, forms a characteristic horizon in all tectonic-facies units of the Outer Carpathians (Sujkowski & Różycki, 1930; Sujkowski, 1931, 1932; Burtanówna *et al.*, 1933; Książkiewicz, 1951; Koszarski, 1956; Koszarski *et al.*, 1959; Liszkowa, 1960; Liszkowa & Nowak, 1962; Geroch *et al.*, 1963, 1967, 1985; Kotlarczyk, 1978, 1988). This informal lithostratigraphic unit, deemed to represent the nearly whole Cenomanian in the lithostratigraphic scheme of the Outer Carpathians (see Ślączka & Kaminski, 1998), is used as a guide horizon within the Cretaceous flysch series.

This unit consists mainly of green non-calcareous shales with intercalations of olive, grey and black shales, partly calcareous. The shales are also intercalated with siltstones, fine-grained sandstones and cherts. The middle part of the unit includes a layer of ferromanganese concretions and black shales with manganese crusts and incrustations, and a few layers of bentonites, tuffites and tuff. A tuff layer from this horizon has been dated at the Międzybrodzie section (the eastern part of the Silesian Nappe) as 91.4 Ma ± 4.7 Ma (Van Couvering *et al.*, 1981). The thickness of the unit ranges from dozens of centimetres to about 15 meters.

Various names have been used for these deposits in the Polish and Ukrainian Outer Carpathians. They were described for the first time as "the green and red shales" in the Skole Nappe (Styrnałówna & Cizancourt, 1925). Later, they have been named as "the red cherts with red and green shales" (Sujkowski & Różycki, 1930), "the radiolarites and siliceous marls" (Sujkowski, 1931, 1932) or "Dołhe Radiolarian Shale Formation" (Kotlarczyk, 1978, 1988).

Other names have been used within the Silesian and Subsilesian tectonic-facies units. Burtanówna *et al.* (1933) described these deposits as the "Radiolarian Shales". Later, they have been named as "Transitional Light-Green Clays" (Teisseyre, 1947),"Variegated Shales with Radiolarites" (Świdziński, 1948), "Jasper Beds and Lower Siliceous Marls" (Książkiewicz, 1951; Geroch *et al.*, 1963), "the non-calcareous dark-green and variegated clays" (Huss, 1957), "Green Shales with Radiolarians" (Koszarski *et al.*, 1959), "Radiolarite Beds" (Geroch *et al.*, 1967), "Green Shales with Radiolarians and Radiolarites" (Koszarski in: Ślączka *et al.*, 1993), "Jasper Beds" (Paul *et al.*, 1996), "Green and Radiolarian Shales" (Ślączka in: Ślączka & Kaminski, 1998).

A similar lithological horizon also occurs in the Grajcarek Unit (see Birkenmajer, 1965) – the southernmost tectonic-facies zone of the Magura Nappe, where it has been distinguished as a formal lithostratigraphic unit – the Hulina Formation (Birkenmajer, 1977).

It should be stressed that the presented names of these deposits, used within the Skole, Silesian and Subsilesian tectonic-facies units denote different lithologies. The lower and upper boundaries of the deposits have been accepted at various lithological horizons.

The age of these deposits was defined imprecisely. It was based mainly on the fossils (often redeposited) from the neighbouring lithostratigraphic units, and on the position of the unit in the successions. Thus, the stratigraphic position of the green shales rich in radiolarians has changed in the schemes during the past 50 years (since the Świdziński's proposition in 1948), from the lower Albian to the Cenomanian.

Taking into account the importance of this level for lithostratigraphic division of the Outer Carpathians (as a guide horizon) and its unclear lithostratigraphic definition we propose to define this unit formally as a formation. The presented definition has been prepared according to the principles of the stratigraphic classification and terminology (Birkenmajer (ed.), 1975). This proposal is based mainly on our detailed mapping, biostratigraphic work and sedimentological investigation made during 1997–2000, and also based on all published materials.

The studied sediments are now best exposed in the Silesian Nappe, if compared with other tectonic-facies units of the Polish Outer Carpathians. Most of the data studied by the present authors and known from literature relate to the sediments in this nappe. Thus the new lithostratigraphic unit defined here is restricted to the Silesian series.

HISTORY OF STUDY IN THE SILESIAN NAPPE

History of investigations of "green shales with radiolarians" in the Silesian Nappe had began in the early 30's. These deposits have been first described in the area near Myślenice (Bukowiec Ridge and Barnasiówka Ridge in the Beskid Wyspowy Mts) by Burtanówna *et al.* (1933) as the "Radiolarian Shales". Cherts and variegated shales (attributed to the lower Albian), situated stratigraphically between the Lgota Beds and the variegated shales have been included to this unit. Burtanówna *et al.* (1933) correlated these deposits with those described by Sujkowski & Różycki (1930) from the Skole Nappe (Dołhe Nadłużańskie).

At the same time, Książkiewicz (1933, 1936, 1939) has described the variegated, green and dark shales, partly siliceous, between the Lgota Beds and the Godula Beds near Lanckorona and Żarek (to the west of the latter sections). Later, the same author (Książkiewicz, 1951) has distinguished the "Jasper Chert Beds and Lower Siliceous Marls" as one complex, related to the "Radiolarian Shales" of Burtanówna *et al.* (1933). The distinguished lithotypes have been described at the Góra Zamkowa hill near Lanckorona.

Koszarski *et al.* (1959) have used the name "Green Shales with Radiolarians" for the lowermost part of the variegated shales, including the radiolarite jaspers, siliceous light-green and light-grey marls (similar to the Globigerina or Submenilite Marls) and the manganese nodules. The authors assigned this horizon to the Cenomanian.

The detailed description of the "Jasper Beds and Lower Siliceous Marls" by Książkiewicz (1951) provided the base for distinguishing this horizon on the geological maps of the Polish Outer Carpathians (including *Detailed Geological Map of Poland*, scale 1:50,000 and *Geological Map of Poland, scale 1:200,000*) (see Koszarski & Nowak, 1960; Burtan (ed.), 1964a-c; Burtan & Szymakowska, 1964; Szymakowska & Żytko (eds), 1965; Nowak (ed.), 1963, 1964; Burtan *et al.*, 1976, 1978). The mapping work has documented that the green shales enriched in radiolarians occur in the whole Outer Carpathians (Koszarski & Żytko, 1965). They have been distinguished within the Silesian Nappe on many sheets of the *Detailed Geological Map of Poland*.

Age assignment

The first data about the age of the green shales rich in radiolarians was based on their position in the sections, between the Lgota Series and the Variegated Shales (Burtanówna *et al.*, 1933). These authors suggested their early Albian age.

Later studies on this horizon (see in details in Table 1) were based on findings of macrofossils (inoceramids) in the neighbouring lithological units (Mitura in: Koszarski *et al.*, 1959), microfossils (foraminifers) mostly in thin sections of the cherts (Koszarski *et al.*, 1959), and in the non-calcareous shales (Geroch, 1959, 1960; Koszarski & Liszkowa, 1963; Geroch, 1967; Geroch *et al.*, 1967). Single specimens of poorly preserved planktonic foraminifers, belonging to *Praeglobotruncana stephani* (Gandolfi), *P. turbinata* (Reichel), *Rotalipora appenninica* (Renz), and *R. cushmani* (Morrow) were the base for a revision of the stratigraphic

Table 1

Stratigraphically important fossils described from the green radiolaria-rich shales and from the neighbouring lithostratigraphic units in the Silesian Series (Polish Outer Carpathians)

Author	Locality	Lithology	Age	Fossils important for stratigraphy
Burtanówna *et al.*, 1933	Barnasiówka- Dalin Ridge, Bukowiec Ridge	radiolarian shales	Early Albian	superposition between Lgota Beds and Godula Beds
Nowak, 1957	Targanice (Beskid Mały Mts)	lower Godula Beds; first series of conglomerates and thick-bedded sandstones (in conglomerate bed)	not older than Turonian	*Globotruncana lapparenti tricarinata* Quereau, *Globotruncana lapparenti lapparenti* Bolli; determined in thin sections
	Targanice (Beskid Mały Mts)	lower Godula Beds; lower part of third shale series	not older than Turonian	*Globigerina infracretacea* Glaesner, *Gümbelina globulosa* Ehrenberg, *Globotruncana* ex gr. *lapparenti* (2 specimens)
	Wielka Puszcza	lower Godula Beds; upper part of third shale series	not older than Turonian	*Globotruncana* ex gr. *lapparenti* (2 specimens)
Koszarski *et al.*, 1959	Targanice (Beskid Mały Mts)	lower part of Green Radiolarian Shales; siliceous shales directly above manganiferous shales	Cenomanian	a few globotruncanids - determined in thin sections
F. Mitura in: Koszarski *et al.*, 1959	Olszówka Górna (Nowak, 1958)	lower Godula Beds; second shale series	not older than Middle Cenomanian	*Inoceramus propinquus* Münster
	Kołowrót (Nowak, 1958)	lower Godula Beds; second sandstone-conglomerate series	not older than Middle Cenomanian	*Inoceramus crippsi* Mantel
	Bystra Śląska (Nowak, 1958)	lower Godula Beds; lower part of second shale series	not older than Middle Cenomanian	*Inoceramus crippsi* Mantel, *Inoceramus etheridgi* Woods
	Straconka (Nowak, 1958)	lower Godula Beds; upper part of third shale series	not older than Middle Cenomanian	*Inoceramus pictus* Sowerby
	Szyndzielnia Dolna (Nowak, 1958)	lower Godula Beds	not older than Middle Cenomanian	*Inoceramus pictus* Sowerby
Koszarski & Liszkowa, 1963	Szynwałd k. Tarnowa;	upper part of Gaize Beds	Late Cenomanian	*Praeglobotruncana stephani stephani* (Gandolfi), *Praeglobotruncana stephani turbinata* (Reichel), *Rotalipora* cf. *appenninica* (Renz), *Rotalipora* cf. *cushmani* (Morrow)
	Frysztak	Green Radiolarian Shales	Cenomanian	*Rotalipora* cf. *appenninica* (Renz)
Geroch *et al.*, 1967	Żarek Hill near Kalwaria Zebrzydowska	Radiolarite Beds	not younger than Cenomanian	*Hedbergella* cf. *delrioensis* (Carsey), *Hedbergella* cf. *planispira* (Tappan)
	composite	Variegated Shales	Late Cenomanian through Early Senonian	*Uvigerinammina jankoi* Majzon
Geroch, 1967	Straconka	Radiolarite Beds	Cenomanian?	agglutinated foraminifers with *Thalmannammina neocomiensis* Geroch, *Plectorecurvoides alternans* Noth, *Trochammina* ex. gr. *globigeriniformis* (Jones & Parker)
	Straconka	upper division of lower Godula Beds	Turonian	agglutinated foraminifers with *Uvigerinammina jankoi* Majzon
Geroch *et al.*, 1985	Brody near Lanckorona	Radiolarite Beds	Late Cenomanian–Early Turonian?	*Hedbergella* cf. *delrioensis* (Carsey), *Whiteinella* cf. *brittonensis* (Loeblich & Tappan). *Praeoglobotruncana* cf. *praehelvetica* (Trujillo)
Gzik, 1990; Gzik & Koszarski, 1992	Brody near Lanckorona	Radiolarite Beds	Late Cenomanian–Early Turonian	*Rotalipora* cf. *cushmani* (Morrow), *Hedbergella* cf. *delrioensis* (Carsey), *Whiteinella brittonensis* (Loeblich & Tappan), *Praeglobotruncana stephani* (Gandolfi)
Bąk, 1994	Międzybrodzie	Radiolarite-bearing deposits	Cenomanian	*Holocryptocanium barbui* Dumitrică, *Gongylothorax siphonofer* Dumitrică, *Protostichocapsa stocki* (Campbell & Clark), *Stichomitra communis* Squinabol
Bąk M., 2000; Bąk K. & Bąk M., 2000	Brody near Lanckorona, Trzemeśnia, Jasienica, Węglówka	green shales enriched in radiolarians	Late Cenomanian–Early Turonian	*Hemicryptocapsa prepolyhedra* Dumitrică, *Hemicryptocapsa polyhedra* Dumitrică, *Alievium superbum* (Squinabol), *Patellula ecliptica* O'Dogerthy, *Patellula andrusovi* Ožvoldová, *Crucella cachensis* (Pessagno), *Uvigerinammina praejankoi* Neagu, *Uvigerinammina jankoi* Majzon

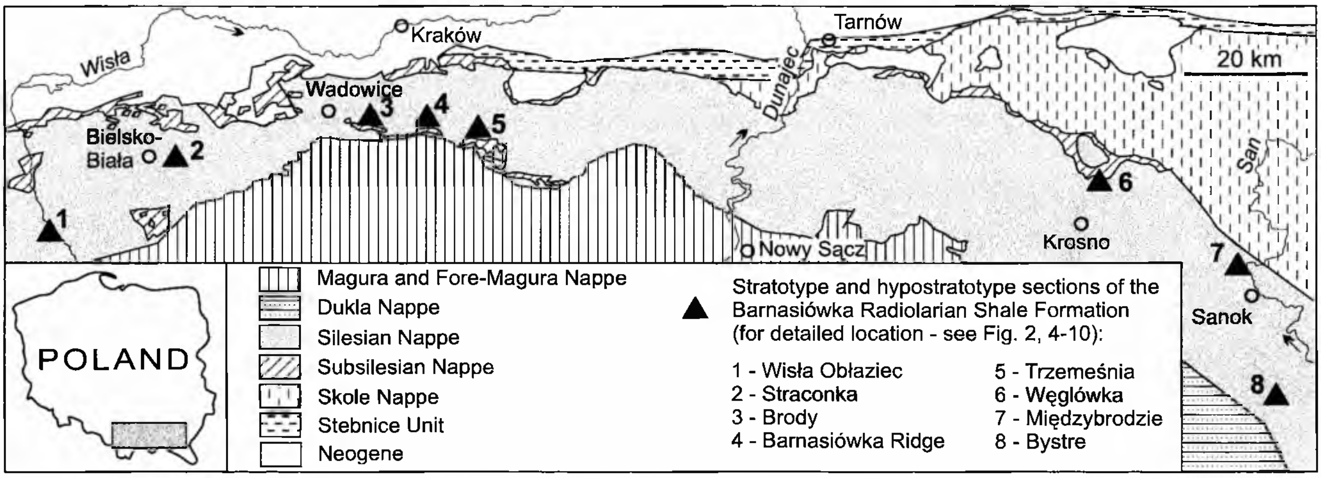

Fig. 1. Geological sketch-map of the Polish Carpathians with location of stratotype and hypostratotype sections of the Barnasiówka Radiolarian Shale Formation

position of this horizon to the Cenomanian. The Cenomanian age of these deposits has been confirmed by a micropalaeontological study of the Variegated Shales, which cover the radiolarian-rich green shales (Table 1). The planktonic and benthonic (deep-water agglutinated) foraminifers, found near the base of the Variegated Shales have included younger assemblages (with *Globotruncana* ex gr. *lapparenti* and *Uvigerinammina jankoi* Majzon) of the Turonian and lower Senonian age (Geroch & Gradziński, 1955; Nowak, 1956; Geroch, 1957, 1960, 1967; Geroch *et al.*, 1967).

Later micropalaeontological studies of the radiolarian-rich green shales have been associated with preparation of a few sheets of the *Detailed Geological Map of Poland* in scale 1:50,000. A synthesis of these studies have been presented in the biostratigraphic schemes of the Polish Outer Carpathians (Morgiel & Olszewska 1981; Geroch & Nowak, 1984; Geroch & Koszarski, 1988; Olszewska, 1997). The studied horizon was placed (Geroch & Koszarski, 1988) within the Middle and Upper Cenomanian in the Silesian, Subsilesian and Skole series, and within the Cenomanian and Turonian (nearly the whole stages) in the Dukla–Grybów and Magura series.

Detailed micropalaeontological studies of the radiolarite series have been carried out in the Lanckorona section (Gzik, 1990). Its age was determined as the Late Cenomanian trough the Early Turonian (Gzik & Koszarski, 1992) on the base of the few poorly preserved planktonic foraminifers (e.g., *Rotalipora* cf. *cushmani* (Morrow), *Praeglobotruncana* cf. *stephani* (Gandolfi) and *Whiteinella brittonensis* (Loeblich & Tappan)).

Radiolaria, which are the most abundant biotic component of these sediments, have not been practically studied at all, up to the 90's of the last century. The only data include an information about the frequent occurrence of specimens from the order Spumellaria (Geroch *et al.*, 1967; Gzik, 1990; Gzik & Koszarski, 1992). Detailed studies were carried out in the Międzybrodzie section near Sanok (Bąk, 1994), from which the radiolarian assemblage was correlated with the Cenomanian radiolarian *Holocryptocanium barbui – Holocryptocanium tuberculatum* Zone.

Recently, detailed study of radiolaria was made in other sections of the Silesian Nappe (Bąk, 2000), where the assemblage is dominated by spherical Nassellaria (60–99% of radiolarian specimens). The Late Cenomanian to Early Turonian age was suggested for these deposits, based on the comparison with radiolarian associations from other oceanic realms. Additional studies, which included both radiolarians and foraminifers from the same samples of the described horizon, allowed us to propose biostratigraphic zones around the Cenomanian/Turonian boundary (Bąk, M. & Bąk, K., 2000; Bąk, K. & Bąk, M., 2000), correlated with chronostratigraphy. These studies are accepted here as the base to the age assignment of the radiolaria-rich green shales.

BARNASIÓWKA RADIOLARIAN SHALE FORMATION – A NEW LITHOSTRATIGRAPHIC UNIT

Name of the formation

The name of the formation (formacja łupków radiolariowych z Barnasiówki (fm) – in Polish) came after exposures located at the Barnasiówka Ridge (the Beskid Wyspowy Mts; Fig. 1), where these deposits were first described in the Silesian Nappe (Burtan *et al.*, 1933). The name also refers to the predominant lithology of the formation.

Type area

The type area of occurrence is the Barnasiówka Ridge (the Beskid Wyspowy Mts) near Myślenice. Burtan (1968) and Burtan & Turnau-Morawska (1978) provided a general description of the deposits from this area.

The deposits are the best exposed now in two quarries in the Barnasiówka Ridge (Barnasiówka-Ostra Góra quarry and Barnasiówka-Jasienica quarry) and in the streams,

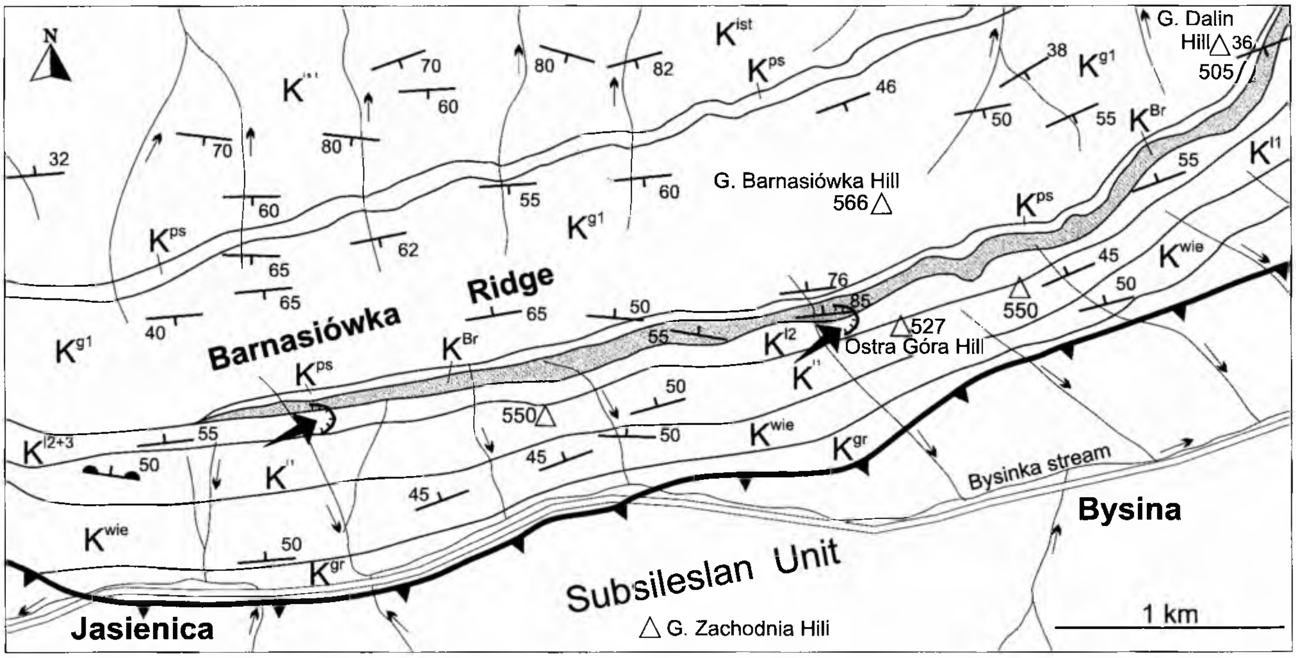

Fig. 2. Geological map of the stratotype area of the Barnasiówka Radiolarian Shale Formation at the Barnasiówka Ridge (Beskid Wyspowy Mts; Outer Carpathians; Silesian Nappe) (after Burtan, 1964a, and Burtan & Szymakowska, 1964): K^{gr} – Hradište Sandstones; K^{wie} – Verovice Shales; K^{l1} – Lower Lgota Beds; K^{l2+3} – Middle Lgota Beds and Mikuszowice Cherts; K^{Br} – **Barnasiówka Radiolarian Shale Formation**; K^{ps} – Variegated Shales; K^{g1} – Lower Godula Beds; K^{ist} – Istebna Sandstones; black arrow – location of stratotype sections

which cross-cut this mountain ridge between the Pisana and Dalin hills (Figs 1, 2).

Barnasiówka-Ostra Góra quarry. The section is located on the left slope of the Safiana stream valley, which cuts the Barnasiówka Ridge near the Ostra Góra hill. The lower part of the formation includes a 10 m-thick series of calcareous and non-calcareous green, grey and black shales, with thin- to medium-bedded siliceous siltstone, fine-grained siliceous sandstone and chert intercalations (Fig. 3). A contact with thick-bedded Mikuszowice Cherts is visible there.

