Geological Quarterly, 2011, **55** (1): 49–62

Wapiennik Breccia Member (Pieniny Klippen Belt, Poland) – revised stratigraphy and origin

Agnieszka ARABAS, Magdalena SIDORCZUK,
Marcin BARSKI and Barbara OLSZEWSKA

Arabas A., Sidorczuk M., Barski M. and Olszewska B. (2011) – Wapiennik Breccia Member (Pieniny Klippen Belt, Poland) – revised stratigraphy and origin. Geol. Quart., **55** (1): 49–62. Warszawa.

The Wapiennik Breccia Member was originally attributed to the Czorsztyn Limestone Formation of the Czorsztyn Succession in the Pieniny Klippen Basin. The breccia was assigned previously to the Callovian–Oxfordian. Based on micropalaeontological and microfacies studies we have determined its age as late Albian. At this time the Czorsztyn Swell was affected by extensional faulting, with subsequent submarine erosion of scarps. The re-evaluated age of the breccia, as well as the lithology of its clasts and its matrix that contains Cretaceous foraminifera, indicate the assignment of the Wapiennik Breccia Member to the Chmielowa Formation.

Agnieszka Arabas, Institute of Geological Sciences, Polish Academy of Sciences, Twarda 51/55, PL-00-818 Warszawa, Poland, e-mail: sobstyl@twarda.pan.pl; Magdalena Sidorczuk and Marcin Barski, Faculty of Geology, University of Warsaw, Żwirki i Wigury 93, PL-02-089 Warszawa, Poland; Barbara Olszewska, Polish Geological Institute – National Research Institute, Carpathian Branch, Skrzatów 1, PL-31-560 Kraków, Poland (received: July 29, 2010; accepted: November 26, 2010).

Key words: Jurassic, Cretaceous, Pieniny Klippen Basin, breccia, foraminifera, microfacies.

INTRODUCTION

The geotectonic evolution of the Pieniny Klippen Basin has been widely discussed (e.g., Książkiewicz, 1972; Birkenmajer, 1986; Golonka *et al*., 2003; Jurewicz, 2005; Krobicki *et al*., 2006; Froitzheim *et al*., 2008; Aubrecht *et al*., 2009). Lower Jurassic to Cretaceous deposits filled the basin (e.g., Birkenmajer, 1977, 1986; Wierzbowski, 1994; Wierzbowski *et al*., 1999; Aubrecht *et al*., 2006) that was transformed into the Pieniny Klippen Belt (PKB), a long narrow structure separating the Outer and Central Carpathians (Plašienka *et al*., 1997; see Fig. 1A). An interesting issue is whether Mesozoic sedimentation in the Pieniny Klippen Basin was affected by tectonic movements. The tectonically induced instability of the basin substratum may be demonstrated by the presence of slumps, breccias, faults, neptunian dykes and so on. Numerous evidence gathered so far from the Jurassic and Cretaceous sedimentary rocks of the PKB points to a dynamic tectonic environment (e.g., Birkenmajer, 1986; Golonka *et al*., 2003; Plašienka, 2003; Jurewicz, 2005).

The breccia from Wapiennik Quarry (Fig. 1B) has been regarded so far as Callovian-Oxfordian in age, suggesting tectonic activity on the Czorsztyn Swell during this interval (Birkenmajer, 1977, 1979). In this study, we re-evaluate the age of this breccia and suggest mid-Cretaceous tectonic activity in the Czorsztyn Swell area.

GEOLOGICAL SETTING

Red limestone breccias cropping out in Wapiennik Quarry close to Szaflary village near Zakopane (Fig. 1B) were attributed to the Wapiennik Breccia Member of the Czorsztyn Limestone Formation by Birkenmajer (1977, 1979). This is the only known occurrence of these rock.

The breccia appearing in the eastern, older part of Wapiennik Quarry was described by Birkenmajer (1952, 1958, 1963, 1977, 1979). It was initially located between the Bajocian white crinoidal limestones and the Callovian-Kimmeridgian red limestones (Birkenmajer, 1952, 1958). In succeeding years Birkenmajer (1977, 1979) described the brec-

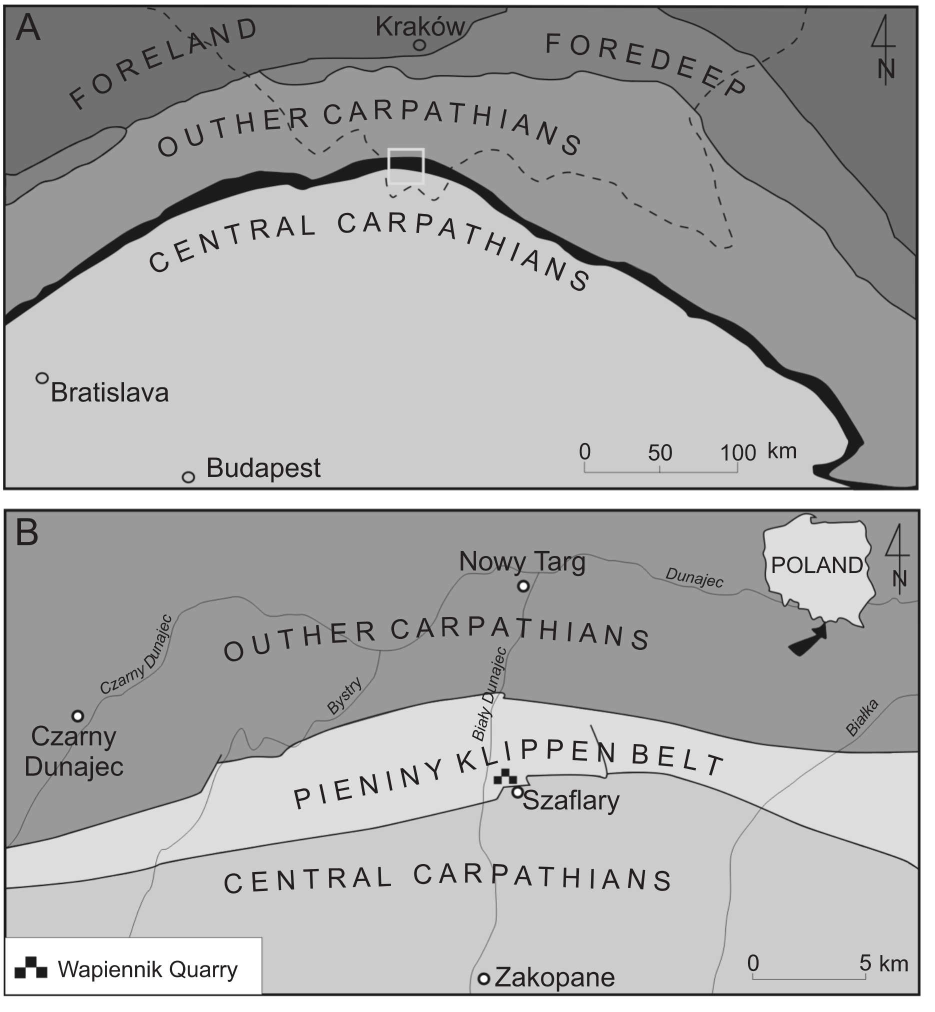

Fig. 1. Location of: A – the Pieniny Klippen Belt (in black) within the Carpathians; B – Wapiennik Quarry in Szaflary, Poland

cia as lying between the eroded surface of the red crinoidal limestones of the Krupianka Limestone Formation and red nodular limestone of the Czorsztyn Limestone Formation (Figs. 2A and 3A).