Green non-calcareous shales dominate there. Alteration of black calcareous shales, dark to grey spotty calcareous shales and green non-calcareous shales is a characteristic feature of this part of the formation. The shales, mainly grey and green, are bioturbated (numerous *Chondrites* ichnsp.), mostly in the lower and middle parts of this series. Intercalations of siltstones, sandstones and cherts are up to 12 cm thick (usually 4–8 cm thick). Their number decreases upwards in the section. The ratios of siltstones, sandstones and cherts to shales range from 1:1 (in the lowermost 3.5 m thick series), through 2:3 and 1:3 (in the next 3.8 m and 1.4 m thick series, respectively) to 1:5 (in the uppermost part of the series). Most of the siltstones and sandstones are strongly siliceous; however, they also contain carbonate particles. Content of $CaCO_3$ decreases markedly in the upper part of the series. The colour of the beds varies from grey-green through grey-brown to black. The weathered surfaces are yellow-red.

The middle part of the formation includes a 2 m-thick series of green, olive and black non-calcareous shales, black tuffites and light-green bentonites. Yellow ferrous incrustations occur on the contact zones between the black shales and bentonites. The series is predominantly argillaceous and devoid of siltstone and sandstone intercalations. It is covered by 1.2 m-thick series of siliceous black and green shales, tuffites and very thin light-green bentonite layers. Black parallel-laminated, porous ferromanganese layer (9 cm thick) occurs in the uppermost part of this series. The layer weathers into ellipsoidal nodules, whose diameters are of a few centimetres. A 3 cm layer of light-green bentonite overlies the ferromanganese bed; it terminates the middle part of the formation.

The upper part of the formation is a series of 60 cm-thick, green and red, highly siliceous mudstones and cherts, disintegrating along parallel-laminated surfaces. The thickness of the beds ranges from 4 to 18 cm. Non-calcareous green shales and very thin-bedded siliceous green mudstones appear higher up in the succession. The first red shale layer (1–2 cm thick) occurs 20 cm above the top of the firmly cemented of the siliceous mudstones and cherts. This red layer is accepted as a base of the Variegated Shales. A few centimetres-thick horizon of ferromanganese crust (layer?) appears 5 cm higher up. The predominance of the red non-calcareous shales within the Variegated Shales begins one meter upwards in the succession.

Barnasiówka-Jasienica quarry. The section is located on the left slope of the valley which cuts the Barnasiówka Ridge near the Szklary pass at Jasienica (Figs 1, 2). The lower part of the formation with transition to the Mikuszowice Cherts is visible here. It includes green, grey and black shales, mostly non-calcareous, with numerous in-

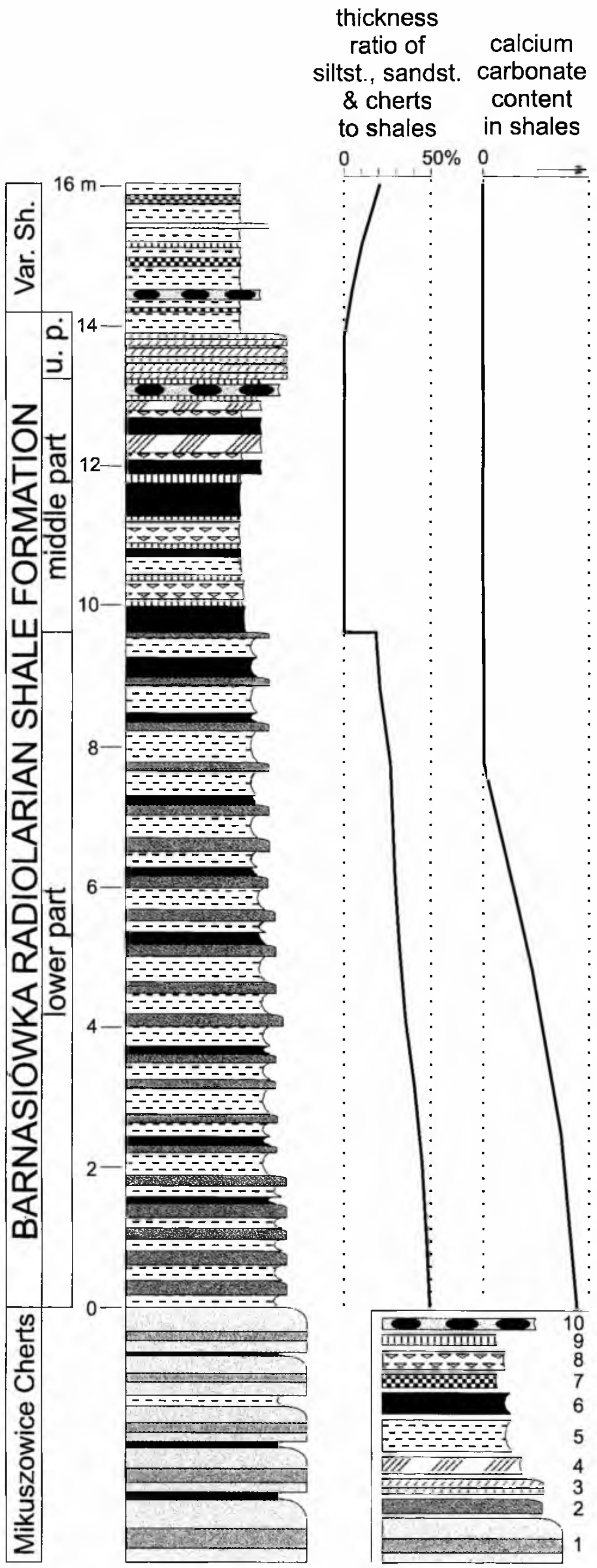

Fig. 3. Lithostratigraphical column of the Barnasiówka Radiolarian Shale Formation in the Barnasiówka-Ostra Góra quarry: *1* – thick-bedded sandstone with chert (grey-blue spongolite); *2* – grey-green, grey-brown and dark siliceous thin- to medium-bedded fine-grained sandstone, mudstone or chert; *3* – thin-to medium-bedded green and red strongly siliceous mudstone; *4* – siliceous black and green shale; *5* – grey (spotty), olive and green shale; *6* – black shale; *7* – variegated and red claystone; *8* – tuffite; *9* – bentonite; *10* – black parallel-laminated, porous, ferromanganese layer, weathered to ellipsoidal nodules; Var. Sh. – Variegated Shales; u. p. – upper part

Reference sections (hypostratotypes)

Hypostratotypes are the sections which have been well exposed during our investigations and those described in details in literature. They include (from west to east): Wisła – Obłaziec quarry, Straconka near Bielsko-Biała, Brody village near Lanckorona, Trzemeśnia village, Czarny Potok stream near Węglówka, Międzybrodzie near Sanok, and Jabłonki stream near Bystre village.

Wisła – Obłaziec quarry. The section is located in a large quarry on the left bank of the Wisła river, north of the Gahura stream at Wisła village (Figs 1, 4). Thick- and thin-bedded Godula sandstones exploited in this quarry belong to the Brenna – Obłaziec anticline (Burtanówna *et al.*, 1937), with the Lgota Beds or the Lower Godula Beds in its core.

The deposits of the Barnasiówka Radiolarian Shale Formation are strongly tectonically deformed in this section (Burtan, 1968). The unit contacts tectonically with the sandstones of the Godula Beds and its lower boundary (with the Mikuszowice Cherts) is not visible. The section (Burtan, 1968) includes the lower and middle parts of the formation (about 15 m thick). The lower part includes siliceous glauconitic sandstones, alternating with non-calcareous green shales, dark-green spongolites, green jaspers and single layers of grey marly shales. A few layers of black tuffites and intercalations of thin- to medium-bedded siltstones, fine-grained sandstones and cherts. The features of shales and sandy intercalations are the same as in the Barnasiówka-Ostra Góra quarry.

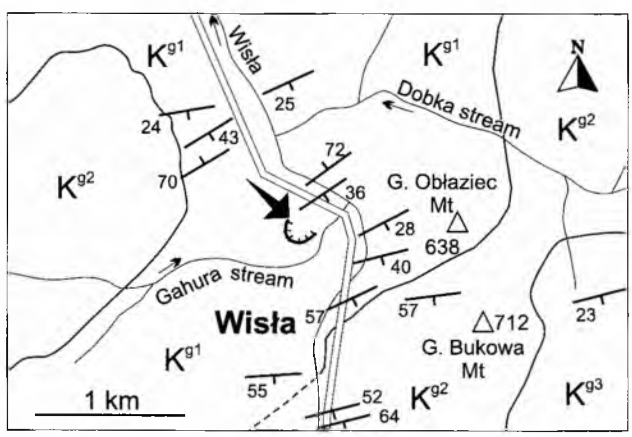

Fig. 4. Geological map of the area near the hypostratotype section of the Barnasiówka Radiolarian Shale Formation at Wisła (Beskid Śląski Mts; Outer Carpathians; Silesian Nappe) (after Burtan, 1964b; Nowak, 1964): K^{g1} – Lower Godula Beds; K^{g2} – Middle Godula Beds; K^{g3} – Upper Godula Beds; black arrow – location of hypostratotype section

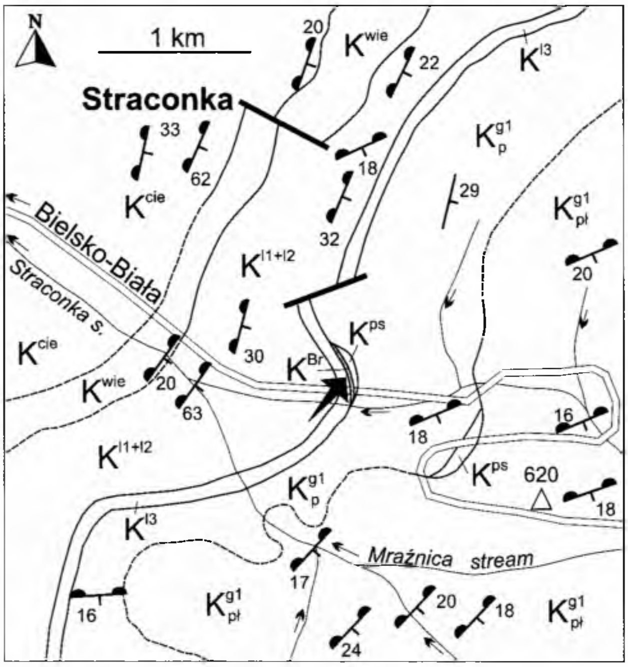

Fig. 5. Geological map of the area near the hypostratotype section of the Barnasiówka Radiolarian Shale Formation at Straconka quarry near Bielsko-Biała (Beskid Mały Mts; Outer Carpathians; Silesian Nappe) (after Nowak, 1963): K^{cie} – Cieszyn Beds; K^{wie} – Verovice Shales; K^{l1+l2} – Lower and Middle Lgota Beds; K^{l3} – Mikuszowice Cherts; K^{Br} – **Barnasiówka Radiolarian Shale Formation**; K^{ps} – Variegated Shales; K_p^{g1} – Lower Godula Sandstones; $K_{pł}^{g1}$ – sandstones and shales of Lower Godula Beds; black arrow – location of hypostratotype section

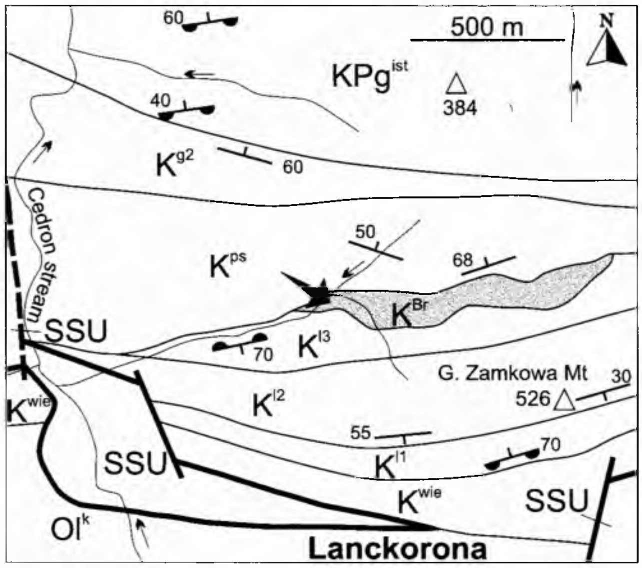

Fig. 6. Geological map of the area near the hypostratotype section of the Barnasiówka Radiolarian Shale Formation at Brody near Lanckorona (Beskid Wyspowy Mts; Outer Carpathians; Silesian Nappe) (after Szymakowska & Żytko, 1965): K^{wie} – Verovice Shales; K^{l1} – Lower Lgota Beds; K^{l2} – Middle Lgota Beds; K^{l3} –Mikuszowice Cherts; K^{Br} – **Barnasiówka Radiolarian Shale Formation**; K^{ps} – Variegated Shales; K^{g2} – Middle Godula Beds; KPg^{ist} – Istebna Beds; Ol^{k} – Krosno Beds; SSU – Subsilesian tectonic-facies Unit; black arrow – location of hypostratotype section

light-green bentonites, and brown-black ferromanganese nodules occur near the thick layer of sandstone, which forms the middle part of the formation. Burtan & Turnau-Morawska (1978) have studied mineralogy of this unit.

Straconka quarry near Bielsko-Biała. The section is located in a quarry, near the road Bielsko-Biała – Międzybrodzie Bialskie at Straconka (Figs 1, 5). Thick- and thin-bedded Godula sandstones are exploited in this quarry. The formation, about 20 m thick, lies here between the Mikuszowice Cherts and the Variegated Shales.

The lower part of the formation consists of green, grey (spotty) and black shales with thin intercalations of cherts and glauconitic sandstones. Black and green shales with layers of tuffites, light-green bentonites and ferromanganese nodules appear higher up in the succession (middle part of the formation). The upper part of the formation consists of muddy claystones, siliceous shales with intercalations of thin-bedded cherts, sandstones and rare bentonites.

Gucwa & Wieser (in Gucwa & Pelczar, 1992) studied the geochemical content of the chert and clay mudstone layers (5 analysis) from this section.

Brody village near Lanckorona. The section is located between Lanckorona and Brody, on the northern slope of the Zamkowa Góra hill, along the stream which is a right tributary of the Cedron creek (Figs 1, 6). The Barnasiówka Radiolarian Shale Formation lies here between the Mikuszowice Cherts and the Variegated Shales (Książkiewicz, 1951). The sediments are strongly tectonically deformed. Recently, the whole lithological sequence of the formation has been reconstructed from several outcrops along the stream (Gzik, 1990).

Black and green non-calcareous, partly siliceous shales, disintegrating into small flakes, with intercalations of thin-bedded siliceous glauconitic sandstones, represent the lower part of the formation (4.5 m thick) in this section. Black manganiferrous non-calcareous shales with ferromanganese micro- and macronodules (up to 6 cm in diameter) and intercalations of green non-calcareous shales and bentonites lie higher up in the section. They form the middle part of the formation, 2 m thick. The ferromanganese micronodules consist of birnesite, which create pseudomorphs after former carbonates, such as rhodochrosite or Ca-rhodochrosite (Wieser in: Geroch *et al.*, 1985). Peripheral parts of the birnesite micronodules are enriched in Mn, Ca, Cu, Ni and Zn, while their central parts – in Fe and Mg (*op. cit.*). Olive-green and green non-calcareous thin- to medium-bedded siliceous claystones, with very thin green non-calcareous shale intercalations are characteristic lithologies in the upper part of the formation. This part is about 4 m thick, though, tectonic repetition is possible here. Thin-bedded glauconitic sandstones and thin- to medium-bedded green cherts (jaspers of Książkiewicz, 1951), partly laminated, occur in the uppermost part of the formation.

Książkiewicz (1951) described microstructure of the cherts (2 samples) and so-called siliceous marls (2 samples). Gucwa and Wieser (in Gucwa & Pelczar, 1992) have studied the chemical composition of the cherts (5 analyses) and

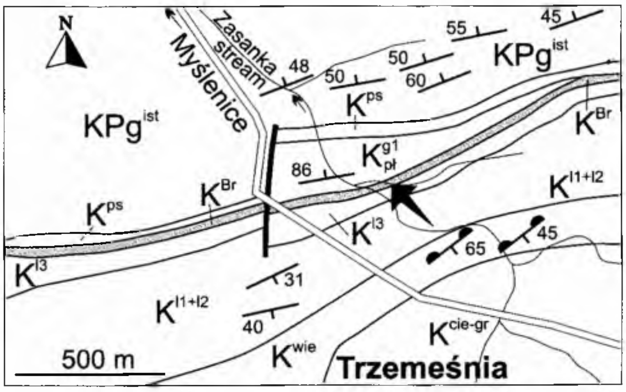

Fig. 7. Geological map of the area near the hypostratotype section of the Barnasiówka Radiolarian Shale Formation at Trzemeśnia near Myślenice (Beskid Wyspowy Mts; Outer Carpathians; Silesian Nappe) (after Burtan, 1964b, c): $K^{cie\text{-}gr}$ – Cieszyn Beds and Hradište Sandstones; K^{wie} – Verovice Shales; K^{l1+l2} – Lower and Middle Lgota Beds; K^{l3} – Mikuszowice Cherts; $\boldsymbol{K^{Br}}$ – **Barnasiówka Radiolarian Shale Formation**; K^{ps} – Variegated Shales; $K_{pł}^{g1}$ – sandstones and shales of Lower Godula Beds; KPg^{ist} – Istebna Beds; black arrow – location of hypostratotype section

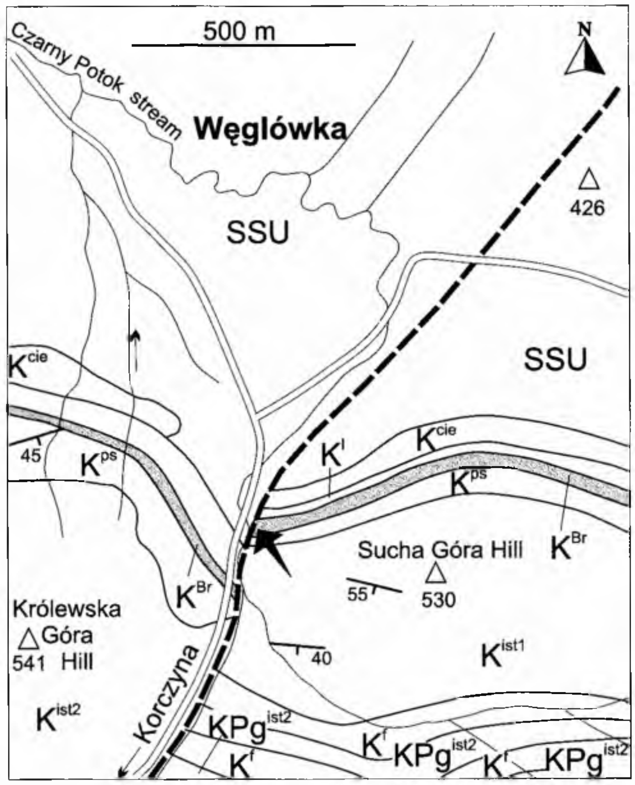

Fig. 8. Geological map of the area near the hypostratotype section of the Barnasiówka Radiolarian Shale Formation in Czarny Potok stream at Węglówka near Krosno (Dynów Foothills; Outer Carpathians; Silesian Nappe) (after Jucha, Mitura & Świdziński in Wdowiarz, 1968): K^{cie} – Cieszyn Beds; K^{l} – Lgota Beds; $\boldsymbol{K^{Br}}$ – **Barnasiówka Radiolarian Shale Formation**; K^{ps} – Variegated Shales; K^{f} – Fucoide Marls; K^{ist1} – Lower Istebna Beds; KPg^{ist2} – Upper Istebna Beds; SSU – Subsilesian tectonic-facies Unit; black arrow – location of hypostratotype section

claystone layers (3 analyses) from this section.

Trzemeśnia. This section is situated in Trzemeśnia, about 10 km east of Myślenice town, near the mouth of a right tributary of the Zasanka creek at the Łęki settlement (Figs 1, 7). The formation occurs here between the Mikuszowice Cherts and the Variegated Shales. Sedimentary contact with the overlying Variegated Shales is visible in this section.

The lower part of the formation (a few metres thick) is composed of green and black non-calcareous shales with intercalations of thin- to medium-bedded cherts and glauconitic sandstones. Thin layers of olive-green marly shales occur sporadically. Two thin layers of conglomerates have been also described from the lowermost part of the sequence (Burtan & Turnau-Morawska, 1978). Black non-calcareous manganiferrous shales with intercalations of a thick green tuffite layer, thin light-green bentonite layers, green and black siliceous claystones and a layer of manganese nodule, a few cm thick, occur higher up in the section. This is the middle part of the formation, 2.8 m thick. A few ferromanganese crusts (up to 5 cm thick) occur in the contact zone between the black shales and the light-green bentonites. Green siliceous claystones dominate in the upper part of the formation. They alterate with very thin- and thin-bedded grey-green laminated sandstones and cherts, and very thin layers of green non-calcareous shales.

Burtan and Turnau-Morawska (1978) have studied mineral composition of the chert, bentonite and tuffite layers, based on thin sections.

Czarny Potok in Węglówka. This section is located in the right bank of the Czarny Potok stream in Węglówka (Figs 1, 8). The formation occurs between the Lgota Beds and the Variegated Shales (Koszarski, 1956; Wdowiarz, 1968). Sedimentary contact with the Variegated Shales is visible in this section. The formation is in tectonic contact with the Middle Lgota Beds (Koszarski, 1956). The section is situated within a northern limb of the Czarnorzeki – Zmiennica – Turze Pole Fold, near the frontal thrust of the Silesian Nappe (Teisseyre, 1947).

The formation consists mainly of non-calcareous green, olive-green, grey and black shales. Silty and calcareous shales occur in the lower part of the section. Very thin- and thin-bedded fine-grained sandstones and cherts are more frequent in the upper part.

Międzybrodzie near Sanok. The section is located in the left bank of the San river at Międzybrodzie near Sanok (Figs 1, 9). The formation lies between the Gaize Beds and the Variegated Shales (Koszarski, 1956). Sedimentary contacts with the neighbouring units have been noted in this section (Koszarski in: Geroch *et al.*, 1963). The outcrop area belongs to the small anticline, a part of the Grabownica – Załuż Fold, the northernmost part of the Silesian Nappe (Wdowiarz, 1953). However, it should be noted that the Cretaceous succession in this fold of the Gaize Beds and the Węglówka Marls resembles that of the Subsilesian rather than the Silesian Nappe. This area could thus be a transitional zone between these realms during the Cretaceous period.

A series dominated by green, grey-green, dark-grey and

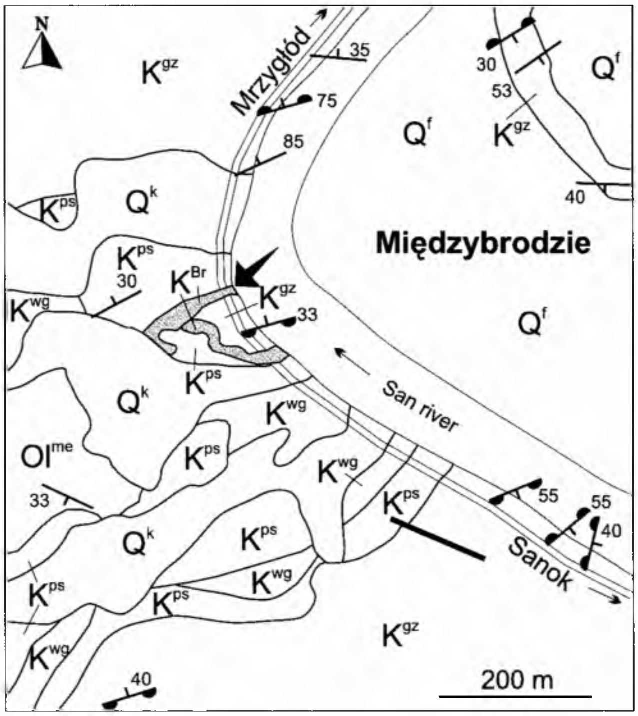

Fig. 9. Geological map of the area near the hypostratotype section of the Barnasiówka Radiolarian Shale Formation at Międzybrodzie near Sanok (Sanok Foothills; Outer Carpathians; Silesian Nappe) (after Koszarski, 1968): K^{gz} – Gaize Beds; $\boldsymbol{K^{Br}}$ – **Barnasiówka Radiolarian Shale Formation**; K^{ps} – Variegated Shales; K^{wg} – Węglówka Marls; Ol^{me} – Menilite Shales; Q^{k} – colluvium; Q^{f} – alluvium; black arrow – location of hypostratotype section

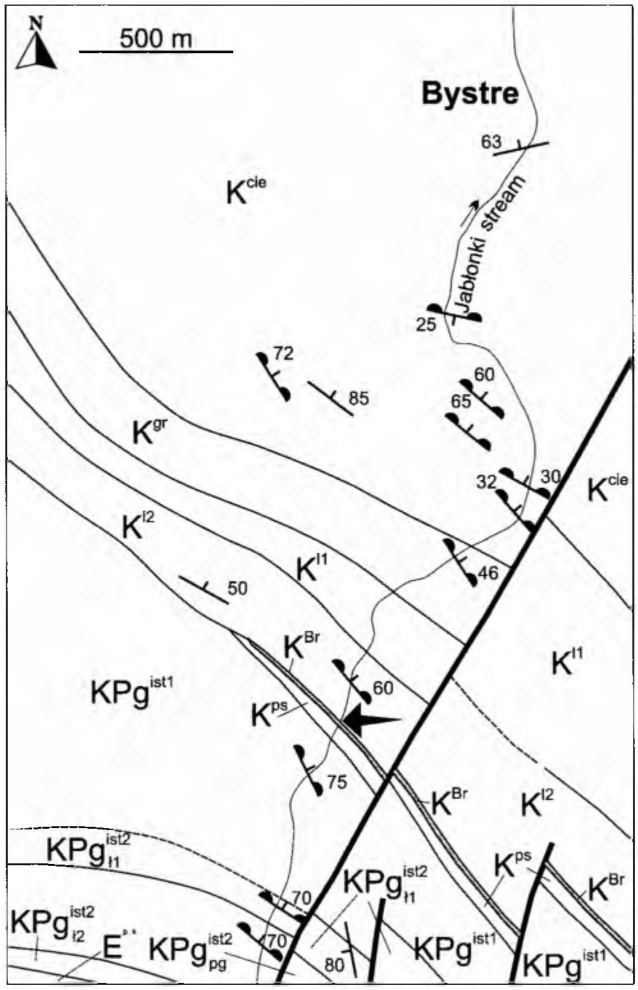

Fig. 10. Geological map near the hypostratotype section of the Barnasiówka Radiolarian Shale Formation in Jabłonki stream at Bystre near Cisna (Bieszczady Mts; Outer Carpathians; Silesian Nappe) (after Ślączka, 1973): K^{cie} – Cieszyn Beds; K^{gr} – Hradište Sandstones; K^{l1} – Lower Lgota Beds; K^{l2} – Upper Lgota Beds; $\boldsymbol{K^{Br}}$ – **Barnasiówka Radiolarian Shale Formation**; K^{ps} – Variegated Shales; KPg^{ist1} – Lower Istebna Sandstones; $KPg_{l1}{}^{ist1}$ – Lower Istebna Shales; KPg^{ist2} – Upper Istebna Sandstones; $KPg_{l2}{}^{ist2}$ – Upper Istebna Shales; E^{ps} – Variegated Shales; black arrow – location of hypostratotype section

black shales with intercalations of sandy siliceous marls, silicified gaizes and fine-grained laminated sandstones and mudstones forms the lower part of the formation. These deposits have been described as the uppermost part of the Gaize Beds by Koszarski (1968). They do not outcrop now, so their thickness can not be reliably determined. The middle part of the formation is 2 m thick and consists of green-grey to black shales with manganiferrous shales, which include ferromanganese nodules (Koszarski, 1968). A few thin layers of yellow bentonite (0.3–2.0 cm) and tuff occur within the black manganiferrous shales. The heavy minerals assemblage in the bentonites is enriched in titanite and apatite (Wieser, 1973). The tuff layer has been dated as 91.4 ± 4.7 Ma ("Międzybrodzie Tuff 5"; Van Couvering *et al.*, 1981), based on zircon fission-tracks. Non-calcareous green and dark claystones, in a series 1.75 m thick, occur 80 cm above the third bentonite layer. The main mineral component of the claystones is clinoptilolite, accompanied by montmorillonite, and accesorric illite, quartz and albite. The claystones contain also barite and celestobarite crystals (Wieser, 1973, 1982a).

The upper part of the formation includes green shales, a few metres thick, silicified in the lower part, with a few thin layers of white-grey siliceous marls and lenses of radiolarites (Koszarski, 1968).

Gucwa and Wieser (in Gucwa & Pelczar, 1992) have studied the geochemistry of the chert (1 analysis), clay mudstone layers (5 analyses) and manganiferous shales (2 analyses) from this section.

Jabłonki stream near Bystre. The section is located in the left bank of the Jabłonki stream at Bystre (Figs 1, 10). The formation occurs between the Lgota Beds and the Variegated Shales, which belong to the Bystre Slice (Ślączka, 1959). Sedimentary contact with the Variegated Shales is visible in this section.

The formation is condensed in this section. Its lower part comprises non-calcareous, partly siliceous, green, dark-grey and black shales, with numerous intercalations of thin-bedded grey and green siliceous siltstones and very fine-grained sandstones. The green non-calcareous shales, devoid of silty intercalations represent the upper part of the formation.

Lithology

Several different lithologies have been distinguished in the Barnasiówka Radiolarian Shale Formation. These are green and black shales, grey, green and red cherts, ferromanganese layer, tuff, tuffites and bentonites, and siliciclastic turbidite intercalations.

Green shales. They are the dominant lithology within the Barnasiówka Radiolarian Shale Formation. The green shales make up to 54% of the total thickness of the formation. Thickness of the most shale layers ranges from 1 to 8 cm; the maximum thickness is 30 cm. Colour of the shales changes from pale-green to dark-olive. The shales are calcareous in the lower part of the formation (Fig. 3). Most of them are highly bioturbated (Fig. 11A) with numerous *Chondrites* traces (Fig. 11D). In the middle and upper parts of the formation, shales are only siliceous. The siliceous shales are enriched in the manganese. This related to the presence of diagenetic carbonates of Mn, Fe and Mg, like rhodochrosite, Fe-rhodochrosite, Ca-rhodochrosite, manganocalcite, oligonite and siderite (Geroch *et al.*, 1985). The carbonates form micronodules, which grew on radiolarian skeletons. The copper (up to 1216 ppm), chrome (up to 46 ppm) and vanadium (220 ppm) are the most frequent trace elements in the green shales (Gucwa & Pelczar, 1992).

The observations of sedimentary structures in thin sections show that most of the green shales represent upper parts of turbidite sequences. They are the *D* and *E* Bouma divisions.

Some of the shales are pelagic sediments, representing radiolarian and foraminiferal microfacies. Marly shales contain very small tests of planktonic foraminifers of genera *Globigerinelloides, Hedbergella* and *Heterohelix* (Fig. 11A, B). They are associated with rare agglutinated foraminifers (Fig. 11C). This microfacies is characteristic for the lower part of the formation.

Siliceous shales (olive and dark-grey) contain abundant radiolarians (genera: *Holocryptocanium*, *Dictyomitra*, *Pseudodictyomitra*, *Crucella* and *Patellula*) and sponge spicules. Radiolaria (Nassellaria) and sponge spicules are oriented parallel to the bedding. Most radiolarian skeletons are not deformed (Fig. 11E). Many shale layers have thin laminae of silty siliciclastic and mixed siliciclastic-organic material at their base. Some shales are wavy- and parallel-laminated; radiolarian tests are their main component.

Black shales. The black shales (up to 5% of the total thickness of the formation) are the most characteristic lithological variety in the lower and middle parts of the formation, where they are at bases of repetitive successions, passing upwards to dark-grey spotty calcareous shales and green non-calcareous shales. The thickness of the black shales in these sequences increases from a few millimetres in the lower part of the formation to 10–20 cm in the middle part. The maximum thickness reaches 70 cm in the Brody section in the middle part of the formation, where they are dominant lithological type. The black shales are calcareous only in the lower part of the section. Weathered surfaces of the shales are often covered with light-yellow jarosite.

Parallel or wavy lamination is visible in thin sections of the black shales, emphasised by laminae of organic matter within biogenic-terrigenous material (Figs 11E, 12C). Radiolarians are the only biotic component of the shales. Besides them the black shales include angular quartz grains, weathered glauconite grains, and fragments of claystones (Turnau-Morawska, 1978).

Grey, green and red cherts. The grey, green and red cherts occur in single beds or packages, up to 1.2 m thick (the Brody section). Thin layers (3–9 cm) predominate; thicker ones, up to 20 cm, are rare. Single chemical analysis from the cherts show enrichment in ferrous oxides (up to 3.2 weight percent). The trace elements such as vanadium, molybdenum, nickel, cobalt, chrome and zinc do not exceed clark contents, besides copper whose concentrations are up to 650 ppm.

The occurrence of siliceous and calcareous skeletons of marine microfossils in the cherts was used to distinguish three types of deposits: radiolarite, spongolite and silicified pelagic limestone. Radiolarites predominate especially in the upper part of the formation. The grey and green radiolarites consist predominantly of radiolarian tests (Figs 11F, 12D), locally with rare planktonic foraminifers. Red radiolarites, which occur near the upper boundary of the formation (a single bed in the stratotype area), include also rare agglutinated foraminifers. Spongolites include, beside the sponge spicules, a significant amount of radiolarian tests (Fig. 12A). Silicified pelagic limestones include abundant small tests of planktonic foraminifers of genera: *Globigerinelloides, Heterohelix*, and *Hedbergella* (Fig. 12B).

Some of the cherts are turbidites, with mixed biogenic and terrigenous material and parallel, cross or convolute lamination.

Sandstones and siltstones. The proportion of fine-grained sandstone and siltstone beds varies in the studied sections. These lithological varietes make up to 50% of the total thickness of the formation in the western part of the Silesian Nappe. Layers, up to 30 cm thick occur there; their thickness is 3–12 cm. In the north-eastern part of the Silesian Nappe (Międzybrodzie and Węglówka sections), the number and thickness of the sandy and silty beds significantly decrease. They make up to 30% of total thickness of the formation, with most frequent thickness of 1–5 cm; the maximum value reaches 10 cm.

These deposits are turbidites with Bouma divisions (parallel and cross lamination predominate, with convolute lamination occasionally). Clasts of green and black shale occur in the some thick sandstone beds in the lower part of the formation. The sandstone beds include glauconite grains, which are abundant in some layers (Fig. 12E). The sandstones and siltstones are generally cemented with silica, partly with calcareous cement. Calcite is more frequent as organic grains (foraminiferal tests). Thin mudstone layers are locally bioturbated. Trace fossils (tube traces ex gr. *Planolites* ichnsp. as well as *Thalassinoides* ichnsp. and *Chondrites* ichnsp.) occur on soles and tops of the some thin to medium-thick mudstone and sandstone layers (only in the lower part of the formation).

Two thin beds of conglomerate have been described in the Trzemeśnia section (Burtan & Turnau-Morawska, 1978). They include small pebbles of quartz, and green and black shales. Numerous glauconite grains are dispersed in

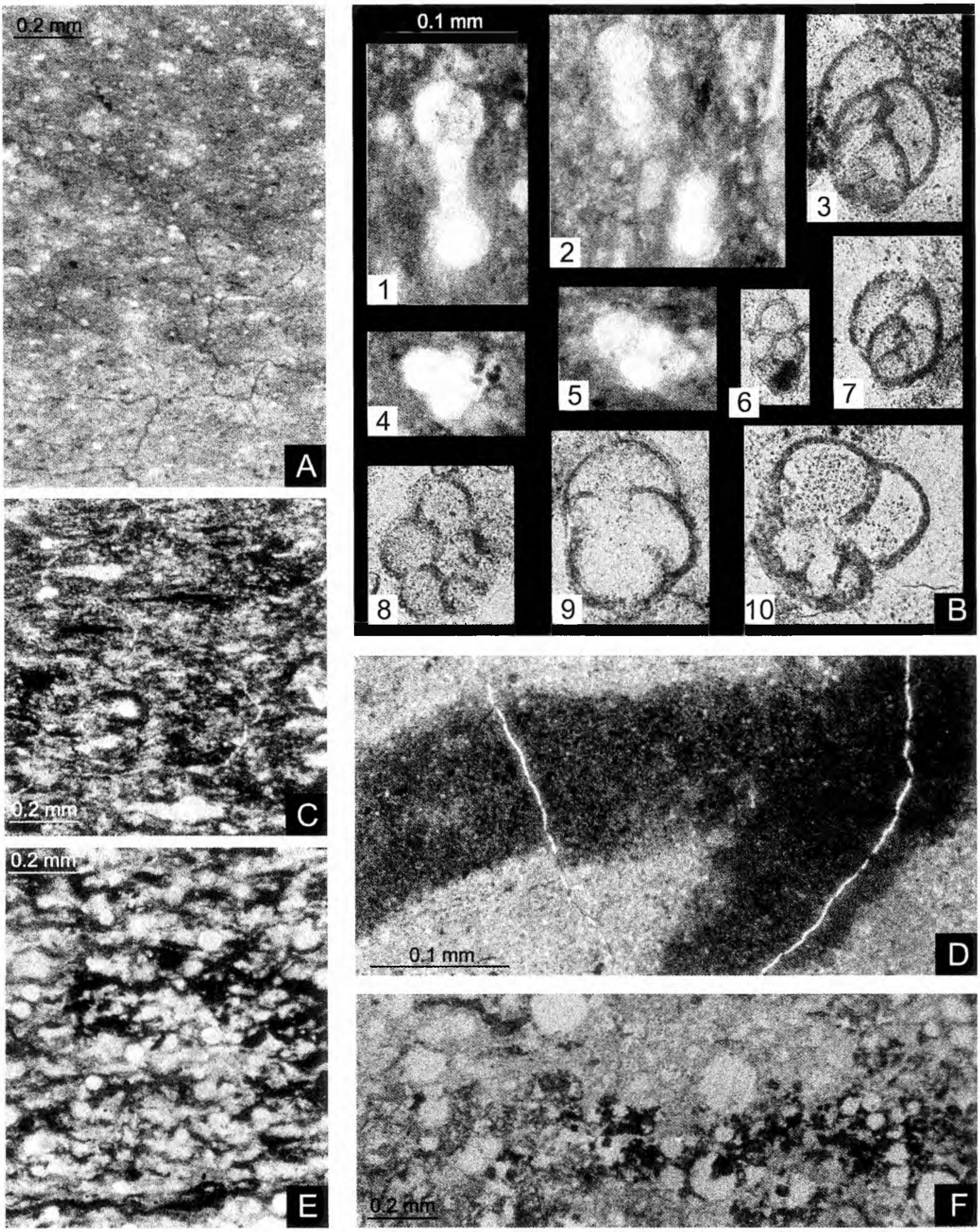

Fig. 11. Foraminiferal and radiolarian microfacies of the Barnasiówka Radiolarian Shale Formation. **A.** Bioturbated green calcareous claystone with small tests of planktonic foraminifers (Cz.P.-21.3a). **B.** Small tests of planktonic foraminifers from green calcareous claystone beds: **1, 2**. *Globigerinelloides ultramicra* (Subbotina) (Cz.P.-21.1b); **3**. *Heterohelix* sp. (Lc-8); **4-6**. *Hedbergella* sp. (Cz.P.-21.1b); **7**. *Heterohelix* sp. (Lc-8); **8-10**. *Hedbergella* sp. (Lc-8). **C.** Dark-grey claystone with abundant agglutinated foraminifers (gerochaminids) (Lc-21). **D.** *Chondrites* ichsp. in green calcareous bioturbated claystone (Jas.-20.1). **E.** abundant radiolarians in black siliceous shale (PS-8). **F.** abundant radiolarians in light-grey radiolarite (Lc-22)

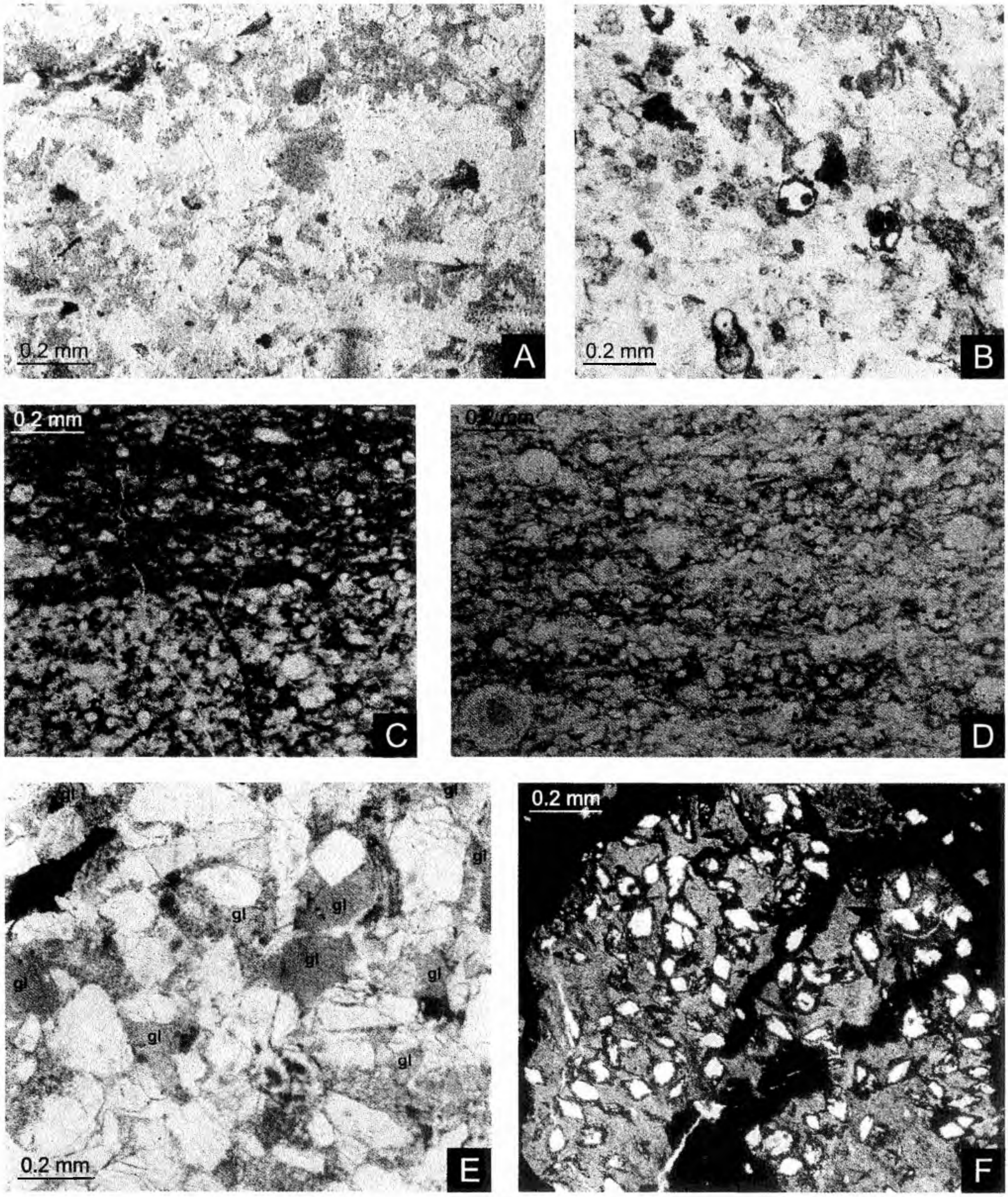

Fig. 12. **A**. Sponge spicules and radiolarians in the light-green chert bed from the lower part of the Barnasiówka Radiolarian Shale Formation (Lc-9). **B**. Silicified pelagic limestone with small tests of planktonic foraminifers (*Hedbergella* sp., *Globigerinelloides* sp.); lower part of the Barnasiówka Radiolarian Shale Formation (Lc-8a). **C**. Parallel-laminated radiolarite bed with layers of densely packed radiolarians and layers enriched in organic matter. **D**. Dark-grey radiolarite bed (PS-6). **E**. Glauconitic (gl) sandstone bed (Lc-6). **F**. Fragment of ferromanganese nodule with rhomboedral (light) crystals of rhodochrosite (Tr-0)

the matrix of the conglomerates.