The breccia was firstly reported to be composed of red and white crinoidal limestone clasts in a red limestone matrix (Birkenmajer, 1952, 1958). Birkenmajer (1963) observed that the lower part of the breccia consists of angular fragments of white and red crinoidal limestones in a pink crinoidal limestone matrix, whereas its upper part comprises fragments of red microcrystalline, crinoidal limestones and subcrystalline limestones. Subsequently, Birkenmajer (1977, 1979) reported the breccia to be composed of angular fragments of red crinoidal limestones of the Krupianka Limestone Formation and white crinoidal limestones of the Smolegowa Limestone Formation, cemented by a red or pink limestone matrix rich in manganese oxides and scattered crinoid fragments.

The breccia was attributed to the Bathonian or Callovian (Birkenmajer, 1952), Bathonian–Callovian? (Birkenmajer, 1958), middle Callovian (Birkenmajer, 1963) and finally Callovian–Oxfordian based on its stratigraphic position (Birkenmajer, 1977, 1979).

A tectonic or sedimentary origin of the breccia was postulated (Birkenmajer, 1958). Its formation was linked with vertical tectonic movements of the sea-floor and underwater or subaerial erosion (Birkenmajer, 1963, 1979). The underlying Middle Jurassic crinoidal limestones were interpreted to have been crushed in a fault zone, transported by sea currents and cemented with a red limestone matrix (Birkenmajer, 1979).

DESCRIPTION OF THE BRECCIA FROM WAPIENNIK QUARRY IN SZAFLARY

LITHOLOGY

Today, only a part of the exposure originally described by Birkenmajer exists (Fig. 2). The accessible exposure is about 13 m long and about 6 m high. It is located in the eastern wall of

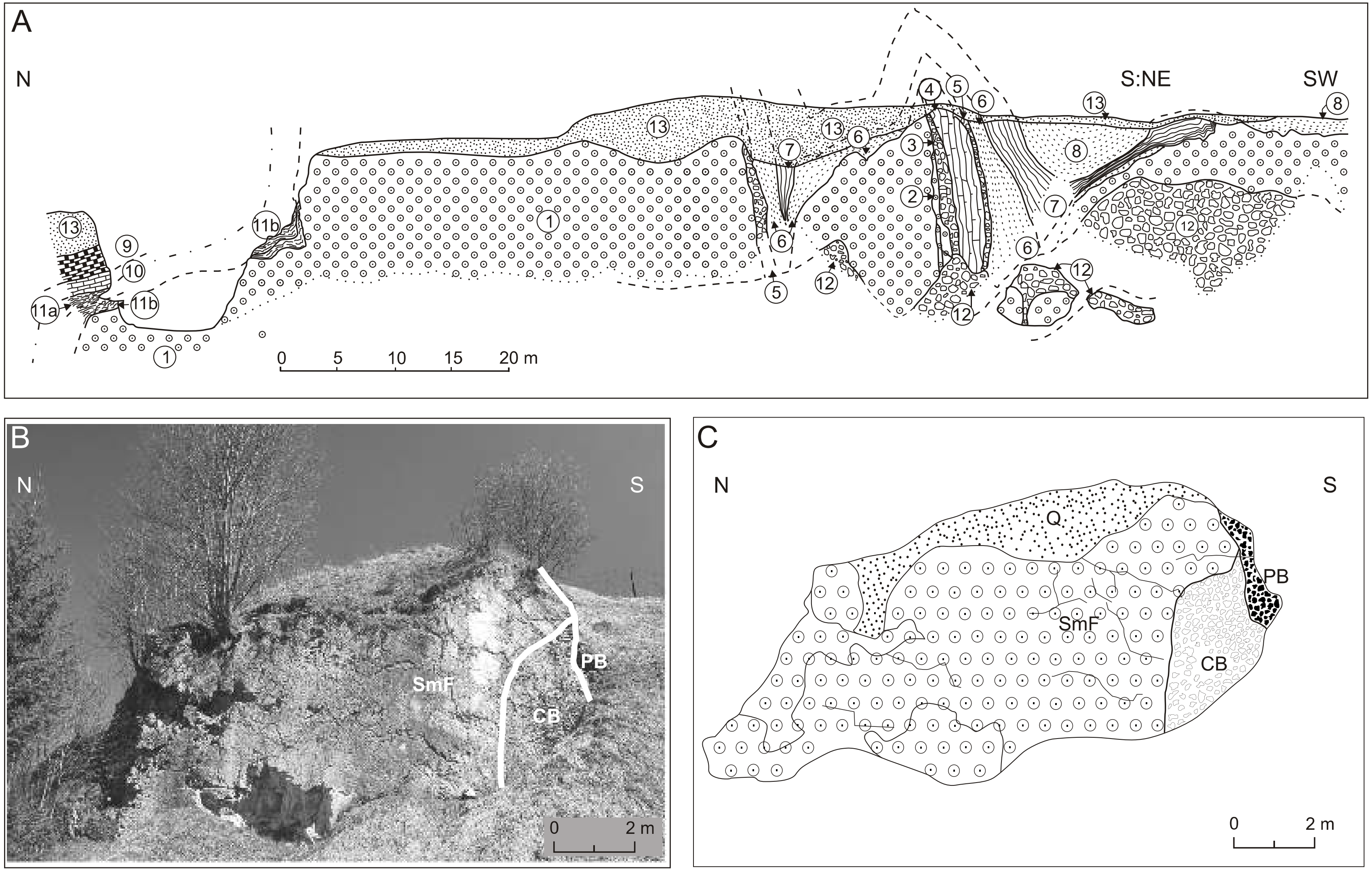

Fig. 2. The eastern wall of the eastern (older) part of Wapiennik Quarry in Szaflary

A – geological interpretation after Birkenmajer (1979) – **Czorsztyn Succession**: 1 – Smolegowa Limestone Formation, 2 – Krupianka Limestone Formation, 3 – Wapiennik Breccia Member, 4 – Czorsztyn Limestone Formation, 5 – sedimentary breccia (Łysa Limestone Formation), 6 – Skalski Marl Member, 7 – Altana Shale Bed, 8 – Pustelnia Marl Member; **Grajcarek Unit**: 9 – Czajakowa Radiolarite Formation, 10 – Pieniny Limestone Formation; **tectonic breccias**: 11 – breccia (a – Cretaceous marls and Aalenian shales, b – composed mainly of Aalenian shales – Skrzypny Shale Formation), 12 – breccia composed of white crinoidal limestones (Smolegowa Limestone Formation); 13 – Quaternary; **B** – present-day photograph of the exposure; **C** – lithological view of the exposure (present-day situation); CB – crinoidal limestone breccia of the Wapiennik Breccia Member, PB – pelitic limestone breccia of the Wapiennik Breccia Member, SmF – white crinoidal limestone of the Smolegowa Limestone Formation, Q – weathered