Benthonites, tuffites, tuff and ferromanganese deposits. Many layers of light-green bentonites have been found in the formation. A few layers, 1–5 mm thick, occur in the lower part of the formation. They are an important component in the middle part of the formation, forming 0.1–5.0 cm thick intercalations within black manganiferous shales, green shales and dark to green tuffites (Fig. 13D). The bentonites include heavy minerals with occasionally abundant titanite and apatite (Wieser, 1973) or they do not contain heavy minerals (Szymakowska, 1962).

Brown to black ferromanganese crusts, up to 5 cm thick, occur between bentonites and black shales in the middle part of the formation (Fig. 13C). Similar crusts appear as incrustations on bedding and cleavage surfaces near contacts between the fine-grained sandstones and bentonites. The crusts are composed mainly of goethite, pyrolusite and birnesite (Wieser in: Geroch *et al.*, 1985). Similar ferromanganese crusts appear also higher up of the sequence, in the lowermost part of the Variegated Shales.

Other characteristic feature of the middle part of the formation is the occurrence of a ferromanganese layer, up to 9 cm thick (Fig. 13A, B). Mezoscopically the layer is black, parallel-laminated, and highly porous. Some internal parts of the layer are yellow-brown in colour with very small (up to 0.3 mm) rhomboedral crystals of manganese carbonates (Fig. 12F). Yellow, optically isotropic volcanic glass is also visible in thin sections (Burtan & Turnau–Morawska, 1978). Ellipsoidal nodules, a few centimetres thick, are wheathered residuum of the layer. A 3 cm layer of light-green bentonite follows the ferromanganese bed (Fig 13A, B). The bentonite and underlying ferromanganese layer are present in several sections of the western part of the Silesian Unit in the same stratigraphic position (Wisła – Obłaziec, Straconka, Brody, Barnasiówka, Trzemeśnia). They are probably a correlation horizon in the western part of the Silesian Nappe. The horizon with manganese concretions was also described from the Międzybrodzie section (Koszarski, 1968) in the northeastern part of the Silesian Nappe. However, the lack of a detailed lithological profile of this outcrop and the lack of exposures now, do not allow precise correlation of this section with the profiles from other localities.

The large ferromanganese nodules occur also in the Lgota Beds and in the Variegated Shales, where their chemical composition was examined (Gucwa & Wieser, 1978; Wieser in: Geroch *et al.*, 1985). The chemical composition of the ferromanganese layer from the Barnasiówka Radiolarian Shale Formation has not been studied yet.

The tuff layer occurs below the ferromanganese nodules at the "Międzybrodzie section" (*pers. inf.* by Tadeusz Wieser). Its age was approximately determined as 91.4 ± 4.7 Ma, based on zircon fission-track analysis (Van Couvering *et al.*, 1981). Unfortunately, the position of the tuff has not been documented. Recently, this section is not exposed.

Grey-green to black tuffite layers, brick-red on wheathered surfaces, up to 40 cm thick occur in the middle part of the formation. They are compact, parallel-laminated, with white laminae enriched in quartz, feldspars and micas, and black laminae composed of clay minerals. Rhomboedral crystals of rhodochrosite, spherolites of saledonite? (brown spherules, 10 μm in diameter), yellow volcanic glass, sponge spicules and radiolarian tests (filled by glauconite?) are dispersed in the clay laminae (Burtan & Turnau-Morawska, 1978).

Lower boundary of the formation

The lower boundary of the Barnasiówka Radiolarian Shale Formation is located at the top of the last thick sandstone bed which includes chert layers in its middle part. This sandstone bed represents the top of the Mikuszowice Cherts (Figs 14, 16A). Two dark-grey chert layers (5.0 cm and 2.5 cm thick) occur in this very fine-grained sandstone bed (31 cm thick) in the stratotype at the Barnasiówka-Ostra Góra quarry (Fig. 15). The sandstone bed passes upwards to a 4 cm-thick, grey-green parallel-laminated siltstone, and a 2 cm-thick, grey-green calcareous bioturbated marly shale.

The top of the last bed of the Mikuszowice Cherts is the base of a series of green, mostly calcareous, subordinary dark-grey calcareous shales, with intercalations of very thin-bedded (0.5–2.5 cm) grey to green, bioturbated siltstone and thin-bedded (0.3–11.0 cm) very fine-grained sandstone as well as chert (gaize-type) layers (Figs 14, 16B). The green and dark-grey shales comprise 47% of the total thickness in the lowermost 1 m of the Barnasiówka Radiolarian Shale Formation in the stratotype. Siltstone and sandstone layers comprise, respectively, 18% and 36 % of the lowermost 1 m-thick series in the same section.

The base of the first thick layer of green shales, whose thickness is greater than the thickness of the siltstone or sandstone beds in the Upper Lgota Beds is the base of the Barnasiówka Radiolarian Shale Formation in the sections, where the Mikuszowice Cherts do not occur (mainly in the eastern part of the Silesian Nappe: e.g., the Jabłonki section at Bystre).

Upper boundary of the formation

The upper boundary of the Barnasiówka Radiolarian Shale Formation is placed at the sole of the first red claystone layer of the Variegated Shales (Figs 15, 16C). The red non-calcareous, 0.5–3.0 cm thick, clay layer occurs within a series of green non-calcareous shales, intercalated with thin black manganiferous shales (tuffites?), very thin layers of light-green bentonite and very thin- to thin-bedded very fine-grained light-green silicified sandstones in the stratotype section at the Barnasiówka-Ostra Góra quarry. A few thin-bedded (1.5–5.0 cm) non-calcareous variegated claystones (green colours prevail) occur above the first red-clay layer (Figs 15, 16C). The red shales and claystones dominate over the green shales 1–5 m above the first red-clay layer. The proportion of red shales near the base of the Variegated Shales varies from section to section. The transitional series (with glauconitic sandstone intercalations), where the green shales prevail is characteristic of the western part of the Silesian Nappe. On the other hand, the red non-calcareous shales contact with the green shales of the Barnasiówka Radiolarian Shale Formation in the north-eastern part of the Silesian Nappe (e.g., Węglówka section).

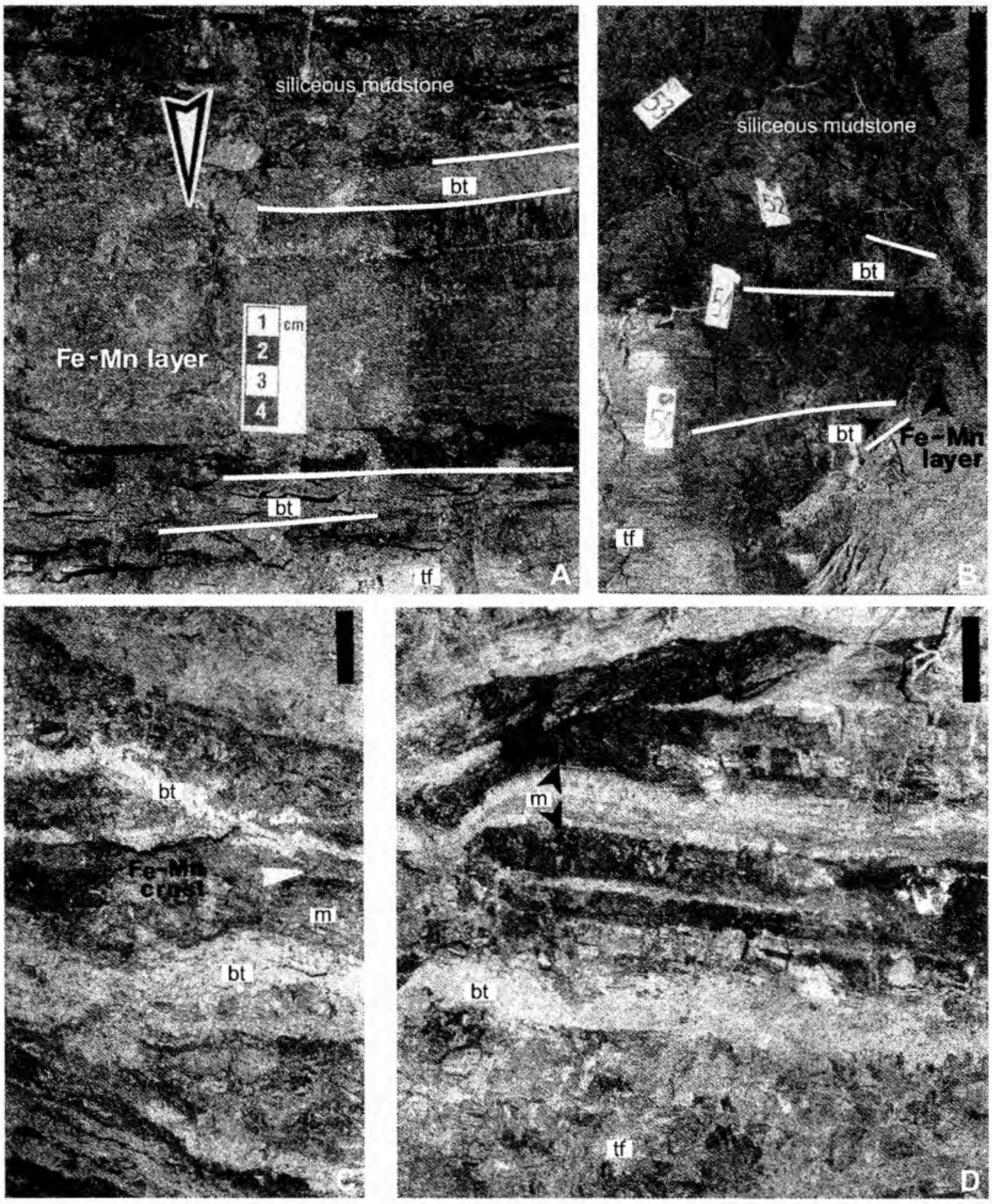

Fig. 13. A. Ferromanganese layer with light-green bentonite (arrow; bt) and grey-green tuffite layer (tf); the top of the middle part of the Barnasiówka Radiolarian Shale Formation; Barnasiówka-Ostra Góra section. **B.** Ferromanganese layer covered by crust of manganese oxides; light-green bentonites (bt) below and above of the ferromanganese layer; the top of the middle part of the Barnasiówka Radiolarian Shale Formation; Trzemeśnia section. **C.** Ferromanganese crust (arrow) between manganiferous shales (m) and light-grey bentonite layers (bt); the middle part of the Barnasiówka Radiolarian Shale Formation; Trzemeśnia section. **D.** Folded series of light-grey bentonites (bt) and managniferous shales (m) (partly tuffites) with 40 cm-thick, grey-green tuffite layer (tf) (petrographic determination by Burtan & Turnau-Morawska, 1978); the middle part of the Barnasiówka Radiolarian Shale Formation; Trzemeśnia section

The upper boundary is placed at the base of the first thick bed of glauconitic sandstone of the Godula Beds where the Variegated Shales are not present (the Silesian Beskid Mts; e.g., Wisła – Obłaziec section).

Thickness of the formation

The total thickness of the Barnasiówka Radiolarian Shale Formation ranges from 0.5 m in the eastern part (reduced tectonically?) up to about 14–15 m in the middle and the western parts of the Silesian Nappe. These differences are related to the increase in the number and thickness of sandy and silty turbidite intercalations westward. The same trend is a characteristic feature of the other Cretaceous flysch series in the Silesian Nappe within the Polish Carpathians.

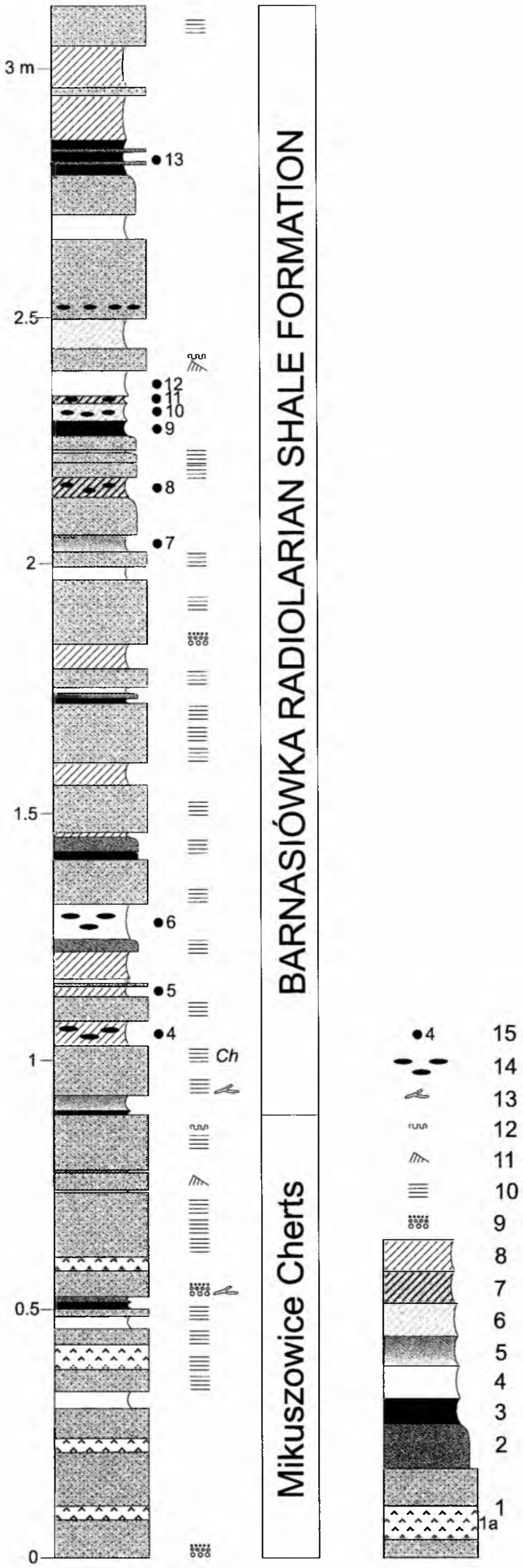

Fig. 14. Lower boundary of the Barnasiówka Radiolarian Shale Formation in the stratotype area at the Barnasiówka-Jasienica quarry. *1* – fine-grained grey sandstone with clasts of green shale, and chert intercalation (*1a*), *2* – dark-grey to dark-green siltstone; *3* – black calcareous shale; *4* – light-grey calcareous shale; *5* – grey-green calcareous shale; *6* – green non-calcareous shale; *7* – green calcareous shale; *8* – olive calcareous shale; *9* – graded bedding; *10* – parallel lamination; *11* – cross lamination; *12* – convolute lamination; *13* – trace fossil on a sole of a bed; *14* – bioturbations; *15* – location of sample for micropalaeontological studies; *Ch* – *Chondrites* ichnsp.

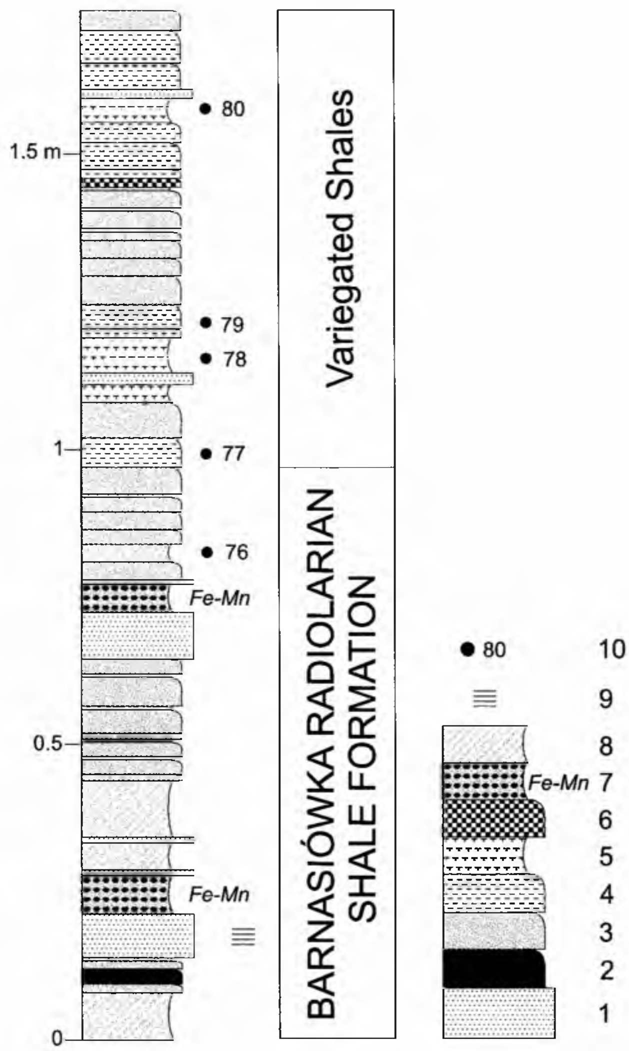

Fig. 15. Upper boundary of the Barnasiówka Radiolarian Shale Formation at the Trzemeśnia section. *1* – light-green siliceous fine-grained sandstone; *2* – black siliceous siltstone; *3* – green non-calcareous claystone, brick-red on weathered surfaces; *4* – variegated non-calcareous claystone; *5* – variegated non-calcareous shale; *6* – red non-calcareous claystone; *7* – ferromanganesse crust (*Fe-Mn*); *8* – green non-calcareous shale; *9* – horizontal lamination; *10* – sample location (see Fig. 16)

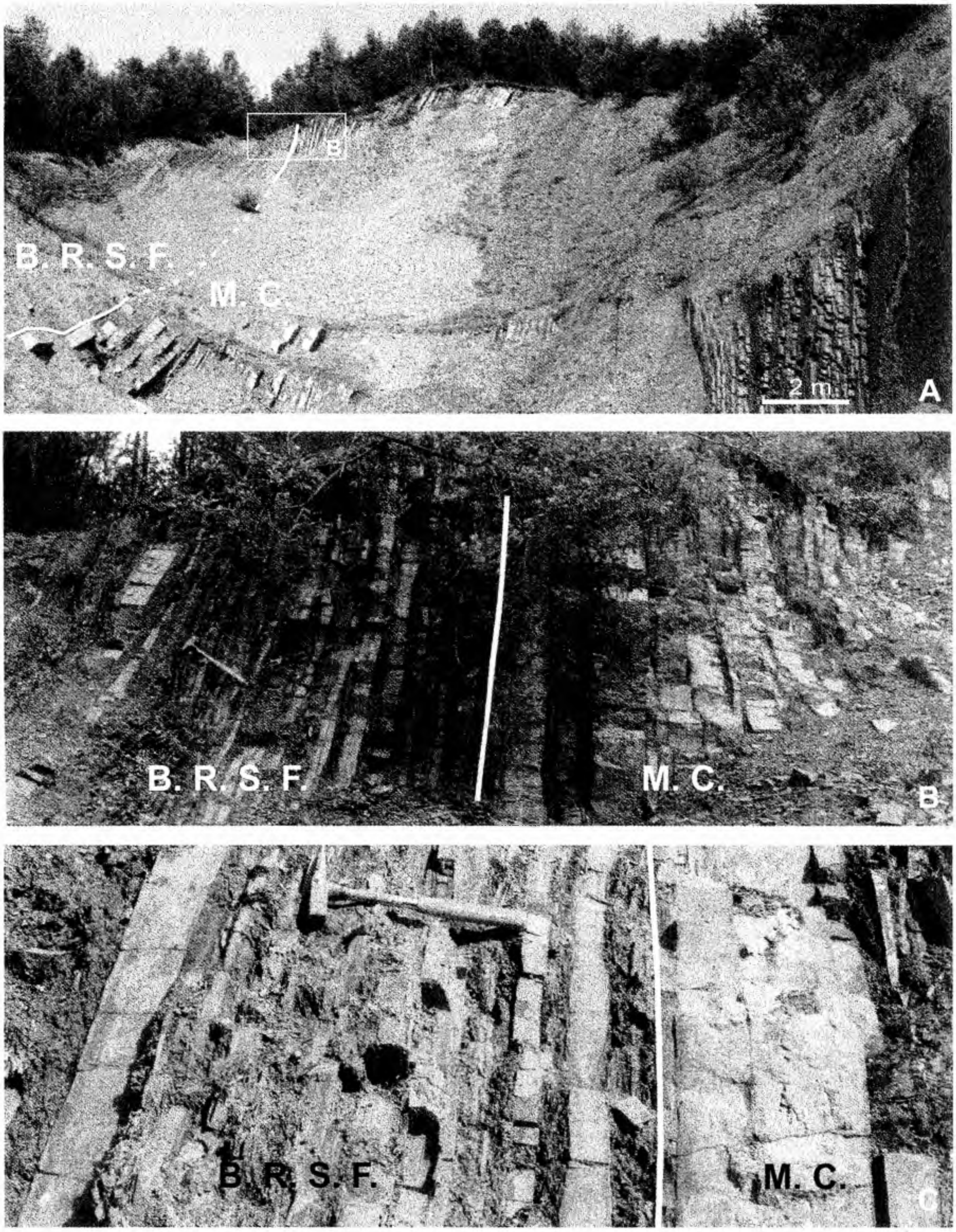

Fig. 16. **A, B.** The uppermost part of the Mikuszowice Cherts (M. C.) and the lowermost part of the Barnasiówka Radiolarian Shale Formation (B. R. S. F.) in the stratotype area; Barnasiówka-Jasienica quarry; hammer length – 32 cm. **C.** Lower boundary of the Barnasiówka Radiolarian Shale Formation (B. R. S. F.) in the stratotype section at the Barnasiówka-Ostra Góra quarry; M. C. – Mikuszowice Cherts, hammer length – 32 cm.

Age of the formation

The age of the Barnasiówka Radiolarian Shale Formation is here determined based on the radiolarian and foraminiferal assemblages. The biostratigraphical studies have been carried out in five sections (Brody, Barnasiówka-Jasienica, Trzemeśnia, Węglówka and Międzybrodzie), including also sediments from neighbouring lithostratigraphic units.

The abundant and diversified radiolarians were base for biostratigraphic division of the formation. They have been determined from nearly 100 samples. Twenty species of radiolaria belong to the order Nassellaria and fifteen species belong to Spumellaria. Most of them are moderately- to well-preserved and come from black, green and olive shales. Some radiolarian specimens from black shales are poorly preserved, due to pyritization. Radiolaria are rare both in the underlying Lgota Beds and in the Variegated Shales.

The assemblage from the Barnasiówka Radiolarian Shale Formation includes mainly spherical cryptothoracic and cryptocephalic Nassellaria (60–99% of total number of specimens), belonging mainly to the species *Holocryptocanium barbui* Dumitrică (Fig. 17H, I) and *H. tuberculatum* Dumitrică. The assemblage includes also *H. geysersensis* Pessagno (Fig. 17N), *Hemicryptocapsa prepolyhedra* Dumitrică (Fig. 17M), *H. polyhedra* Dumitrică (Fig. 17L), *Pseudodictyomitra pseudomacrocephala* (Squinabol) (Fig. 17D), *Dictyomitra pseudoscalaris* (Tan) (Fig. 17E), *D. napaensis* Pessagno (Fig. 17K) and *Cryptamphorella conara* (Foreman) (Fig. 17O). Spumellarians, which are less common (1–40% of the total number of specimens), are represented mainly by the genera such as *Pseudoaulophacus* (Fig. 17B), *Patellula* (Fig. 17F), *Alievium* (Fig. 17C, G), *Crucella* (Fig. 17A) and *Praeconocaryomma*. Detailed systematic description of the radiolarian assemblage has been presented by M. Bąk (1994, 2000).

The most important for biostratigraphy is the occurrence of assemblage with *Holocryptocanium barbui* Dumitrică and *H. tuberculatum* Dumitrică, as well as first occurrences (FO) of *Hemicryptocapsa prepolyhedra* Dumitrică, *H. polyhedra* Dumitrică, *Alievium superbum* (Squinabol), *Crucella cachensis* Pessagno, *Patellula andrusovi* Ožvoldová and *P. ecliptica* O'Dogherty.

The radiolarian assemblage with *Holocryptocanium barbui-Holocryptocanium tuberculatum*, which dominates in the lower part of the Barnasiówka Radiolarian Shale Formation (Figs 18, 19) is here correlated with the associations presented by Dumitrică (1975) from the Romanian Carpathians (for detailed discussion see Bąk, 2000). The association represents the Late Cenomanian in the zonal scheme for the Radiolaria-bearing deposits in Romania (Dumitrică, 1975), calibrated using planktonic foraminifers.

The first occurrences of *Hemicryptocapsa prepolyhedra* Dumitrică and *H. polyhedra* Dumitrică mark the lower boundaries of the *H. prepolyhedra* and *H. polyhedra* radiolarian zones, respectively, distinguished and calibrated with chronostratigraphy in pelagic environment (Bąk, 1999; M. Bąk & K. Bąk, 1999; for discussion see Bąk, 2000). The lower and middle parts of the formation could be correlated with these zones. In pelagic environment, the FO of *Hemicryptocapsa prepolyhedra* is documented within the *Rotalipora cushmani* planktonic foraminiferal Zone (Late Cenomanian), and *Hemicryptocapsa polyhedra* appears in the *Praeglobotruncana delrioensis* Zone (above the last occurrences of rotaliporids – near the Cenomanian/Turonian boundary; K. Bąk, 1998).

The FOs of *Alievium superbum* (Squinabol), *Crucella cachensis* Pessagno, *Patellula andrusovi* Ožvoldová and *P. ecliptica* O'Dogherty, which are documented in the upper part of the Barnasiówka Radiolarian Shale Formation (Figs 20, 21), are here correlated with those in the radiolarian biozonation from the Mediterranean region (O'Dogherty, 1994), and also with the association from the Czorsztyn Succession of the Pieniny Klippen Belt (Sýkora *et al.*, 1997).

Alievium superbum is the index species of the "*superbum* zone", distinguished by O'Dogherty (1994), the base of which (determined as the FO of the *A. superbum*) is correlated via planktonic foraminifers and calcareous nannoplankton with the base of the *Watinoceras coloradoense* ammonite Zone of the Hanckock's (1984, 1991) and Kennedy's (1984) zonations. Most European ammonite workers regarded the base of this ammonite zone as the base of the Turonian stage. However, the formal definition of the Cenomanian–Turonian boundary differs now from that proposed by Hanckock (1984) and Kennedy (1984). It is placed at the base of Bed 86 in the section at Rock Canyon Anticline, west of Pueblo (Colorado, USA) coincident with the FO of the ammonite *Watinoceras devonense* Wright & Kennedy (Bengston, 1996), as proposed at the Second International Symposium on Cretaceous Stage Boundaries in Brussels. The FO of *W. coloradoense* is placed in this section within the Bed 97 (1.5 m above the base of *W. devonense*) (Kennedy & Cobban, 1991; fig. 8). Consequently, the radiolarian species *Alievium superbum* may be regarded as the first Turonian taxon within the radiolarian assemblage, whose FAD is near the base of the C–T boundary.

The FOs of *Crucella cachensis* Pessagno, *Patellula andrusovi* Ožvoldová and *P. ecliptica* O'Dogherty are also referred to the Early Turonian (using the planktonic foraminifers determination; Sýkora *et al.*, 1997).

Foraminifers are additional markers for biostratigraphy of the Barnasiówka Radiolarian Shale Formation. They have been determined from the same samples as the radiolarians, and additionally in thin sections of the chert layers. The planktonic forms include only small tests of genera *Globigerinelloides*, *Hedbergella* and *Heterohelix* (Fig. 11), not diagnostic for age, except for the lowermost part of the formation, where single rotaliporids, *Rotalipora appenninica* (Renz) and *R. greenhornensis* (Morrow), have been found (sample Jas-7 on Fig. 18). Single planktonic foraminifers including *Rotalipora* cf. *cushmani* have been also determined from the green shales at the top of the Gaize Beds (Książkiewicz in: Koszarski *et al.*, 1959; Koszarski & Liszkowa, 1963). This shows that the lower part of the formation belongs to the *Rotalipora cushmani* Zone (probably to its uppermost part, because of the extremely rare occurrences of rotaliporids, in contrast to numerous hedbergellids). The lack of helvetoglobotruncanids (index taxa for the Lower Turonian) in the uppermost part of the formation may suggest the earliest Turonian age of these deposits. However, it should be stressed that the upper part of the formation is generally devoid of planktonic foraminifers (due to their dissolution?).

The suggested age is confirmed by the assemblage of deep-water agglutinated foraminifera (DWAF), which occur in many pelagic and hemipelagic sediments of the formation. Most of them belong to long-ranging, environmentally tolerant species from genera *Recurvoides*, *Trochammina*, *Ammodiscus*, *Glomospira*, *Hyperammina* and *Rhabdammina* (Figs 22, 23). However, some of them have

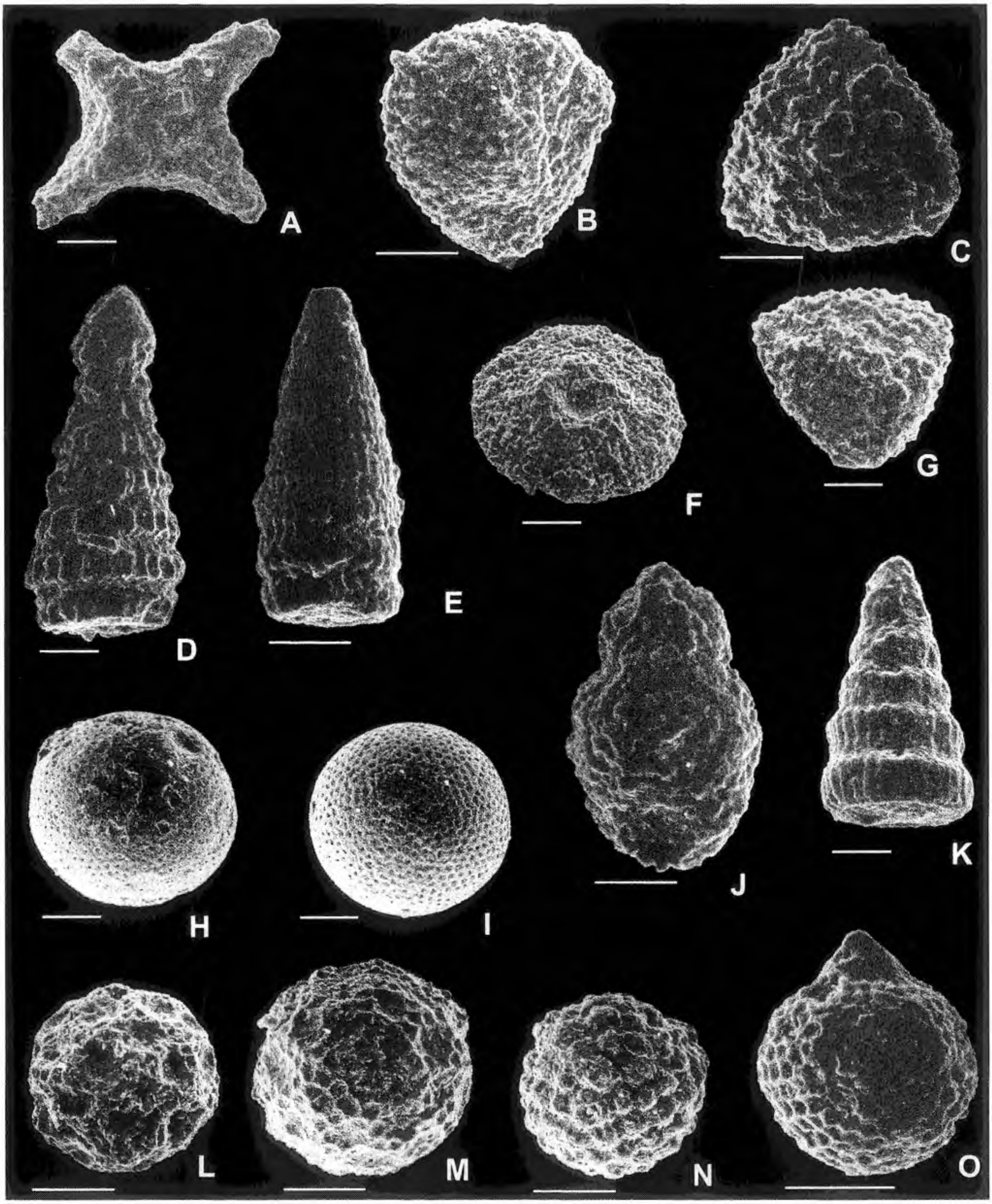

Fig. 17. Late Cenomanian–Early Turonian radiolarians from the Barnasiówka Radiolarian Shale Formation and the neighbouring units (Silesian Nappe; Outer Carpathians): **A.** *Crucella cachensis* Pessagno, sample Lcm-26023; **B.** *Pseudoaulophacus putahensis* Pessagno, sample Lcm-7021; **C.** *Alievium superbum* (Squinabol), Lcm-26032; **D.** *Pseudodictyomitra pseudomacrocephala* (Squinabol), sample Lcm-26033; **E.** *Dictyomitra pseudoscalaris* (Tan), sample Lcm-26025; **F.** *Patellula andrusovi* Ožvoldová, sample Tr-15A004; **G.** *Alievium superbum* (Squinabol), sample Lcm-26026; **H, I.** *Holocryptocanium barbui* Dumitrică, sample: H – Jas-1502811, I – Jas-1502813; **J.** *Diacanthocapsa* sp., sample Lcm-26031; **K.** *Dictyomitra napaensis* Pessagno, sample Lcm-26015; **L.** *Hemicryptocapsa polyhedra* Dumitrică, sample Jas-1502815; **M.** *Hemicryptocapsa prepolyhedra* Dumitrică, sample Jas-1502909; **N.** *Holocryptocanium geysersensis* Pessagno, sample Lcm-7021; **O.** *Cryptamphorella conara* (Foreman), sample Lcm-26019. A-E, G, J, K, N, O – Brody section; F – Trzemeśnia section; H, I, L, M – Barnasiówka-Jasienica section. Scale bar – 100 μm

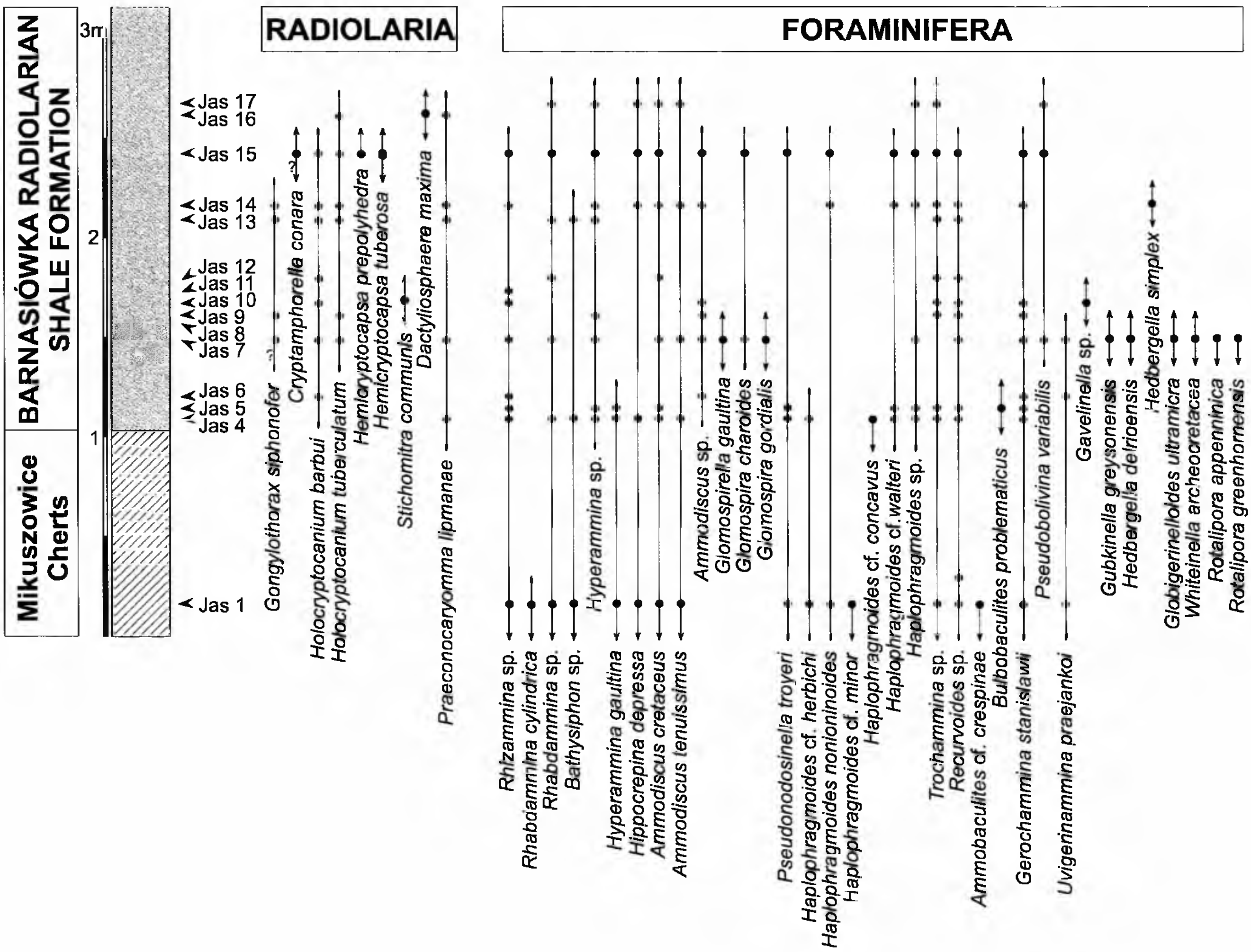

Fig. 18. Occurrence range chart of the Late Cenomanian Radiolaria and Foraminifera near the lower boundary of the Barnasiówka Radiolarian Shale Formation in the Barnasiówka-Jasienica section (Silesian Nappe, Outer Carpathians)

stratigraphic significance, such as *Hippocrepina depressa* Vašiček (Fig. 22E), *Haplophragmoides nonioninoides* (Reuss) (Fig. 22N-P), *Plectorecurvoides alternans* Noth (Fig. 23E), *Uvigerinammina praejankoi* Neagu (Fig. 23H, I, K) and *Uvigerinammina jankoi* Majzon (Fig. 23J).

Last occurrences of *Hippocreppina depressa, Haplophragmoides nonioninoides* and *Plectorecurvoides alternans* take place in the middle part of the studied formation, below the series of black shales with numerous tuffites and bentonites (K. Bąk – unpublished data). Their extinction is known from literature near the Cenomanian–Turonian boundary, and is connected with great changes in DWAF assemblages at that time (e.g., Geroch & Nowak, 1984; Moullade *et al.*, 1988; Neagu, 1990; Kuhnt *et al.*, 1992).

The occurrence of *Uvigerinammina praejankoi* Neagu in the lowermost part of the formation and also in the uppermost part of the Mikuszowice Cherts (Fig. 18), together with the Cenomanian DWAF assemblage, suggests the Upper Cenomanian age of the lower part of the formation by taking into account data from the Romanian Flysch Carpathians (Neagu, 1990), where *U. praejankoi* occurs in sediments of the *Whiteinella archeocretacea* through the *Marginotruncana schneegansi* zones (Upper Cenomanian–Lower Turonian).

The uppermost part of the studied formation includes DWAF assemblage with *Uvigerinammina jankoi* Majzon, whose first appearance datum was described from many environments near the base of the Turonian stage (e.g., Geroch, 1957; Geroch & Nowak, 1984; Moullade *et al.*, 1988; Kuhnt *et al.*, 1992; Bąk, 1998; Bąk, 2000).

To summarise, the occurrences of Radiolaria and Foraminifera show that the lower and middle parts of the Barnasiówka Radiolarian Shale Formation represent the Upper Cenomanian. The upper part of the Formation is correlated with the lowermost Turonian (Fig. 24).

CORRELATION WITH DEPOPSITS IN THE OUTER CARPATHIANS

The Barnasiówka Radiolarian Shale Formation has the lithological equivalents (Cenomanian–Turonian) in the other Outer Carpathian nappes (*i.e.* Subsilesian, Skole and Magura nappes).

Very similar lithotypes occur in the Subsilesian Nappe. The deposits similar to those from the middle and upper

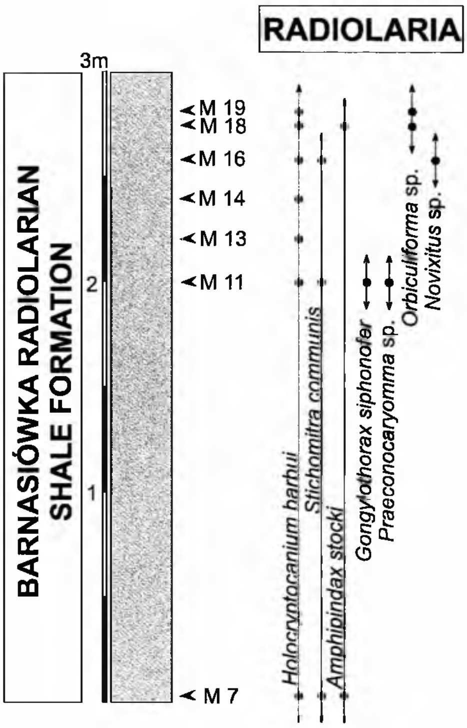

Fig. 19. Occurrence range chart of Late Cenomanian Radiolaria in the lower part of the Barnasiówka Radiolarian Shale Formation in the Międzybrodzie section (Silesian Nappe, Outer Carpathians)

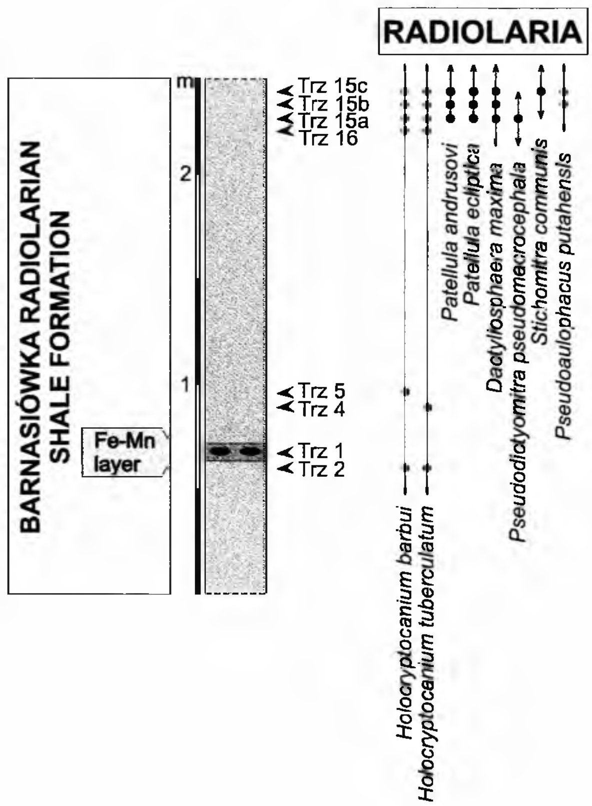

Fig. 20. Occurrence range chart of the Late Cenomanian–Early Turonian Radiolaria in the middle and upper parts of the Barnasiówka Radiolarian Shale Formation in the Trzemeśnia section (Silesian Nappe, Outer Carpathians)