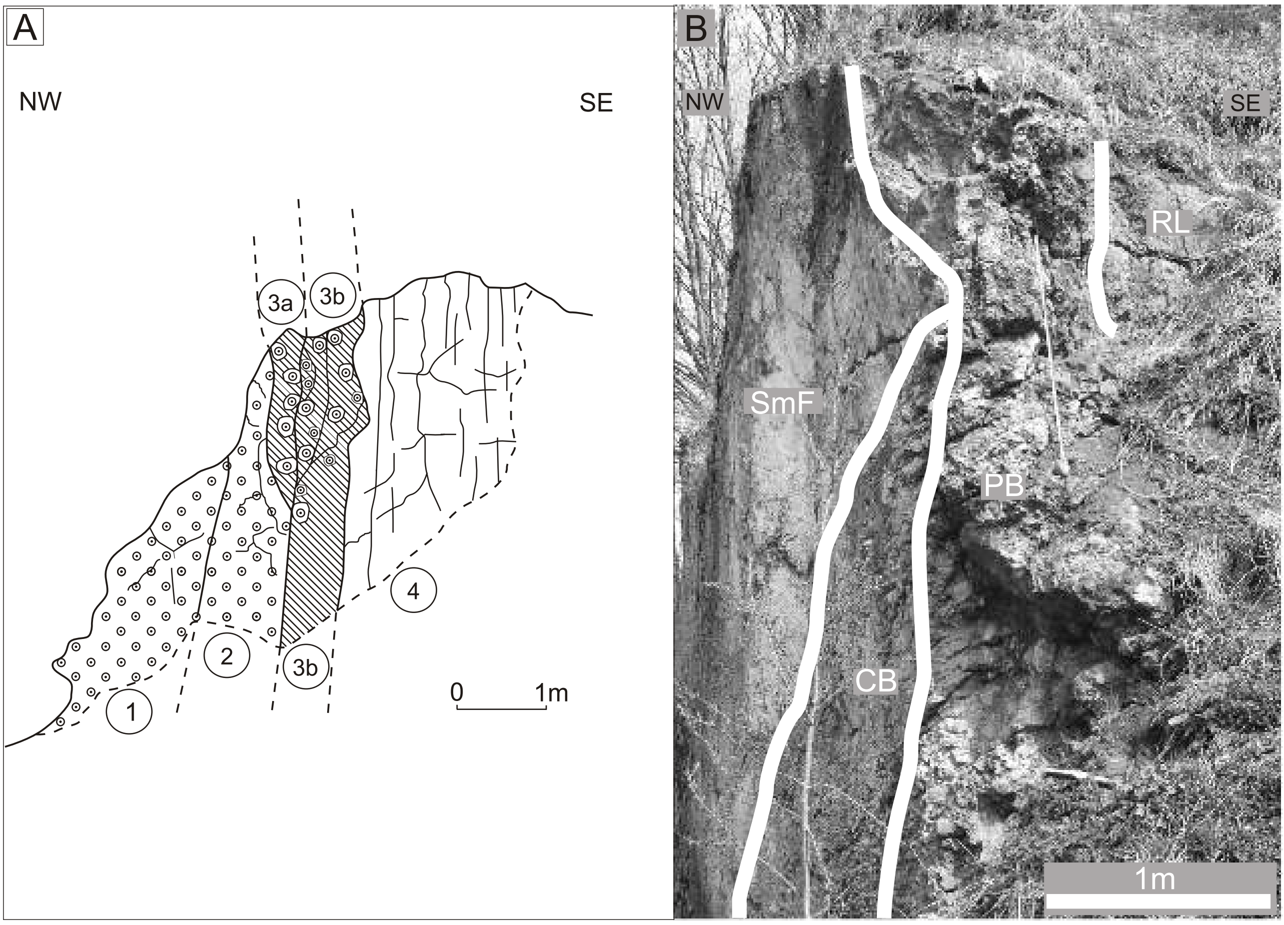

Fig. 3. The southern side of the eastern wall in the eastern part of Wapiennik Quarry in Szaflary

A – Czorsztyn Limestone Formation, Czorsztyn Succession: 1 – Smolegowa Limestone Formation, 2 – Krupianka Limestone Formation, 3 – Wapiennik Breccia Member (nodular matrix in quantity: a – larger, b – smaller), 4 – Czorsztyn Limestone Formation; **B** – current exposure: RL – red limestone, for other explanations see Figure 2

the eastern, older part of Wapiennik Quarry, along a 170/85S-oriented fault surface.

White crinoidal limestones of the Smolegowa Limestone Formation contact with a massive breccia, referred to herein as the crinoidal limestone breccia (Fig. 2C). The breccia consists mainly of clasts of white crinoidal limestone in a red pelitic limestone matrix. The exposed part of the breccia is approximately 2.40 m-thick. The clasts of the breccia range mostly within 1.5–2 cm in diameter. The largest clasts occur in the south of the quarry, where they reach 7 cm in size, whereas in the northern part, the largest clasts are up to 5 cm. The clasts have an irregular shape. The clast roundness increases from the north, where they are mostly angular, to the south, where they are mostly sub-rounded. The sorting of the clasts increases from very poor in the southern part of the quarry to poor in the north. The breccia has a compact framework and a clast-supported fabric. The texture of the breccia is chaotic and clast/matrix boundaries are sharp. The volume of the matrix increases southwards.

The crinoidal limestone breccia contacts with another massive breccia, referred to herein as the pelitic limestone breccia (Fig. 2C) the larger part of this breccia is exposed in the southern side of the eastern wall of the quarry (Fig. 3B). The pelitic limestone breccia consists mainly of clasts of red pelitic limestones in a red pelitic limestone matrix. The thickness of the pelitic limestone breccia ranges from 1 to 1.3 m. Diameters of the angular breccia clasts are generally in the range of 4 to 5 cm. The clasts have a predominantly irregular shape and their sorting is poor. The pelitic limestone breccia has a compact framework, clast-supported fabric and a chaotic texture. The clasts and matrix are partly coated with dark Fe-Mn crusts and the deposit contacts with red pelitic limestones (Fig. 2C).

The red crinoidal limestones of the Krupianka Limestone Formation, which were documented as components of the Wapiennik Breccia Member (Birkenmajer, 1952, 1958, 1963, 1977, 1979), have not yet been found in the present research.

Similar pelitic limestone breccias appear also in the southern and western walls of the eastern part of Wapiennik Quarry. Crinoidal limestone breccias were also found in the southern wall of the eastern part of the quarry, as well as in the southern wall of its western part, where they occur in the vicinity of Jurassic neptunian dykes (Sidorczuk, 2005).

MICROFACIES

Deposits of the breccias described represent several microfacies types. The crinoid, filament and *Globuligerina* microfacies are the most common in the crinoidal limestone breccia clasts. The *Saccocoma* microfacies and the *Globuligerina*-filament microfacies are less common in crinoidal breccia clasts. The crinoidal limestone breccia matrix represents the *Hedbergella* microfacies. The filament, *Globuligerina*, *Saccocoma*, *Hedbergella* and *Globuligerina*-filament microfacies most often occur in the clasts of the pelitic limestone breccia. The crinoid, filament-juvenile gastropod and micritic microfacies are less common in clasts of the pelitic limestone breccia. The *Hedbergella* and micritic microfacies occur in the pelitic limestone breccia matrix.

MICROFACIES OF THE CRINOIDAL AND PELITIC LIMESTONE BRECCIA CLASTS

Crinoid microfacies (Fig. 4A). Packstones and grainstones. The dominant components are crinoid skeletal elements (80–90% of the clast area in thin section). Fragments of brachiopod shells, bryozoan colonies, echinoid spines and grains of detrital quartz are less common.

The crinoid microfacies occurs in the crinoidal and pelitic limestone breccia clasts.

Filament microfacies (Fig. 4B). Packstones rich in filaments, which are thin bivalve shells of the genus *Bositra* (60–80% of the clast area in thin section). They are accompanied by fragments of crinoids, *Globochaete* spores, shells of juvenile gastropods, grains of detrital quartz and foraminifera representing the genus *Lenticulina* Lamarck.

The filament microfacies occurs in crinoidal and pelitic limestone breccia clasts.

***Globuligerina* microfacies** (Fig. 4C). Wackestones and packstones with dominant of planktonic foraminifera representing the genus *Globuligerina* (40–60% of the clast area in thin section). Filaments, fragments of crinoids, foraminifers of the genus *Lenticulina*, juvenile gastropods, fragments of bryozoan colonies and peloids are less common.

The *Globuligerina* microfacies occurs in crinoidal and pelitic limestone breccia clasts.

***Saccocoma* microfacies** (Fig. 4D). Packstones rich in fragments of planktonic crinoids *Saccocoma* (50–80% of the clast area in thin section). They are accompanied by fragments of sessile crinoids, filaments, grains of detrital quartz, foraminifera of the genus *Lenticulina*, peloids, *Globochaete* spores and shells of juvenile gastropods.

The *Saccocoma* microfacies occurs in crinoidal and pelitic limestone breccia clasts.

***Hedbergella* microfacies** (Fig. 4E). Packstones, rich in planktonic foraminifera (about 60–90% of the clast area in thin section) with domination by the genus *Hedbergella* – *H. planispira* Tappan (Fig. 5A), *H. delrioensis* Carsey (Fig. 5B), *Ticinella* sp., *Globigerinelloides bentonensis* Morrow (Fig. 5C), *Heterohelix moremani* Cushman (Fig. 5D), *Guembelitria cenomana* Keller (Fig. 5E), and *Rotalipora appenninica* Renz (Fig. 5F). Benthic foraminifera, e.g. *Dorothia trochus* d'Orbigny and *Tritaxia* sp. are less common. They are accompanied by filaments and peloids.

The *Hedbergella* microfacies occurs only in the pelitic limestone breccia clasts.

***Globuligerina*-filament microfacies** (Fig. 4F). Packstones with domination by foraminifers of the genus *Globuligerina* (50% of the clast area in thin section) and filaments (30% of the clast area in thin section). Fragments of bryozoan colonies are less common.

The *Globuligerina*-filament microfacies occurs in crinoidal and pelitic limestone breccia clasts.

Filament-juvenile gastropod microfacies (Fig. 4G). Packstones rich in filaments (35–45% of the clast area in thin section) and shells of juvenile gastropods (15–20% of the clast in thin section). Peloids and fragments of other shells also occur.

The filament-juvenile gastropod microfacies occurs only in the pelitic limestone breccia clasts.

Micritic microfacies (Fig. 4H). Mudstones with numerous peloids, fragments of crinoids, filaments or grains of detrital quartz.

The micritic microfacies occurs in crinoidal and pelitic limestone breccia clasts.

MICROFACIES OF THE CRINOIDAL LIMESTONE BRECCIA MATRIX

***Hedbergella* microfacies**. Mudstones, wackestones and rarely packstones rich in foraminifers (30–60% surface of the matrix area in thin section) with domination by the genus *Hedbergella*: *H. planispira*, *Heterohelix moremani*, *Globigerinelloides bentonensis*, *Guembelitria cenomana* and *Rotalipora appenninica*. Filaments and peloids are less common.

MICROFACIES OF THE PELITIC LIMESTONE BRECCIA MATRIX

***Hedbergella* microfacies**. Wackestones and packstones. The dominant components in this microfacies are foraminifers (40–70%), mostly of the genus *Hedbergella*: *H. planispira*, *H. delrioensis*, *Ticinella* sp., *Globigerinelloides bentonensis*, *Heterohelix moremani*, *Planomalina buxtorfi* Gandolfi (Fig. 5G), *Rotalipora appenninica*, *Praeglobotruncana delrioensis* Plummer (Fig. 5H), and *Rotalipora ticinensis* Gandolfi. Filaments, grains of detrital quartz and benthic foraminifera of the genus *Dorothia trochus* are less common.

Micritic microfacies. Mudstones with several fragments of crinoids and grains of detrital quartz.

STRATIGRAPHIC ANALYSIS

The age of the breccia studied is determined on the basis of foraminifera recognized in thin sections. Thirteen foraminifera species from 16 thin sections are documented. Foraminifers