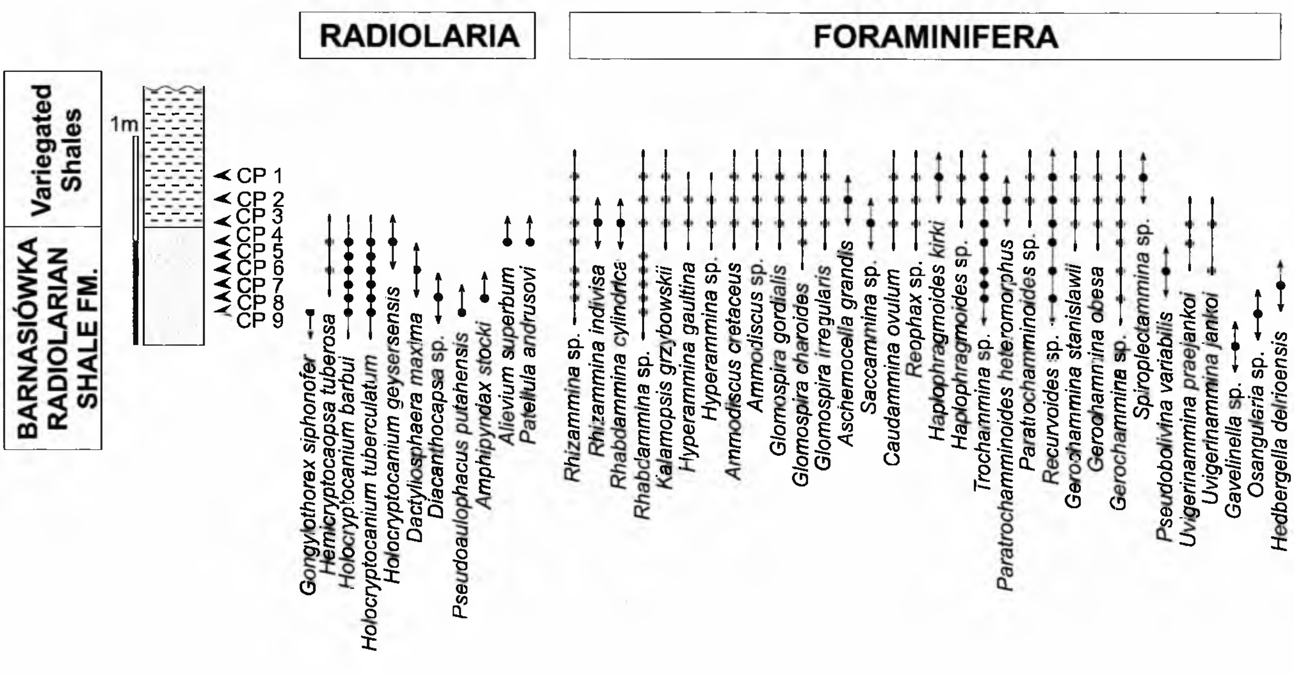

Fig. 21. Occurrence range chart of the Late Cenomanian–Early Turonian Radiolaria and Foraminifera near the upper boundary of the Barnasiówka Radiolarian Shale Formation in the Węglówka section (Silesian Nappe, Outer Carpathians)

parts of the Barnasiówka Radiolarian Shale Formation have been described from Zasań near Myślenice and at Myślenice (Burtan & Turnau-Morawska, 1978; figs 7, 8). The series of black tuffites, light-green bentonites, light-coloured cherts (radiolarites and calcareous spongolites) with a ferro-manganese layer (within the light-green bentonites) occurs

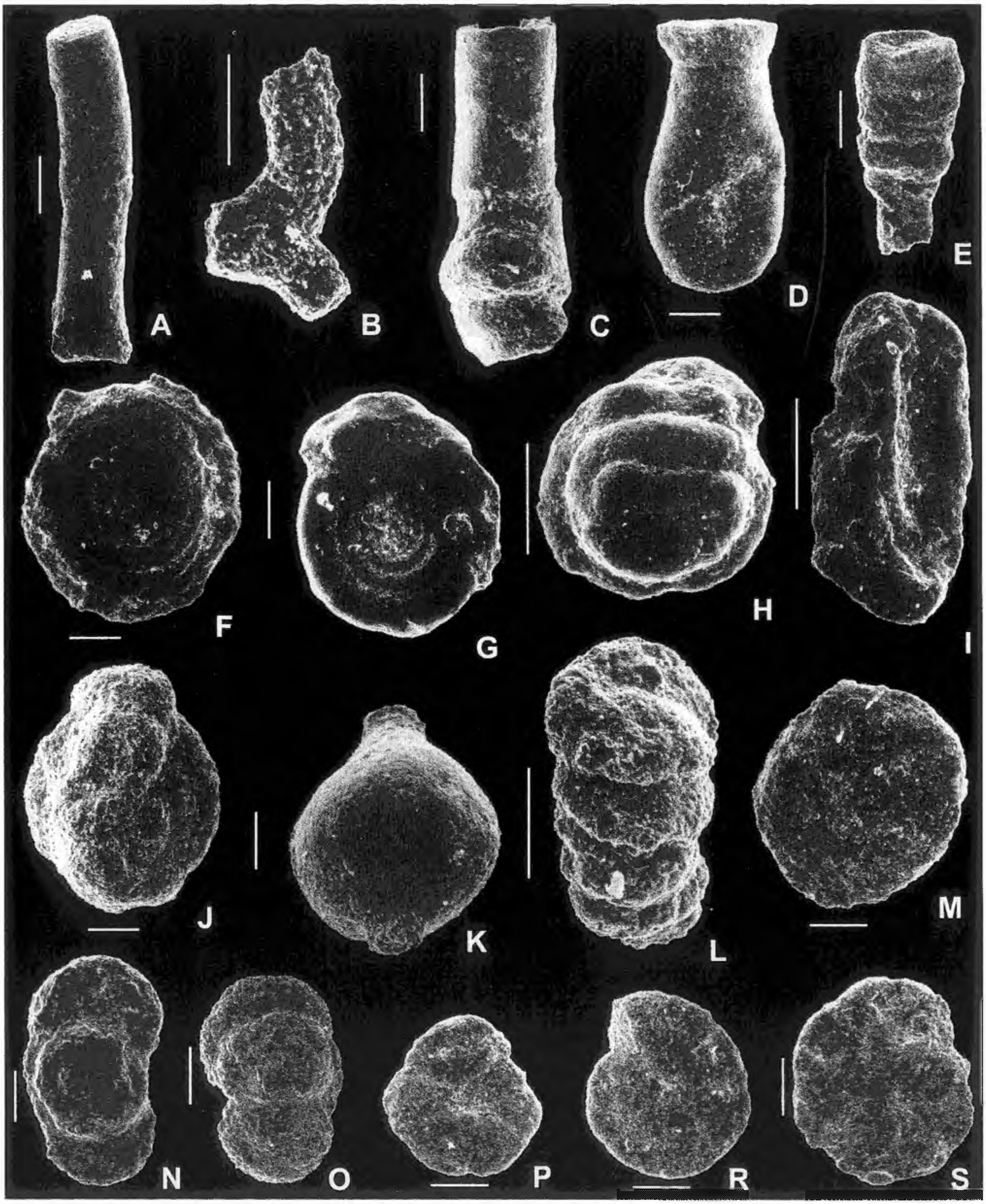

Fig. 22. Late Cenomanian–Early Turonian agglutinated foraminifers from the Barnasiówka Radiolarian Shale Formation and the neighbouring units (Silesian Nappe, Outer Carpathians): **A.** *Rhabdammina cylindrica* Glaessner, sample Lc-13; **B.** *Rhizammina* sp., sample Cz.P.-2; **C.** *Bathysiphon* sp., sample Cz.P.-2; **D.** *Kalamopsis* cf. *grzybowskii* (Dylążanka), sample Cz.P.-2; **E.** *Hippocrepina depressa* Vašiček, sample Jas-1; **F.** *Ammodiscus tenuissimus* Grzybowski, sample Jas-14; **G.** *Ammodiscus cretaceus* Reuss, sample Lc-13; **H.** *Glomospira charoides* (Jones & Parker), sample Lc-13; **I.** *Glomospira serpens* (Grzybowski), sample Lc-5; **J.** *Glomospira irregularis* (Grzybowski), sample Cz.P.-3; **K.** *Caudammina silesica* (Hanzlikovà), sample Cz.P.-6; **L.** *Pseudonodosinella troyeri* (Tappan), sample Jas-29; **M.** *Saccammina* sp., sample Jas-23; **N-P.** *Haplophragmoides nonioninoides* (Reuss), sample Jas-4; **R, S.** *Haplophragmoides* cf. *walteri* (Grzybowski), sample: R – Jas-14, S – Jas-4. A, G-I – Brody section; B-D, J, K – Węglówka section; E, F, L-S – Barnasiówka-Jasienica section. Scale bar – 100 μm

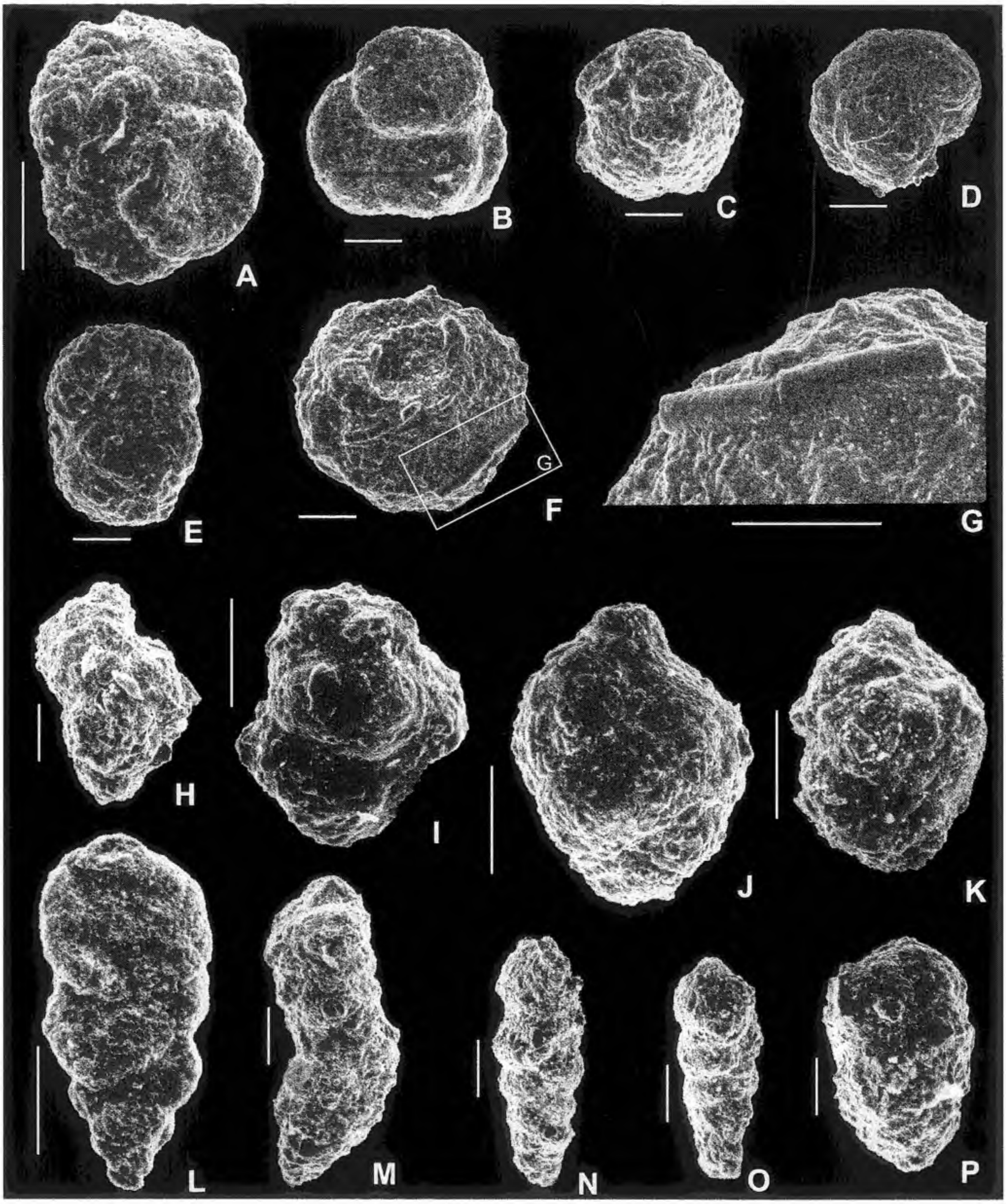

Fig. 23. Late Cenomanian–Early Turonian agglutinated foraminifers from the Barnasiówka Radiolarian Shale Formation and the neighbouring units (Silesian Nappe, Outer Carpathians). **A, B.** *Trochammina* sp., sample Jas-14; **C, D.** *Recurvoides* sp., samples Jas-14 & Lc-14, respectively; **E.** *Plectorecurvoides alternans* Noth, sample Lc-12; **F.** *Recurvoides* sp., sample Lc-11; **G.** Fragment of the *Recurvoides* test (Fig. F) with agglutinated sponge spicules, sample Lc-11; **H, I, K.** *Uvigerinammina praejankoi* Neagu, samples Cz.P-6 & Cz.P-4, respectively; **J.** *Uvigerinammina jankoi* Majzon, sample Cz.P.-3; **L-O.** *Gerochammina stanislawii* Neagu – samples: L – Jas-4, M-O – Jas-23; **P.** *Gerochammina obesa* Neagu, sample Cz.P.-3. A-C, L-O – Barnasiówka-Jasienica section; D-G – Brody section; H-K, P – Węglówka section. Scale bar – 100 μm

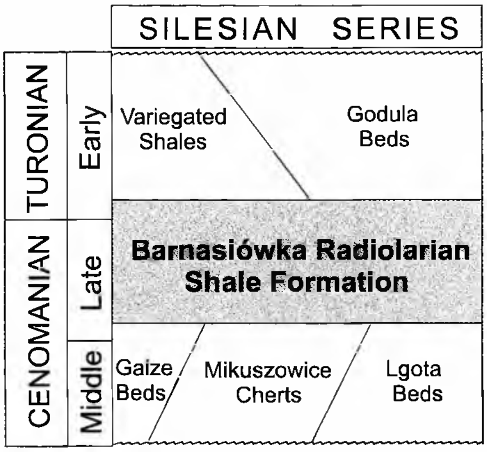

Fig. 24. Lithostratigraphy near the Cenomanian-Turonian boundary in the Silesian series (Polish Outer Carpathians)

above the Gaize Beds (thin-bedded sandstones containing numerous siliceous sponge spicules and detritic quartz, with intercalations of grey, black and green shales). They are followed by green non-calcareous shales, rare black shales with intercalations of light green radiolarite, calcareous spongolite and occasionally of thin-bedded glauconite, gaize-type sandstone beds. The series passes to the Variegated Shales.

Recently, the series with the ferromanganese layer has been studied in relation to its stratigraphic position, based on radiolaria and dinocysts at the Zasań section (Bąk M. *et al.*, 2000; Gedl & Bąk, 2000). Radiolaria indicate latest Cenomanian age of the ferromanganese layer. Early Turonian species with *Alievium superbum* (Squinabol) appear above the ferromanganese layer, within the green to grey hard siliceous shales. The dinocyst assemblage confirms the latest Cenomanian? through Early Turonian age of this series.

The green radiolarian shales have been also described in the Skole Nappe (Styrnałówna & Cizancourt, 1925; Sujkowski & Różycki, 1930; Sujkowski, 1931, 1932; Zhurakowsky, 1968; Gucwa, 1966; Burov *et al.*, 1972; Kotlarczyk, 1978; Kotlarczyk & Gaździcka, 1988). The described sections are located in the marginal zone of the Skole Nappe (e.g., Szczepanowice near Wojnicz – Ślączka & Kaminski, 1998; Zawada near Tarnów – Koszarski & Morgiel, 1963; Niedźwiada near Dębica – Gucwa, 1966) and in the more internal part in Poland (near Rybotycze and Spława localities; Kotlarczyk, 1978) and Ukraine (Skole skiba and Paraszka skiba: at Dołhe in the Stryj valley – Sujkowski, 1931, 1932; Zhurakovsky, 1968).

The deposits from the marginal part of the Skole Nappe, which can be correlated with the studied formation, are represented by a 2 m thick series (tectonically reduced?) of green radiolarian shales in the Szczepanowice and Zawada sections (Ślączka & Kaminski, 1998; Koszarski & Morgiel, 1963). Other type of deposits, corresponding probably to the middle part of the Barnasiówka Radiolarian Shale Formation, is a 3 m thick series of siliceous radiolarian shales, partly calcareous and bituminous, with intercalations of bentonitized tuffite and "manganese siderite" (Gucwa, 1966). Geochemical composition of this series has been described at Niedźwiada near Dębica. Variegated Shales cover the described series in both sections.

The Barnasiówka Radiolarian Shale Formation could be also correlated with a succession of green shales (up to 12 m thick), green calcareous shales, with intercalations of black shale and radiolarite (up to 18 m thick), and green-grey shales with intercalations of thin-bedded siliceous marl, green radiolarite and black shale (up to 4.5 m thick). This succession occurs in the internal part of the Skole Nappe, near Spława and Rybotycze localities (Kotlarczyk, 1978, 1988; Kotlarczyk & Gaździcka, 1988).

The Barnasiówka Radiolarian Shale Formation could be also correlated with a series of thin-bedded parallel-laminated dark to black cherts (radiolarian and foraminiferal microfacies), 10–12 m thick, overlain by black non-calcareous, strongly bituminous, partly manganiferous shales (6 m thick), with yellow-brown crusts of ferrous oxides on weathered surfaces, that has been described at Dołhe (Sujkowski, 1931, 1932). A six to eight metres thick series of the variegated (mainly red) shales, with intercalations of red and green radiolarites (jaspers) and the Mn-rich nodules, occur higher up in the succession in the Dołhe area (Sujkowski, 1931, 1932). This series could be correlated to similar deposits of the Silesian series in the area near Lanckorona (Geroch *et al.*, 1985), which belong to the Variegated Shales.

The mentioned deposits from the Skole Nappe, enriched in radiolaria, have been distinguished as an informal unit, under various names, and in various lithostratigraphic sense.

Zhurakovsky (1968) has distinguished the "Golovnin series" at the Stryj locality, which includes both the green radiolarian shales and the variegated shales with radiolarites. The same deposits have been named "Ilemka Formation" (svita), after the location of the Ługi-1 (Łuhy-1) borehole in the Ilemka valley (Burov *et al.*, 1972), where these deposits are very thick (up to 400 m). Microfossils cited from this borehole suggest, however, a tectonic repetition within the described deposits at this locality.

Kotlarczyk (1978) has proposed an other name for the same deposits – the "Dołhe Radiolarian Shale Formation", based on the earlier published materials (mainly by Sujkowski, 1932). The proposed stratotype section of these deposits is located in the Ukrainian part of the Carpathians (near the Dołhe Podłużańskie village in the Stryj valley; Sujkowski, 1931, 1932). Unfortunately, the hypostratotypes, proposed by Kotlarczyk (1978), near Rybotycze and Spława villages (Polish part of the Skole Nappe), have not been correlated to those from the Dołhe area. The proposed stratotype at Dołhe lacks any biostratigraphical data, and the stratigraphic position (Albian–Cenomanian) of the hypostratotypes should be revised. The cited by Kotlarczyk (1978) agglutinated foraminifers from these deposits have long stratigraphic ranges according to recent studies. The calcareous nannoplankton, referred earlier to the CC8 and CC9 zones *sensu* Sisingh (1977) of Albian–Cenomanian (Kotlarczyk & Gaździcka, 1988), belongs to a redeposited older assemblage in younger sediments. These sediments have been recently correlated to the CC9 and CC11 calcareous nannoplankton zones (Gaździcka, 2001), referred to the Late Albian–Early Turonian. The younger age of these deposits is confirmed by the radiolarian assemblage described by Górka (1996) from the Spława section. Samples taken from the green-grey shales at this locality (upper part of the section), dated by calcareous nannoplankton (Kotlarczyk & Gaździcka, 1988) as the CC9 Zone with *Eiffelithus turriseiffelli*, include radiolarian species, whose first occurrences are from the latest Cenomanian and the earliest Turonian (Sýkora *et al.*, 1997; Bąk, M. 1999, 2000).

The presented new (and revised) biostratigraphical data, based on calcareous nannoplankton and radiolaria, suggest that at least the uppermost part of the grey-green shales represents the Lower Turonian in the Skole Nappe.

The Barnasiówka Radiolarian Shale Formation has also equivalent deposits in the Magura Nappe. The Hulina Formation, described in the Grajcarek tectonic-facies zone (Birkenmajer, 1977), and found also in the more internal parts of the Magura Nappe (Obidowa IG-1 borehole: 2453–2510 m – Cieszkowski & Sikora, 1976; Mszana Dolna tectonic window – Burtan *et al.*, 1976, 1978; Burtan & Łydka, 1978) corresponds to the studied formation. Two members have been distinguished in the Hulina Formation: the Groń Radiolarite Member and the Ubocz Shale Member (Birkenmajer, 1977). The Groń Radiolarite Member (2–6 m thick) with numerous thin- to medium-bedded black, brownish, green and bluish cherts (radiolarites) alternating with argillaceous or siliceous radiolaria-bearing, green, dark-green and black shales (Birkenmajer, 1977), may correspond to the lower part of the Barnasiówka Radiolarian Shale Formation. The Ubocz Shale Member (1.5–5.0 m thick), with prevailing black, grey and green argillaceous laminated shales, manganese oxide-coated shales, bentonites, rare thin intercalations of pyriferous sandstone and siderite concretions, corresponds to the middle part of the Barnasiówka Radiolarian Shale Formation. The upper boundary of the Hulina Formation is the base of the variegated shales (Malinowa Shale Formation; Birkenmajer, 1977), similarly like in the Silesian series.

CONCLUSIONS

A new formal lithostratigraphic unit, named the Barnasiówka Radiolarian Shale Formation, including the so-called "green radiolarian shales", is defined in the Silesian Nappe of the Outer Carpathians. This formation together with the equivalent deposits from other tectonic-facies zones, forms a distinctive correlation horizon near the Cenomanian–Turonian boundary in the Outer Carpathians within thick series of Cretaceous flysch.

A characteristic feature of the formation is the occurrence of numerous layers of pyroclastic deposits, associated with black organic-rich shales and a black to brown, porous ferromanganese layer (weathered into large nodules). The similar stratigraphic position of this layer, between two bentonites, in sections which lie about 90 km away from each other, may suggest that it is a significant correlation horizon near the Cenomanian–Turonian boundary.

The detailed biostratigraphical research, based on radiolaria and foraminifers, allowed us to revise the stratigraphic position of the biosiliceous and organic-rich deposits in the Silesian Nappe. The formation belongs to the Upper Cenomanian through the lowermost Turonian and corresponds to similar deposits widespread in the western Mediterranean and the Atlantic Ocean, related to the so called Cenomanian–Turonian Anoxic Event (Schlanger & Jenkyns, 1976; Arthur *et al.*, 1987).