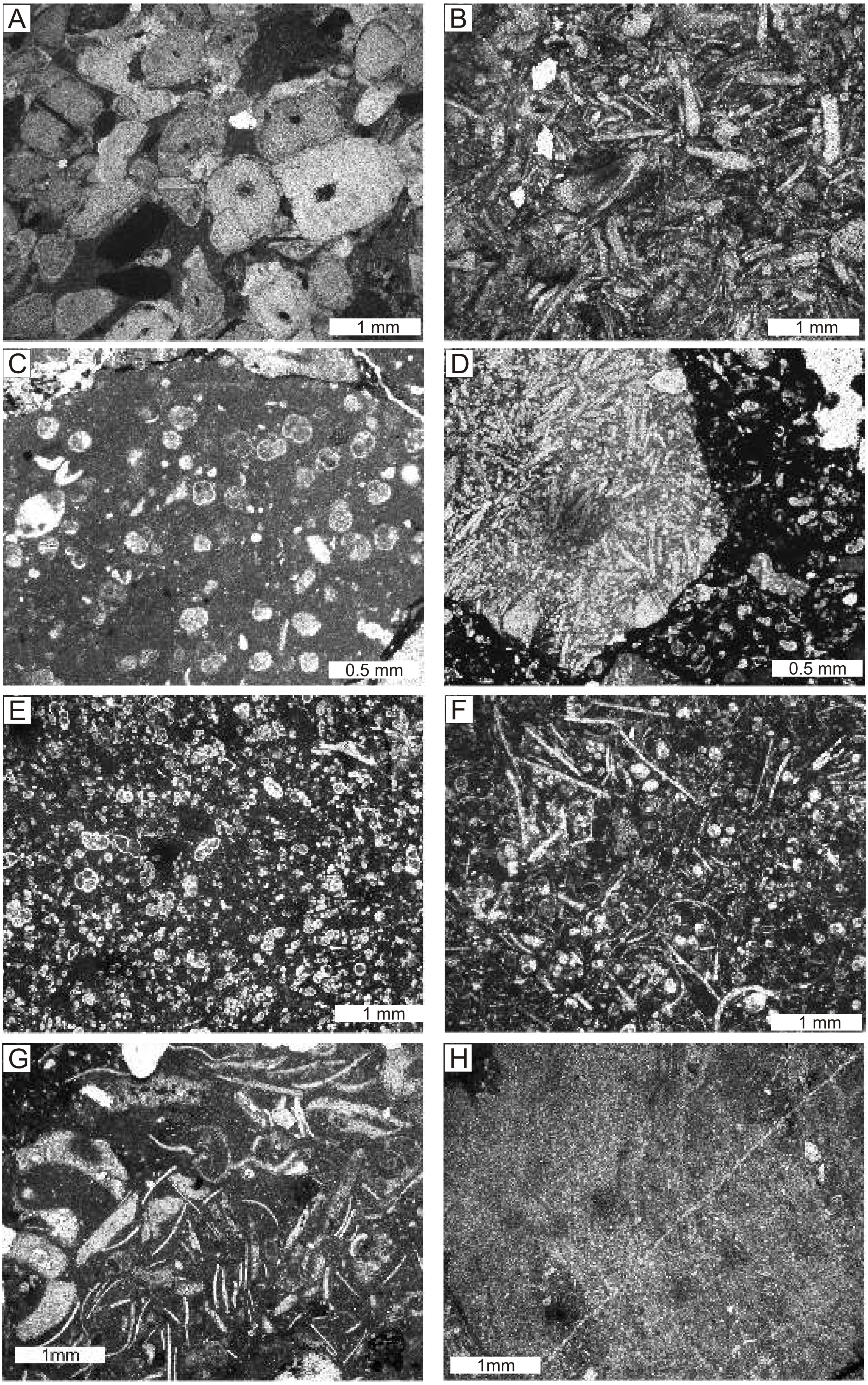

Fig. 4. Microfacies of the crinoidal and pelitic limestone breccias

A – crinoid microfacies, **B** – filament microfacies, **C** – *Globuligerina* microfacies, **D** – *Saccocoma* microfacies, **E** – *Hedbergella* microfacies, **F** – *Globuligerina*-filament microfacies, **G** – filament-juvenile gastropod microfacies, **H** – micritic microfacies