This study do not include the interpretation of the palaeoenvironment of the Silesian Basin during the sedimentation of the Barnasiówka Radiolarian Shale Formation. Previous interpretations of the palaeoenvironment have only a general character. According to Książkiewicz (1975), the depth of deposition of these deposits was about 1500–2000 m, above the CCD. A different opinion was presented by Geroch *et al.* (1985), who suggested occurrence of greater depths (up to 3,500 m), on the grounds of geochemical data. Hanzliková (1973), who studied foraminifers from the Variegated Shales, suggested that the Silesian Basin could be under influence of cold sea currents. Similar remarks were presented in relation to the manganese nodule occurrences in the Variegated Shales and in the underlying biosiliceous organic-rich facies (Geroch *et al.*, 1985).

The palaeoecological aspect of the deposits near the Cenomanian–Turonian boundary will be a subject of separate studies, supplemented by additional microfaunal and geochemical data on the sediments.

Acknowledgements

This paper is dedicated to the memory of Jadwiga Burtan who initiated the study of the mid-Cretaceous radiolarian-rich deposits of the Silesian series.

We would like to thank T. Wieser (Polish Geological Institute) for his discussion during the field studies and discussion on ferromanganese nodules. K. Żytko (Polish Geological Institute) and an anonymous reviewer are gratefully acknowledged for reviewing of the manuscript. Thanks are due to G. Haczewski (Cracow Pedagogical University) for valuable comments, and for improving the English of the manuscript. Thanks are extended to M. Krobicki (University of Mining and Metallurgy, Kraków) for editorial suggestions and to J. Faber (Jagiellonian University, Kraków) who made the SEM photographs. Grant BW –004/G/2000 (to K. B.) and grant KBN/0430/PO4/97/12 (to M. B.) supported this contribution.

REFERENCES

Arthur, M. A. & Premoli Silva, I., 1982. Development of widespread organic carbon-rich strata in the Mediterranean Tethys. In: Schlanger, S. O. & Cita, M. B. (eds), *Nature and origin of Cretaceous carbon-rich facies, Academic Press, London*, pp. 7–54.

Arthur, M. A., Schlanger, S. O. & Jenkyns, H. C., 1987. The Cenomanian–Turonian Anoxic Event, II: palaeoceaonographic controls on organic matter production and preservation. In: Brooks, J. & Fleet, A. (eds), *Marine Petroleum Source Rocks, Geological Society Special Publication, London*, 26, pp. 401–420.

Bąk, K., 1998. Planktonic foraminiferal biostratigraphy of the Upper Cretaceous red deep-water deposits in the Pieniny Klippen Belt, Carpathians, Poland. *Studia Geologica Polonica*, 111: 7–92.

Bąk, K., 2000. Biostratigraphy of deep-water agglutinated Foraminifera in Scaglia Rossa-type deposits of the Pieniny Klippen Belt, Carpathians, Poland. In: Hart, M. B., Kaminski, M. A. & Smart, C. (eds), *Proceedings of the Fifth International Workshop on Agglutinated Foraminifera, Plymouth, England, September 12-19, 1997. Grzybowski Foundation Special Publication*, 7, pp. 15–40.

Bąk, M., 1994. Radiolaria from Cenomanian deposits of the Silesian Nappe near Sanok, Polish Carpathians. *Bulletin of the Polish Academy of Sciences, Earth Sciences*, 42: 145–153.

Bąk, M., 1999. Cretaceous radiolarian zonation in the Polish part of the Pieniny Klippen Belt (Western Carpathians). *Geologica Carpathica*, 50: 21–31.

Bąk, M., 2000. Radiolaria from the Upper Cenomanian–Lower Turonian deposits of the Silesian Unit (Polish Flysch Carpathians). *Geologica Carpathica*, 51: 309–324.

Bąk, K. & Bąk, M., 2000. The Cenomanian–Turonian Boundary Event in deep-water flysch sediments of the Silesian Unit (Polish Western Carpathians) – agglutinated foraminifera and radiolaria record. In: *Abstracts of the 6th International Cretaceous Symposium, August 27 to September 4, 2000, Vienna, Austria*, p. 12.

Bąk, M. & Bąk, K., 1999. Correlation of the early Albian–late Turonian radiolarian biozonation with planktonic and agglutinated foraminifera zonations in the Pieniny Klippen Belt, Polish Carpathians. *Geodiversitas*, 21: 525–536.

Bąk, M. & Bąk, K., 2000. Biostratygrafia głębokowodnych utworów na granicy cenomanu i turonu w jednostce śląskiej Karpat fliszowych. (In Polish only). In: Zapałowicz-Bilan *et al.* (eds), *Referaty, komunikaty, postery: 17 Konferencja Paleontologów, 21-23.09.2000 Kraków; Historia basenów sedymentacyjnych a zapis paleontologiczny*, pp. 15–16.

Bąk, M., Gedl, E. & Bąk, K., 2000. Zespoły radiolarii, otwornic i dinocyst na granicy cenomanu i turonu w jednostce podśląskiej. (In Polish only). In: Zapałowicz-Bilan *et al.* (eds), *Referaty, komunikaty, postery: 17 Konferencja Paleontologów, 21- 23.09.2000 Kraków; Historia basenów sedymentacyjnych a zapis paleontologiczny*, pp. 12–13.

Bengston, P., 1996. The Turonian stage and substage boundaries. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique*, 66: 69–79.

Bieda, F., Geroch, S., Koszarski, L., Książkiewicz, M. & Żytko, K. 1963. Stratigraphie des Karpates externes polonaises. *Biuletyn Instytutu Geologicznego*, 181: 5–174.

Birkenmajer, K., 1965. Outlines of the geology of the Pieniny Klippen Belt of Poland. *Annales Societatis Geologorum Poloniae*, 35: 327–356.

Birkenmajer, K. (ed.), 1975. Zasady polskiej klasyfikacji, terminologii i nomenklatury stratygraficznej. (In Polish only). *Instrukcje i metody badań geologicznych*, 33: 1–63.

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

Brumsack, H.-J. & Thurrow, J., 1986. The geochemical facies of black shales from the Cenomanian/Turonian Boundary Event. In: Degens, E. T. *et al.* (eds), *Biogeochemistry of black shales. Mitteilungen Geologia und Paläontologia*, 60: 247–265.

Burov, V. S., Vishnyakov, I. B., Dabagyan, N. V., Kurilets, I. I., Mykita, B. W., Hadykin, F. T. & Shakin, W. O., 1972. Novi dany pro Kreidowy vyklady Skibovoy zony Karpat. (In Russian). *Geologiya i Geokhimya Goryuchikh Kopalin, Kiev*, 32: 3–7.

Burtan, J. (ed.), 1964a. *Szczegółowa Mapa Geologiczna Polski (bez utworów czwartorzędowych) 1:50 000; Rejon Karpat i Przedgórza: arkusz Myślenice*. Wydawnictwa Geologiczne, Warszawa.

Burtan, J. (ed.), 1964b. *Szczegółowa Mapa Geologiczna Polski (bez utworów czwartorzędowych) 1:50 000; Rejon Karpat i Przedgórza: arkusz Wisła*. Wydawnictwa Geologiczne, Warszawa.

Burtan, J. (ed.), 1964c. *Szczegółowa Mapa Geologiczna Polski (bez utworów czwartorzędowych) 1:50 000; Rejon Karpat i Przedgórza: arkusz Mszana Dolna*. Wydawnictwa Geologiczne, Warszawa.

Burtan, J., 1968. The Silesian Beskid. In: Książkiewicz, M. (ed.), *Geology of the Polish Flysch Carpathians; Guide to Excursion No. C44 Poland; International Geological Congress, 23 Session, Prague*. Wydawnictwa Geologiczne, pp. 11–14.

Burtan, J. & Łydka, K., 1978. On metamorphic tectonites of the Magura Nappe in the Polish Flysch Carpathians. *Bulletin of the Polish Academy of Sciences, Serie Terre*, 26: 95–101.

Burtan, J. & Szymakowska, F. (eds), 1964. *Szczegółowa Mapa Geologiczna Polski (bez utworów czwartorzędowych) 1:50000; Rejon Karpat i Przedgórza: arkusz Osielec*. Wydawnictwa Geologiczne, Warszawa.

Burtan, J. & Turnau-Morawska, M., 1978. Biochemical siliceous rocks of the West Carpathian Flysch. (In Polish, English summary). *Prace Geologiczne Polskiej Akademii Nauk – Oddział w Krakowie, Komisja Nauk Geologicznych*, 111: 1–36.

Burtan, J., Paul, Z. & Watycha, L., 1976. *Szczegółowa Mapa Geologiczna Polski, 1:50,000; arkusz Mszana Górna*. Państwowy Instytut Geologiczny, Warszawa.

Burtan J., Paul, Z. & Watycha, L., 1978. *Szczegółowa Mapa Geologiczna Polski, 1:50,000; arkusz Mszana Dolna*. Państwowy Instytut Geologiczny, Warszawa.

Burtanówna, J., Konior, K. & Książkiewicz, M., 1937. *Carte géologiques des Karpates de Silésie*. Polska Akademia Umiejętności, Wydawnictwo Śląskie, Kraków, 104 pp.

Burtanówna, J., Książkiewicz, M. & Sokołowski, S., 1933. Über das Auftreten der Radiolaritschiefer in der mittleren Kreide der West-Beskiden. (In Polish, German summary). *Annales de la Société Géologique de Pologne*, 9: 96–99.

Cieszkowski, M. & Sikora, W., 1976. Wyniki badań geologicznych z wiercenia Obidowa IG-1; Polskie Karpaty Zewnętrzne. (In Polish only). *Kwartalnik Geologiczny*, 2: 441–442.

Dumitrică, P., 1975. Cenomanian Radiolaria at Podul Dîmdovitei, In: *Micropaleontological Guide to the Mesozoic and Tertiary of the Romanian Carpathians; 14th European Micropaleontological Colloquium, Romania*. Institute of Geology and Geophysics, Buchurest, pp. 87–89.

Gaździcka, E., 2001. Development stages of Skolski depositional basin in the Cretaceous and early Paleogene – nannoplankton documentation. (In Polish only). *Przegląd Geologiczny*, 49: 449–451.

Gedl, E. & Bąk, M., 2000. Mid-Cretaceous dinosysts and Radiolaria from the Zasań section (Subsilesian Unit, Polish Outer Carpathians) – a CTBE problem. In: *Abstracts of 6th International Cretaceous Symposium, August 27 to September 4, 2000, Vienna, Austria*, p. 36.

Geroch, S., 1957. *Uvigerinammina jankói* Majzon (Foraminifera) in the Carpathian flysch. (In Polish, English summary). *Annales de la Société Géologique de Pologne*, 25: 231–244.

Geroch, S., 1959. Stratigraphic significance of arenaceous foraminifera in the Carpathian flysch. *Paläontologische Zeitschrift*, 33: 113–122.

Geroch, S., 1960. Microfaunal assemblage from the Cretaceous and Palaeogene Silesian unit in the Beskid Śląski Mts., Western Carpathians. *Instytut Geologiczny–Biuletyn*, 153: 1–138.

Geroch, S., 1967. A some assemblages of microfauna from the Silesian Series of the Western Polish Carpathians. *Instytut Geologiczny–Biuletyn*, 211: 369–381.

Geroch, S. & Gradziński, R., 1955. Stratigraphy of the Sub-Silesian Series in the tectonic window of Żywiec. (In Polish, English summary). *Annales de la Société Géologique de Pologne*, 24: 3–62.

Geroch, S. & Koszarski, L., 1988. Agglutinated foraminiferal stratigraphy of the Silesian Flysch Trough. *Abhandlungen der Geologischen Bundesanstalt*, 41: 73–79.

Geroch, S. & Nowak, W. 1984. Proposal of zonation for the Late Tithonian–Late Eocene, based upon arenaceous Foraminifera from the Outer Carpathians, Poland. In: Oertli, H. J. (ed.), *BENTHOS '83: 2nd International Symposium on Benthic Foraminifera (Pau, April 11-15, 1983)*. Elf-Aquitane, ESO REP and TOTAL CFP, Pau & Bordeoux, pp. 225–239.

Geroch, S., Gucwa, I. & Wieser, T., 1985. Manganese nodules and other indications of regime and ecological environment in lower part of the Upper Cretaceous – exemplified by Lanckorona profile. In: Wieser, T. (ed.), *13th Congress of Carpatho- Balkan Geological Association: Fundamental researches in the western part of the Polish Carpathians, Guide to Excursion I*. Geological Institute, Cracow, pp. 88–100.

Geroch, S., Koszarski, L. & Książkiewicz, M., 1963. Cretace. In: Bieda *et al.* (eds), *Stratigraphie des Karpates externes polonaises: Recherches géologiques dans les Karpates; 6th Congress of Carpatho-Balkan Geological Association, Warsaw – Cracow. Instytut Geologiczny–Biuletyn*, 181: 18–90.

Geroch, S., Jednorowska, A., Książkiewicz, M. & Liszkowa, J. 1967. Stratigraphy based upon microfauna in the Western Polish Carpathians. *Instytut Geologiczny–Biuletyn*, 211: 185–282.

Górka, H., 1996. Cenomanian Radiolaria from Spława, Polish Carpathians. *Geological Quarterly*, 40: 555–574.

Gucwa, I., 1966. Results of geochemical examinations of radiolarian shales from Niedźwiada, near Ropczyce. (In Polish, English summary). *Kwartalnik Geologiczny*, 10: 1047–1059.

Gucwa, I. & Pelczar, A., 1992. *Katalog analiz chemicznych skał Karpat Polskich za lata 1963-1985: Część 1, Skały osadowe*. (In Polish only). Państwowy Instytut Geologiczny, Warszawa, 299 pp.

Gucwa, I. & Wieser, T., 1978. Ferromanganese nodules in the Western Carpathian flysch deposits of Poland. *Annales de la Société Géologique de Pologne*, 48: 147–182.

Gzik, M., 1990. *Charakterystyka mikropaleontologiczna serii radiolarytowej rejonu Lanckorony*. (In Polish only). Unpublished MSc. Thesis, Instytut Nauk Geologicznych, Uniwersytet Jagielloński, 99 pp.

Gzik, M. & Koszarski, L., 1990. The sedimentation and microfauna of a series of Cretaceous radiolarites from the vicinity of Lanckorona in the Carpathians. *Sprawozdania z Posiedzeń Komisji Nauk Geologicznych Polskiej Akademii Nauk w Krakowie*, 34: 220–223.

Hancock, J. M., 1984. Some possible boundary-stratotype for the base of the Cenomanian and Turonian stages. *Bulletin of the geological Society of Denmark*, 33: 123–128.

Hancock, J. M., 1991. Ammonite scales for the Cretaceous System. *Cretaceous Research*, 12: 259–291.

Hanzlikovà, E., 1973. Foraminifers of the Variegated Godula Member in Moravia (Cenomanian–Turonian). *Sbornik Geologickych Věd, Paleontologie*, 15: 119–184.

Herbin, J. P., Malmaison, R., Magniez-Janin, F. & Muller, D. C., 1986a. Mesozoic organic-rich sediments in the South Atlantic: distribution in time and space. *Mitteilungen Geologia und Paläontologia*, 60: 71–97.

Herbin, J. P., Montadert, L., Mueller, C., Gomez, R., Thurow, J. & Wiedmann, J., 1986b. Organic-rich sedimentation at the Cenomanian–Turonian Boundary in oceanic coastal basins in the North Atlantic and Tethys. In: Summerhayes C. P. & Shackleton, N. J. (eds), *North Atlantic Palaeoceanography, Geophysical Society Special Publication*, 22, pp. 389–422.

Huss, F., 1957. Stratigraphy of the Węglówka unit in the light of its microfauna. (In Polish, English summary). *Acta Geologica Polonica*, 7: 29–69.

Kennedy, W. J., 1984. Ammonite faunas and the "standard zones" of the Cenomanian to Maastrichtian stages in their type areas, with some proposal for the definition of the stage boundaries by ammonites. *Bulletin of the geological Society of Denmark*, 33: 147–161.

Kennedy, W. J. & Cobban, W. A., 1991. Stratigraphy and interregional correlation of the Cenomanian–Turonian transition in the Western Interior of the United States near Pueblo, Colorado, a potential boundary stratotype for the base of the Turonian stage. *Newslatters on Stratigraphy*, 24: 1–33.

Koszarski, L. 1956. Stratygrafia serii śląskiej i podśląskiej na północ od Sanoka. (In Polish only). *Przegląd Geologiczny*, 4: 461–463.

Koszarski, L., 1968. Marginal zone of the Silesian Unit in the valley of the river San. In: Książkiewicz, M. (ed.), *Geology of the Polish Flysch Carpathians; Guide to Excursion No. C44; International Geological Congress, 23 Session, Prague*. Wydawnictwa Geologiczne, Warszawa, pp. 46–51.

Koszarski, L. & Liszkowa, J., 1963. Nowe dane o cenomanie w Karpatach. (In Polish only). *Kwartalnik Geologiczny*, 7: 557–558.

Koszarski, L. & Morgiel, J., 1963. Wstępne badania nad biostratygrafią kredy jednostki skolskiej koło Tarnowa. (In Polish only). *Kwartalnik Geologiczny*, 7: 555–557.

Koszarski, L. & Nowak, W., 1960. Notes on the age of Lgota Beds, Carpathian Flysch. (In Polish, English summary). *Kwartalnik Geologiczny*, 4: 468–483.

Koszarski, L. & Żytko, K., 1965. Le probleme de la profondeur de la mer du geosynclinal Karpatique de flysch. In: *Carpatho-Balkan Geological Association, 7th Congress, Reports*, part II, v. 2. Sofia, pp. 112–116.

Koszarski, L., Nowak, W. & Żytko, K., 1959. Notes on the age of the Godula Beds (Carpathians Flysch). (In Polish, English summary). *Kwartalnik Geologiczny*, 3: 127–151.

Kotlarczyk, J., 1978. Stratigraphy of the Ropianka Formation or of Inoceramian Beds in the Skole Unit of the Flysch Carpathians. (In Polish, English summary). *Prace Geologiczne Polskiej Akademii Nauk – Oddział w Krakowie*, 108: 1–81.

Kotlarczyk, J. 1988. Zarys stratygrafii brzeżnych jednostek tektonicznych orogenu karpackiego. (In Polish only). In: Kotlarczyk, J. & Pękala, K. (eds), *Przewodnik 59 Zjazdu Polskiego Towarzystwa Geologicznego, Karpaty Przemyskie, 16-18.09.1988*. Wydawnictwo AGH, Kraków, pp. 31–62.

Kotlarczyk, J. & Gaździcka, E., 1988. Formacja z Dołhego i formacja z Ropianki w obszarze hipostratotypowym; stratygrafia za pomocą nannoplanktonu. (In Polish only). In: Kotlarczyk, J. & Pękala, K. (eds), *Przewodnik 59 Zjazdu Polskiego Towarzystwa Geologicznego, Karpaty Przemyskie, 16-18.09.1988*. Wydawnictwo AGH, Kraków, pp. 101–102.

Książkiewicz, M., 1933. Beitrag zur Kenntnis der mittleren Kreide der Godula-Decke in den West-Karpaten. (In Polish, German summary). *Annales de la Société Géologique de Pologne*, 9: 88–95.

Książkiewicz, M., 1936. La structure de la zone de Lanckorona. *Bulletin de l'Académie Polonaise des Sciences, Lett., Ser A.*:

Książkiewicz, M., 1939. Fauna górnoneokomska z Lanckorony. (In Polish only). *Sprawozdania Komisji Fizjograficznej Polskiej Akademii Nauk*, 72:

Książkiewicz, M., 1951. *Objaśnienia do arkusza "Wadowice" Szczegółowej Mapy Geologicznej Polski 1:50,000*. (In Polish only). Państwowy Instytut Geologiczny, Warszawa, 283 pp.

Książkiewicz, M., 1975. Batymetry of the Carpathian Flysch Basin. *Acta Geologica Polonica*, 25: 309–367.

Kuhnt, W., Thurow, J., Wiedmann, J. & Herbin, J. P., 1986. Oceanic anoxic conditions around the Cenomanian/Turonian boundary and the response of the biota. *Mitteilungen Geologia und Paläontologia*, 60: 205–246.

Kuhnt, W., Geroch, S., Kaminski, M. A., Moullade, M. & Neagu, T., 1992. Upper Cretaceous abyssal claystones in the North Atlantic and Western Tethys: current status of biostratigraphical correlation using agglutinated foraminifers and palaeoceanographic events. *Cretaceous Research*, 13: 467–478.

Liszkowa, J., 1956. Mikrofauna serii podśląskiej. (In Polish only). *Przegląd Geologiczny*, 4: 463–468.

Liszkowa, J., 1967. Microfauna of the Upper Cretaceous marls in the Sub-Silesian Series of the Wadowice region (Western Carpathians). *Instytut Geologiczny–Biuletyn*, 211: 341–351.

Morgiel, J. & Olszewska, B., 1981. Biostratigraphy of the Polish External Carpathians based on agglutinated foraminifera. *Micropaleontology*, 27: 1–30.

Moullade, M., Kuhnt, W. & Thurow, J., 1988. Agglutinated benthic foraminifers from Upper Cretaceous variegated clays of the North Atlantic Ocean (DSDP Leg 93 and ODP Leg 103). In: Boillot, G., Winterer, E. L. *et al.* (eds), *Proceedings of the Ocean Drilling Program, Scientific Results*, 103, College Station, TX (Ocean Drilling Program), pp. 247–264.

Neagu, T., 1990. *Gerochammina* n.g. and related genera from the Upper Cretaceous flysch-type benthic foraminiferal fauna, Eastern Carpathians – Romania. In: Hemleben, C. *et al.* (eds), *Palaeoecology, Biostratigraphy, Paleoceanography and Taxonomy of Agglutinated Foraminifera*. Kluver Academic Publishers, pp. 245–256.

Nowak, W. 1956. Seria podśląska na arkuszu Bielsko-Biała. (In Polish only). *Przegląd Geologiczny*, 4: 460–461.

Nowak, W. (ed.), 1963. *Szczegółowa Mapa Geologiczna Polski (bez utworów czwartorzędowych) 1:50 000; Rejon Karpat i Przedgórza: arkusz Bielsko-Biała*. Wydawnictwa Geologiczne, Warszawa.

Nowak, W. (ed.), 1964. *Szczegółowa Mapa Geologiczna Polski (bez utworów czwartorzędowych) 1:50 000; Rejon Karpat i Przedgórza: arkusz Skoczów*. Wydawnictwa Geologiczne, Warszawa.