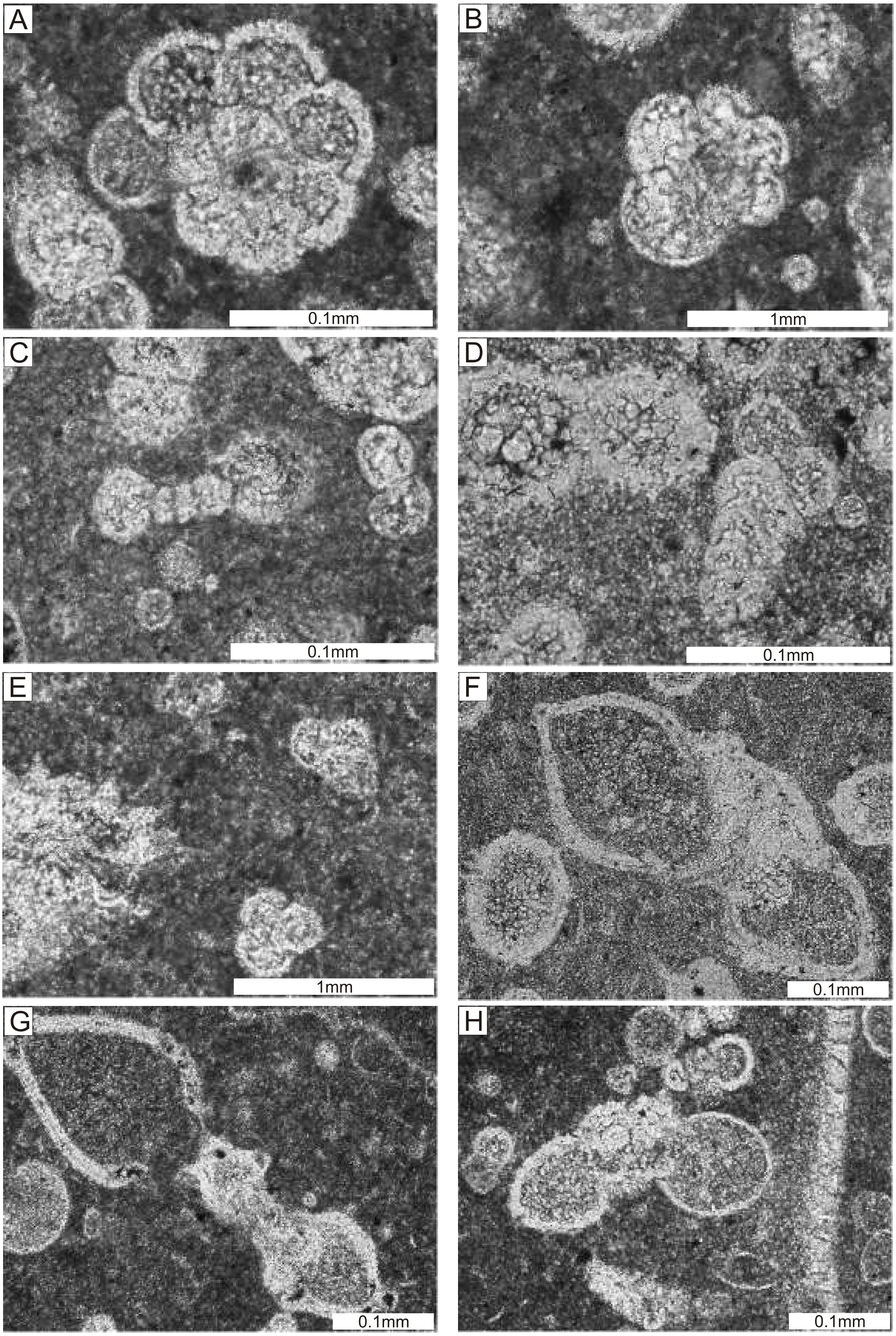

Fig. 5. Foraminifera of the crinoidal and pelitic limestone breccias

A – *Hedbergella planispira* Tappan, **B** – *Hedbergella delrioensis* Carsey, **C** – *Globigerinelloides bentonensis* Morrow, **D** – *Heterohelix moremani* Cushman, **E** – *Guembelitria cenomana* Keller, **F** – *Rotalipora appenninica* Renz, **G** – *Planomalina buxtorfi* Gandolfi, **H** – *Praeglobotruncana delrioensis* Plummer from the breccia matrix and clasts have been analysed separately in order to achieve the most precise age indications. The palaeontological content of the matrix is undoubtedly most indicative for the age assignment of the breccia. The clast stratigraphy has an additional value if the matrix is devoid of marker taxa. In such cases the youngest clast age constrains the age of the breccia. The stratigraphical ranges of the most indicative foraminifera species of the matrix and clasts of the crinoidal limestone and the pelitic limestone breccias are shown in Figures 6 and 7 and are presented after Robaszyński and Caron (1995), Gale *et al*. (1996), Kennedy *et al*. (2004) and Premoli and Verga (2004).

CRINOIDAL LIMESTONE BRECCIA

The matrix of the crinoidal limestone breccia contains the following foraminifera taxa (Fig. 6): *Hedbergella planispira*, *Globigerinelloides bentonensis*, *Rotalipora appenninica*, *Guembelitria cenomana* and *Heterohelix moremani*. The co-occurrence of these species determines the stratigraphical range between the *Rotalipora appenninica* Zone (uppermost Albian) and the lower part of the *Rotalipora cushmani* Zone (upper Cenomanian; Premoli and Verga, 2004).

The assemblage of the crinoidal limestone breccia clasts consists of *Globuligerina* sp., *Ticinella* sp., *Globigerinelloides bentonensis*, *Guembelitria cenomana*, *Rotalipora appenninica* and *Lenticulina* sp. The index taxa (Fig. 6) are in accordance with the stratigraphical interval indicated by species from the breccia matrix.

PELITIC LIMESTONE BRECCIA

The foraminifera assemblage from the matrix of the pelitic limestone breccia consists of: *Hedbergella delrioensis*, *H. planispira*, *Globigerinelloides bentonensis*, *Rotalipora ticinensis*, *R. appenninica*, *Praeglobotruncana delrioensis*, *Planomalina buxtorfi*, *Heterohelix moremani*, *Dorothia trochus* and *Ticinella* sp. The co-occurrence of *Planomalina buxtorfi*, *R. appenninica* and *R. ticinensis* is indicative of the lower part of the *Rotalipora appenninica* Zone (uppermost Albian).

The foraminifera assemblage collected from the pelitic limestone breccia clasts consists of taxa with a lower stratigraphic value. The assemblage is composed of *Globigerina* sp., *Hedbergella planispira*, *H. delrioensis*, *Ticinella* sp., *Dorothia trochus*, *Globigerinelloides bentonensis*, *Heterohelix moremani*, *Guembelitria cenomana*, *Rotalipora appenninica*, *Tritaxia* sp. and *Lenticulina* sp. The co-occurrences of the taxa indicate a stratigraphical range between the *Rotalipora appenninica* Zone (uppermost Albian) and the lower part of the *Rotalipora cushmani* Zone (upper Cenomanian; Premoli and Verga, 2004).

Due to uncertain geometrical relations between the two components of the Wapiennik Breccia Member consisting of the pelitic limestone breccia and the crinoidal limestone breccia, as well as the presence of highly tectonised deposits, the dating of the member is difficult and should be based on foraminifera taxa from both breccias. The most precise stratigraphic data are provided from the matrix of the pelitic limestone breccia. They indicate a latest Albian age of the Wapiennik Breccia Member. The member is limited to the lower part of the *Rotalipora appenninica* Zone (uppermost Albian), which corresponds to the lower part of Stoliczkaia dispar ammonite Zone (Kennedy *et al*., 2004).

DISCUSSION

The Wapiennik Breccia Member was originally attributed to the Czorsztyn Limestone Formation of the Czorsztyn Succession and reported to represent the Callovian–Oxfordian (Birkenmajer, 1977). The stratigraphic data presented herein constrain a new stratigraphic assignment of the member (Sobstyl *et al*., 2009).

The majority of the studied clasts of the Wapiennik Breccia Member consist of white crinoidal limestones representing the Smolegowa Limestone Formation and red pelitic limestones of the Czorsztyn Limestone Formation. The clasts of red limestones that contain Cretaceous Hedbergellidae foraminifera represent the Chmielowa Formation. Moreover, the matrix of the Wapiennik Breccia Member also shows evidence of Cretaceous Hedbergellidae foraminifera. This suggests close relation of the Wapiennik Breccia Member to the Chmielowa Formation (Birkenmajer, 1963, 1977; Alexandrowicz, 1979; Birkenmajer and Jednorowska, 1987; Gasiński, 1988; Bąk *et al*., 1995), which consists of red or variegated marly limestones and shaly or nodular limestones with the *Hedbergella* microfacies (Birkenmajer, 1977), by means of lithology, micropalaeontological content and age of the breccia (Fig. 8).

Clasts of the breccias from Wapiennik Quarry represent various types of limestones known in the PKB area (Wierzbowski, 1994; Wierzbowski *et al*., 1999; Jaworska 2000; Sidorczuk, 2005). The following main clast types were identified: limestones of crinoid microfacies (Bajocian), limestones of filament-juvenile gastropod microfacies (upper Bajocian–lower Bathonian), limestones of filament microfacies (upper Bajocian–upper Callovian), limestones of *Globuligerina* microfacies (upper Callovian–Oxfordian), limestones of *Saccocoma* microfacies (Kimmeridgian to lower Tithonian) and limestones of *Hedbergella* microfacies (upper Albian). The clasts from the Wapiennik breccias show a disordered arrangement, implying a high energy environment, typical of deposition in topographically differentiated basins. The limestones with the *Calpionella* microfacies and limestones with *Globochaete* microfacies, which are characteristic of the upper Tithonian and lower-middle Berriasian parts of the Czorsztyn Succession, have not been recognized. This may suggest erosion, karstic dissolution or non deposition period in that time.