O'Dogherty, L., 1994. Biochronology and paleontology of Mid-Cretaceous Radiolarians from Northern Apennines (Italy) and Betic Cordillera (Spain). *Memoires de Geologie (Lousanne)*, 21: 1–413.

Olszewska, B., 1997. Foraminiferal biostratigraphy of the Polish Outer Carpathians: a record of basin geohistory. *Annales Societatis Geologorum Poloniae*, 67: 325–337.

Paul, Z., Rączkowski, W., Ryłko, W. & Tomaś, A., 1996. Budowa geologiczna zachodniej części Karpat polskich. (In Polish only). In: Poprawa, D. & Rączkowski, W. (eds), *67th Annual Meeting of the Polish Geological Society; Western Beskidy Mts. – new approach to geological structure and natural resources*. Polskie Towarzystwo Geologiczne, Państwowy Instytut Geologiczny, Kraków, pp. 8–31.

Schlanger, S. O. & Jenkyns, H. C., 1976. Cretaceous oceanic anoxic events: causes and consequences. *Geologie en Mijnbouw*, 55: 179–184.

Sissingh, W., 1977. Biostratigraphy of Cretaceous calcareous nannoplankton. *Geologie en Mijnbouw*, 57: 433–440.

Stymałówna, M. & de Cizancourt, H., 1925. O budowie geologicznej okolicy Rybnika nad Stryjem. (In Polish only). *Kosmos*, 50: 13–30.

Sujkowski, Z., 1931. Compte-rendu des recherches pétrographiques exécutees en 1930 dans les Karpates. (In Polish only). *Posiedzenia Naukowe Państwowego Instytutu Geologicznego*. 29: 32–33.

Sujkowski, Z., 1932. Radiolarites des Karpates Polonaises Orientales et leur comparaison avec les radiolarites de la Tatra. (In Polish, French summary). *Sprawozdania Polskiego Instytutu Geologicznego*, 7: 79–168.

Sujkowski, Z. & Różycki, S. Z., 1930. Trouvaille de Radiolarites typiques dans les Karpates orientales. (In Polish only). *Posiedzenia Naukowe Państwowego Instytutu Geologicznego*, 25: 14–15.

Sýkora, M., Ožvoldová, L. & Boorová, D., 1997. Turonian silicified sediments in the Czorsztyn Succession of the Pieniny Klippen Belt (Western Carpathians, Slovakia). *Geologica Carpathica*, 48: 243–261.

Szymakowska, F., 1962. Bentonity z kredy śląskiej pasma Chełm-Czarnorzeki. (In Polish only). *Kwartalnik Geologiczny*, 6: 440–441.

Szymakowska, F. & Żytko, K. (eds), 1965. *Szczegółowa Mapa Geologiczna Polski (bez utworów czwartorzędowych) 1:50000; Rejon Karpat i Przedgórza: arkusz Kalwaria Zebrzydowska*. Wydawnictwa Geologiczne, Warszawa.

Ślączka, A., 1959. Stratigraphy of the Bystre scale (Middle Carpathians). (In Polish, English summary). *Instytut Geologiczny–Biuletyn*, 131: 203–286.

Ślączka, A., 1973. Wycieczka 8 – Roztoki Dolne – Bystre – Jabłonki – Habkowce – Cisna. (In Polish only). In: Żytko K. (ed.), *Przewodnik geologiczny po wschodnich Karpatach fliszowych*. Wydawnictwa Geologiczne, Warszawa, pp. 146–159.

Ślączka, A. & Kaminski, M. A., 1998. *Guidebook to Excursions in the Polish Flysch Carpathians*. Grzybowski Foundation Special Publication, 6, 171 pp.

Ślączka, A., Geroch, S. & Koszarski, L., 1993. *Excursion Guidebook in the Polish Flysch Carpathians; 4th International Workshop on Agglutinated Foraminifera*, Grzybowski Foundation Special Publication No. 2, Kraków, 54 pp.

Świdziński, H., 1948. Stratigraphical index of the Northern Flysch Carpathians. *Institut Geologique de Pologne–Bulletin*, 37: 1–128.

Teisseyre, H., 1947. Budowa geologiczna okolic Węglówki. (In Polish only). *Nafta*, 3:

Van Couvering, J. A., Aubry, M. P., Berggren, W. A., Bujak, J. P., Naeser, P. & Wieser, T., 1981. The terminal Eocene and the Polish connection. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 36: 321–362.

Wdowiarz, S., 1953. Geology of the Grabownica fold. (In Polish, English summary). *Instytut Geologiczny–Biuletyn*, 11: 1–51.

Wdowiarz, S., 1968. Silesian and Sub-Silesian units north of Krosno. In: Książkiewicz, M. (ed.), *Geology of the Polish Flysch Carpathians; Guide to Excursion No. C44; International Geological Congress, 23 Session, Prague*. Wydawnictwa Geologiczne, Warszawa, pp. 58–65.

Wieser, T., 1973. Klinoptylolit w łupkach radiolariowych cenomanu z Międzybrodzia k. Sanoka. (In Polish only). *Kwartalnik Geologiczny*, 17: 651–652.

Wieser, T., 1982a. Barites and celestobarites in the flysch of the Polish Carpathians. *Archiwum Mineralogiczne*, 38: 13–25.

Wieser, T., 1982b. Manganiferous carbonate micronodules of the Polish Carpathian flysch deposits and their origin. *Mineralia*

Polonica, 13: 25–42.
Wieser, T., 1985. Birnesite micronodules in the Polish Carpathian flysch deposits. *Mineralia Polonica*, 16: 23–34.
Zhurakovsky, A. G., 1968. Certain new data on the Cretaceous deposits of the Striy river bassins. (In Russian, English summary). *Geologitseskoy Sbornik*, Lvov, 11: 36–42.

Streszczenie

FORMACJA ŁUPKÓW RADIOLARIOWYCH Z BARNASIÓWKI – NOWA JEDNOSTKA LITOSTRATYGRAFICZNA W GÓRNYM CENOMANIE I NAJNIŻSZYM TURONIE W POLSKICH KARPATACH ZEWNĘTRZNYCH (SERIA ŚLĄSKA)

Krzysztof Bąk, Marta Bąk i Zbigniew Paul

Osady krzemionkowe, wzbogacone w materię organiczną, z pogranicza cenomanu i turonu stanowią charakterystyczny horyzont w wielu profilach obszaru medyterańskiego oraz w rdzeniach wiertniczych z dna Atlantyku (Schlanger & Jenkyns, 1976; Arthur & Premoli Silva, 1982; Arthur *et al.*, 1987; Brumsack & Thurrow, 1986; Herbin *et al.*, 1986a, b; Kuhnt *et al.*, 1986).

Podobny typ facji organicznych i krzemionkowych (zdominowanych przez zielone łupki z radiolariami) występuje we wszystkich jednostkach tektoniczno-facjalnych Karpat Zewnętrznych (Sujkowski, 1932; Burtanówna *et al.*, 1933; Książkiewicz, 1951; Koszarski *et al.*, 1959; Kotlarczyk, 1978; Geroch *et al.*, 1985). W schematach litostratygraficznych Karpat są one wydzielane w randze nieformalnej jednostki litostratygraficznej obejmującej prawie cały cenoman (ostatnia kompilacja: Ślączka & Kaminski, 1998). Używano dotychczas bardzo różnych nazw do definicji tych facji. Po raz pierwszy opisano je jako "zielone i czerwone łupki" w jednostce skolskiej (Stymałówna & Cizancourt, 1925). Później były one tam określane jako "czerwone radiolaryty z łupkami czerwonymi i zielonymi" (Sujkowski & Różycki, 1930), "radiolaryty i margle krzemionkowe" (Sujkowski, 1931, 1932) albo tzw. "formacja łupków radiolariowych z Dołhego" (Kotlarczyk, 1978, 1988).

Innych nazw używano w jednostce śląskiej i podśląskiej. Burtanówna *et al.* (1933) opisała je jako "łupki radiolariowe". Później używano jeszcze innych określeń: "iły przejściowe jasnozielone" (Teisseyre, 1947), "pstre łupki i radiolaryty" (Świdziński, 1948), "warstwy jaspisowe" (Książkiewicz, 1951; Geroch *et al.*, 1963; Paul *et al.*, 1996), "bezwapniste, ciemnoszare i pstre iły" (Huss, 1957), "łupki zielone z radiolariami" (Koszarski *et al.*, 1959), "warstwy radiolariowe" (Geroch *et al.*, 1967), "zielone łupki z radiolariami i radiolaryty" (Koszarski in: Ślączka *et al.*, 1993), "łupki zielone radiolariowe" (Ślączka & Kaminski, 1998). Z kolei w jednostce Grajcarka wydzielono je w randze formalnej jednostki litostratygraficznej, jako formacja hulińska (fm) (Birkenmajer, 1977).

Należy podkreślić, że przedstawione powyżej nazwy jednostek nieformalnych obejmowały różne litologie, a ich granice były niesprecyzowane, bądź umieszczone w różnych horyzontach litologicznych. Wiek facji organicznych i krzemionkowych był zdefiniowany nieprecyzyjnie, najczęściej w oparciu o skamieniałości z jednostek sąsiadujących i w oparciu o pozycję stratygraficzną w profilu. Stąd też prawie każdy schemat litostratygraficzny prezentowany dla Karpat Zewnętrznych zawiera odmienną pozycję stratygraficzną dla opisywanych utworów (od albu do cenomanu, ze zróżnicowanym zasięgiem). Według ostatniej kompilacji, horyzont zielonych łupków radiolariowych obejmuje prawie cały cenoman (Ślączka & Kaminski, 1998).

Niniejsza praca jest propozycją włączenia osadów organicznych i krzemionkowych w obręb nowej formalnej jednostki litostratygraficznej oraz określenia, możliwie najdokładniej, jej pozycji stratygraficznej. Formalizacja litostratygraficzna jest prezentowana zgodnie z "Zasadami polskiej klasyfikacji, terminologii i nomenklatury stratygraficznej" (red. Birkenmajer, 1975) i oparta o własne prace kartograficzne, studia biostratygraficzne i sedymentologiczne prowadzone w latach 1997–2000 oraz materiały publikowane. Proponowana formalizacja obejmuje osady w obrębie jednostki śląskiej, gdzie obecnie istnieje najwięcej odsłonięć i dla której opublikowano najwięcej danych.

Zgodnie z zasadami formalizacji litostratygraficznej przedstawiono historię badań osadów, ze szczególnym uwzględnieniem wyników prac biostratygraficznych (Tab. 1).

Nazwa jednostki – formacja łupków radiolariowych z Barnasiówki (fm). Nazwa pochodzi od miejsca obszaru stratotypowego na grzbiecie Barnasiówka w Beskidzie Wyspowym, gdzie osady te zostały po raz pierwszy opisane w jednostce śląskiej (Burtan *et al.*, 1933); nazwa odzwierciedla również dominujący litotyp formacji.

Obszar typowy – Grzbiet Barnasiówka w Beskidzie Wyspowym, z profilami całej jednostki i jej granic w kamieniołomie Barnasiówka-Ostra Góra i Barnasiówka-Jasienica oraz w potokach rozcinających grzbiet, pomiędzy wzgórzami Pisana i Dalin (Fig. 1, 2).

Profil formacji w obszarze stratotypowym. Dolna część formacji (ok. 10 m miąższości) obejmuje serię wapnistych i bezwapnistych, zielonych, szarych i czarnych łupków, z przeławiceniami cienko- do średnioławicowych mułowców krzemionkowych, drobnoziarnistych piaskowców krzemionkowych i rogowców (Fig. 3). W tej części formacji dominują łupki ilaste. Charakterystycznym typem sekwencji jest powtarzająca się seria czarnych łupków wapnistych przechodzących w szare i plamiste łupki wapniste, a te z kolei w zielone łupki bezwapniste (częściowo krzemionkowe). W najniższej części formacji łupki szare i zielone są zbioturbowane. Mułowce, piaskowce i rogowce tworzą warstwy do 12 cm miąższości (zwykle 4–8 cm); ich ilość i miąższość maleje w górę profilu. Stosunek mułowców z piaskowcami i rogowcami do łupków zmienia się od 1:1 (w najniższej 3,5 m serii), przez 2:3 i 1:3 (w kolejnych pakietach o miąższościach odpowiednio 3,8 m i 1,4 m) do 1:5 (w najwyższej części). Większość ławic mułowców i piaskowców jest skrzemionkowana, jakkolwiek zawierają one miejscami spoiwo i ziarna węglanowe (organiczne). Piaskowce, mułowce i rogowce są szarozielone do ciemnoszarych, a na powierzchniach zwietrzałych – żółte lub brązowe.

Środkowa część formacji obejmuje serię zielonych, oliwkowych i czarnych łupków silnie ilastych (2 m miąższości), z przeławiceniami ciemnych tufitów i jasnozielonych bentonitów. Na kontakcie czarnych łupków i bentonitów występują żółte (żelaziste) skorupy wietrzeniowe. Brak jest w tej części profilu wkładek klastycznych. Powyżej występuje pakiet (1,2 m miąższości) czarnych i zielonych łupków silnie krzemionkowych, z przeławiceniami tufitów i bentonitów. Pomiędzy dwoma cienkimi warstwami bentonitów, w najwyższej części tego pakietu występuje czarna, silnie porowata warstwa żelazisto-manganowa (do 9 cm miąższości). Wykazuje ona ślady wietrzenia elipsoidalnego, tworząc duże formy konkrecyjne.

Górna część formacji obejmuje serię (ok. 2 m miąższości) zielonych i pojedynczych czerwonych, silnie skrzemionkowanych mułowców i rogowców, rozpadających się wzdłuż grubej laminacji równoległej. Miąższość warstw waha się od 4 do 18 cm. Są one przeławicone zielonymi łupkami ilastymi (częściowo skrzemionkowanymi). Pierwsza czerwona warstwa łupku ilastego (1–2 cm miąższości) pojawia się ok. 20 cm powyżej stropu zwartego pakietu krzemionkowych mułowców i rogowców. Jest ona uważana jako spąg pstrych łupków. Nieco powyżej tej warstwy łupku (ok. 5 cm) występuje kolejny horyzont (kilka cm miąższości) żelazisto-manganowy, o charakterze silnie porowatej warstwy. Dominacja czerwonych łupków w pakiecie z łupkami zielonymi ma miejsce około 1 m powyżej w obszarze stratotypowym.

W pracy wydzielono i opisano również profile hipostratotypowe dla formacji łupków radiolariowych z Barnasiówki (fm). Wybrano tutaj takie profile, które w czasie badań autorów były najlepiej odsłonięte oraz te, posiadające szczegółową dokumentację geologiczną. Profile hipostratotypowe znajdują się (z zachodu na wschód): w kamieniołomie Wisła – Obłaziec (Fig. 1, 4), kamieniołomie Straconka k. Bielska-Białej (Fig. 1, 5), w potokach rozcinających G. Zamkową w Brodach k. Lanckorony (Fig. 1, 6), w dolinie potoku Zasanka w Trzemeśni k. Myślenic (Fig. 1, 7), w korycie Czarnego Potoku w Węglówce (Fig. 1, 8), w dolinie Sanu w Międzybrodziu k. Sanoka (Fig. 1, 9) oraz w korycie potoku Jabłonki w Bystrym w Bieszczadach (Fig. 1, 10).

Litotypy wydzielone w obrębie formacji (zielone, szare i czarne łupki, szare, zielone i czerwone rogowce, mułowce i piaskowce, skały piroklastyczne oraz warstwa żelazisto-manganowa) zostały szczegółowo opisane, zarówno pod względem mikrofacji jak i danych geochemicznych (Fig. 11–13).

Dolna granica formacji (Fig. 14; 16A, B) – ostra, przy przejściu do niżejległych rogowców mikuszowickich; umiejscowiona w stropie ostatniej grubej ławicy piaskowca z warstwami szaroniebieskich rogowców. Gdy w spągu występują warstwy gezowe lub lgockie bez rogowców mikuszowickich, granica ma charakter przejściowy; jest umiejscowiona w spągu pakietu łupkowego, w serii o przeważającym udziale łupków zielonych i szarych nad piaskowcami i mułowcami.

Górna granica formacji (Fig. 15; 16C) – ostra; w spągu pierwszej warstwy czerwonych łupków, stanowiących spąg pstrych łupków; lub w spągu pierwszej ławicy zwartego pakietu piaskowców gruboławicowych, glaukonitowych typu godulskiego.

Miąższość formacji – od 0,5 m w części wschodniej jednostki śląskiej (zredukowana tektonicznie?) do około 14–15 m w części środkowej i zachodniej jednostki śląskiej.

Wiek formacji – określony został w oparciu o zespoły radiolarii i otwornic, oznaczonych z tych samych próbek skał. Analizy biostratygraficzne przeprowadzono z wykorzystaniem ok. 100 próbek z 5 profili (Brody, Barnasiówka-Jasienica, Trzemeśnia, Węglówka i Międzybrodzie), włączając do nich również próbki z sąsiadujących jednostek litostratygraficznych.

Podstawą do oznaczenia wieku był zróżnicowany taksonomicznie (35 gatunków) i bogaty ilościowo zespół radiolarii, zdominowany przez formy z rzędu Nassellaria (60–99% liczebności zespołu) (Fig. 17). Wśród form z rzędu Spumellaria (Fig. 17), mniej licznych, występuje kilka gatunków o znaczeniu stratygraficznym. Szczegółowy opis systematyczny całego zespołu przedstawiono w oddzielnych pracach (M. Bąk, 1994, 2000).

Najniższa część formacji jest korelowana z poziomem zespołowym *Holocryptocanium barbui-Holocryptocanium tuberculatum* (Fig. 18, 19), który odpowiada górnemu cenomanowi (Dumitrică, 1975). Wyższa część formacji (do stropu jej środkowej części) należy do poziomów ograniczonego zasięgu *Hemicryptocapsa prepolyhedra* (górny cenoman) i *Hemicryptocapsa polyhedra* (najwyższa część cenomanu), które zostały wyróżnione i skalibrowane z poziomami otwornic planktonicznych w środowisku pelagicznym (M. Bąk, 1999; M. Bąk & K. Bąk, 1999). Najwyższa część formacji należy do poziomu ograniczonego zasięgu *Alievium superbum*, którego dolna granica reprezentuje najniższą część turonu (O'Dogherty, 1994). Potwierdzeniem turońskiego wieku tej części formacji jest ponadto obecność innych taksonów radiolarii, jak *Crucella cachensis* Pessagno, *Patellula andrusovi* Ožvoldová i *Patellula ecliptica* O'Dogherty, których moment pierwszego pojawienia się jest określany na wczesny turon (Sýkora *et al.*, 1997).

Otwornice potwierdzają wiek określony na podstawie radiolarii. W najniższej części formacji znaleziono pojedyncze rotalipory (Fig. 18). Potwierdza to wcześniejsze obserwacje mikropaleontologiczne w innych obszarach, gdzie oznaczono w zielonych łupkach radiolariowych formy z gatunku *Rotalipora* cf. *cushmani* Morrow (Książkiewicz w: Koszarski *et al.*, 1959; Koszarski & Liszkowa, 1963). W wyższej części formacji brak jest diagnostycznych dla wieku otwornic planktonicznych; występują natomiast (dość liczne w niektórych rogowcach) bardzo małych rozmiarów otwornice z rodzaju *Globigerinelloides*, *Hedbergella* i *Heterohelix* (Fig. 11). W najwyższej części (zarówno w łupkach jak i rogowcach) nie znaleziono stratygraficznie ważnych otwornic planktonicznych z rodzaju *Helvetoglobotruncana*.

Otwornice aglutynujące, bardzo liczne, szczególnie w dolnej części formacji, potwierdzają wiek formacji wyznaczony w oparciu o radiolarie. Wśród form długowiecznych należących do rodzaju *Recurvoides*, *Trochammina*, *Ammodiscus*, *Glomospira*, *Hyperammina* i *Rhabdammina* (Fig. 22, 23), występuje kilka gatunków o znaczeniu stratygraficznym, takich jak: *Hippocrepina depressa* Vašiček (Fig. 22E), *Haplophragmoides nonioninoides* (Reuss) (Fig. 22N-P), *Plectorecurvoides alternans* Noth (Fig. 23E), *Uvigerinammina praejankoi* Neagu (Fig. 23H, I, K) i *Uvigerinammina jankoi* Majzon (Fig. 23J).

Momenty ostatniego pojawienia się form z gatunku *Hippocreppina depressa, Haplophragmoides nonioninoides* i *Plectorecurvoides alternans* mają miejsce w obrębie środkowej części formacji, poniżej serii czarnych łupków z licznymi tufitami i bentonitami. Okres wymierania tych taksonów jest odnotowywany w literaturze w pobliżu granicy cenomanu i turonu (np., Geroch & Nowak, 1984; Moullade *et al.*, 1988; Neagu, 1990; Kuhnt *et al.*, 1992). Z kolei obecność form z gatunku *Uvigerinammina praejankoi* Neagu w najniższej części formacji oraz również w najwyższej części rogowców mikuszowickich (Fig. 18), razem z opisanymi powyżej gatunkami, potwierdza późnocenomański wiek tej części formacji. Dolna granica zasięgu tego taksonu opisana z Karpat Rumuńskich sięga bowiem do poziomu *Whiteinella archeocretacea* (Neagu, 1990), odpowiadającemu górnemu cenomanowi.

Najwyższa część formacji zawiera już zespół z *Uvigerinammina jankoi* Majzon, dla którego moment pierwszego pojawienia się jest określany z najstarszego turonu w pobliżu granicy cenomanu i turonu (np., Geroch, 1957; Geroch & Nowak, 1984; Moullade *et al.*, 1988; Kuhnt *et al.*, 1992; Bąk, 1998; Bąk, 2000).

Podsumowując, dane biostratygraficzne oparte na zespołach radiolarii i otwornic wskazują, że formacja łupków radiolariowych z Barnasiówki reprezentuje górny cenoman i najstarszą część dolnego turonu (Fig. 24).

W pracy przedstawiono porównanie wydzielonej formacji z podobnymi facjami tego wieku z innych jednostek tektoniczno-facjalnych Karpat Zewnętrznych.

Praca nie zawiera interpretacji paleośrodowiska w czasie sedymentacji opisywanych osadów organicznych i krzemionkowych. Będzie ona przedmiotem oddzielnych studiów, wymagających uzupełnienia dodatkowymi analizami natury mikropaleontologicznej i geochemicznej.