The biotic components of the red pelitic limestone matrix of breccias from the Wapiennik Quarry, including foraminifera, filaments, juvenile gastropods and fragments of echinoderms, clearly indicate deposition of the breccias in an open marine environment. These findings, along with sedimentological features such as the presence of poorly sorted and sharp-edged

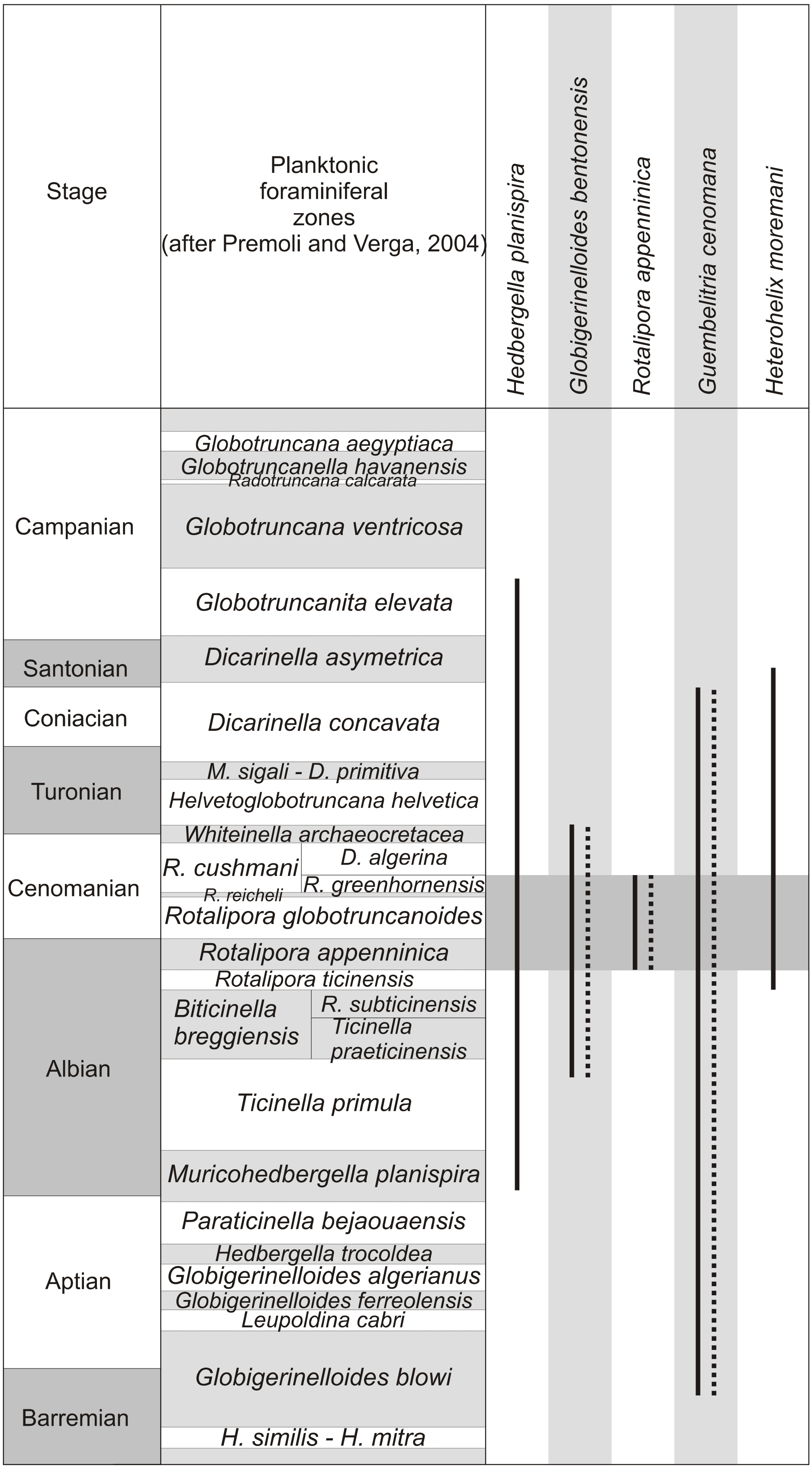

Fig. 6. Stratigraphical range of the most important planktonic foraminifera from the crinoidal limestone breccia matrix (solid lines) and clasts (doted lines)

Ranges of taxa after Premoli and Verga, 2004

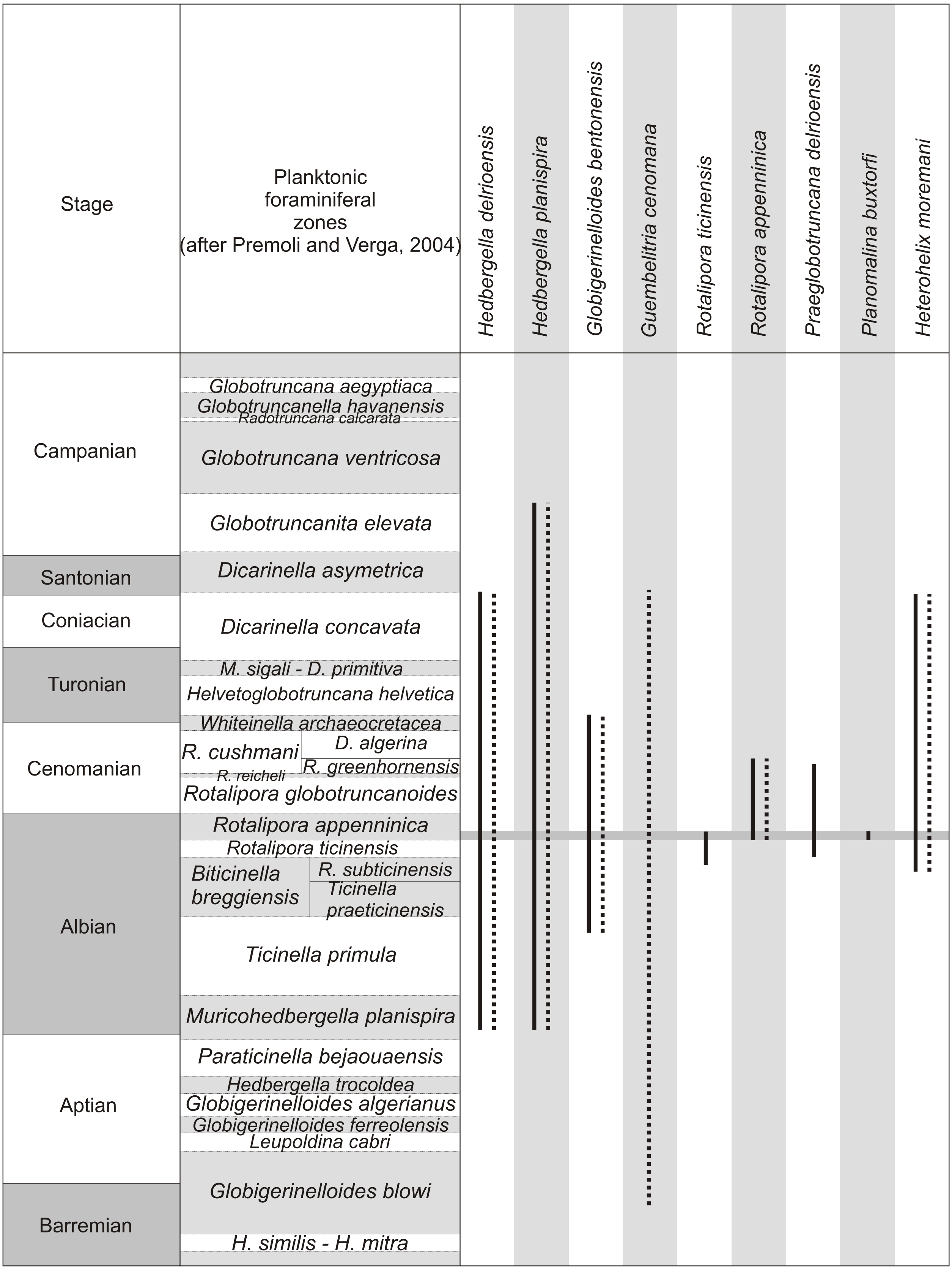

Fig. 7. Stratigraphic range of the most important planktonic foraminifera from the pelitic limestone breccia matrix (solid lines) and clasts (doted lines)

Ranges of taxa after Premoli and Verga, 2004

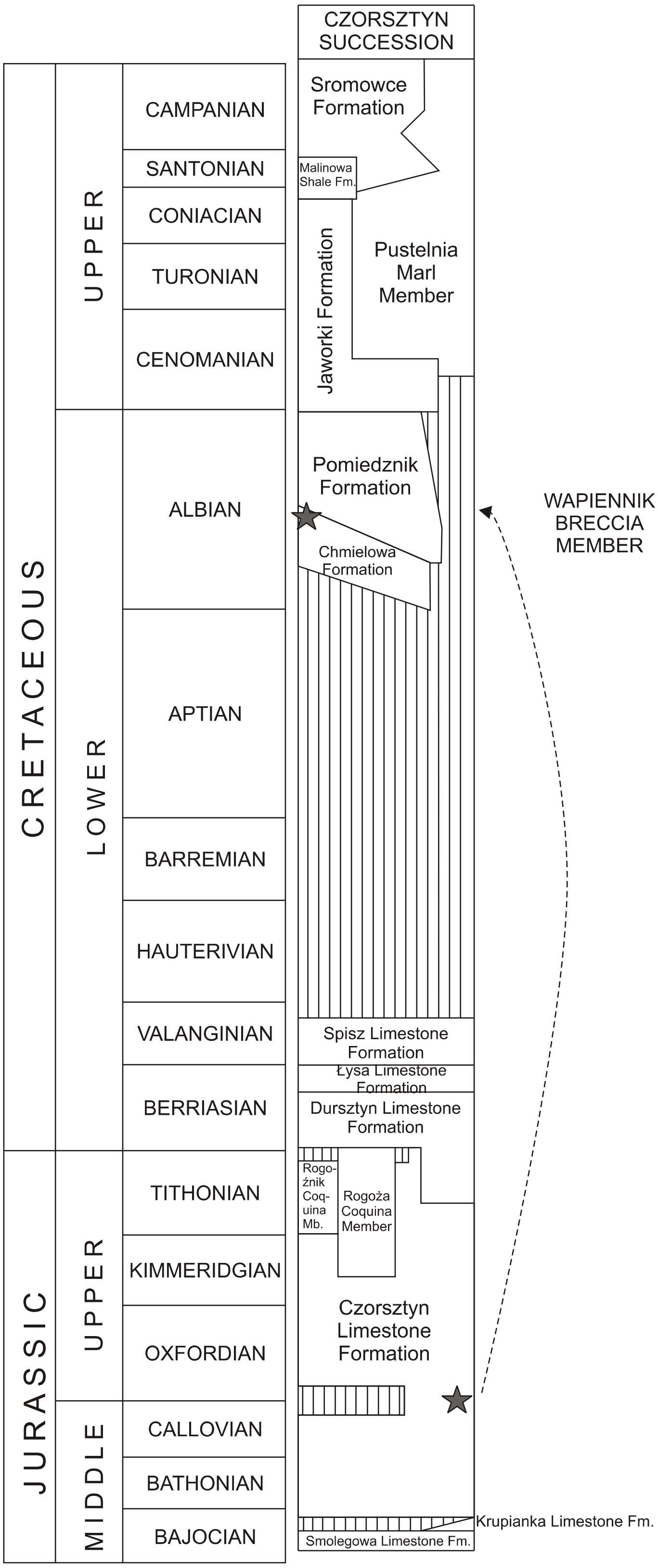

Fig. 8. Stratigraphic table for the Czorsztyn Succession after Ber *et al*. (2008)

Vertical lines indicate hiatus, the grey star indicates the Wapiennik Breccia Member

clasts, strongly suggest a tectonic, synsedimentary origin of the breccias.

Albian marine breccias from the Czorsztyn Succession are also known from Dolný Mlyn and Kamenica in Slovakia (Aubrecht *et al*., 2006). Younger breccias also occur in the PKB: lower Cenomanian microbreccias were described from Vršatec in Western Slovakia (Aubrecht *et al*., 2006) and from Jarabina near Stará Lubovňa in Eastern Slovakia (Aubrecht *et al*., 2006).

The upper Albian breccia from the Wapiennik Quarry contacts directly with Bajocian white crinoidal limestones of the Smolegowa Limestone Formation. Moreover, the oldest clasts of these crinoid limestones were found in upper Albian matrix. This implies relatively deep pre-Albian erosion of the deposits. Deep erosion can be, however, demonstrated from a few other places in the PKB. The first is Horné Sŕnie (Aubrecht *et al*., 2006), where upper Aptian/Albian deposits overlie Bajocian crinoidal limestones and where Albian or Albian-Cenomanian neptunian microdykes were found. Deep erosion and slight tilting between the Bathonian and the Albian has been noted.

A second example of the contact between Bajocian crinoidal limestones and Albian shales of the Pomiedznik Formation is Szczobiny on the western side of the Homole Gorge (Jurewicz, 1997), where Albian neptunian dykes penetrate a crinoidal basement.

Another example is the contact between the Bajocian and the Albian was discovered at Vršatec (Mišík, 1979). It is interpreted as the result of the penetration of Albian neptunian dykes into Bajocian crinoidal limestones.

Additional evidence for tectonic movements is the presence of tiny veins containing Albian to Cenomanian? planktonic foraminifera (*Hedbergella*, *Thalmanninella*, *Rotalipora*) in the upper Tithonian-lowest Berriasian deposits from the Rogoźnik Klippen (Reháková in Wierzbowski *et al*., 2006).

There is no evidence for emergence in the Wapiennik Quarry in Szaflary. However, deep erosion of deposits from the upper Albian to the lower Bajocian is observed. The breccia origin may be related to submarine erosion of scarps, constrained by synsedimentary tectonic activity, which created faults. The tectonic process could be related to the geotectonic evolution of the PKB during the Cretaceous (e.g., Golonka *et al*., 2003; Plašienka, 2003; Csontos and Vörös, 2004; Jurewicz, 2005; Froitzheim *et al*., 2008). Late Albian tectonic activity of the PKB may have been related to the mid-Cretaceous Benkovo Phase (Plašienka, 2002, 2003; Froitzheim *et al*., 2008). However, the origin of submarine scarps, furnishing clasts of the breccias, cannot be unequivocally concluded, although their genetic relation to faulting-induced sea bottom topography seems justified.

CONCLUSIONS

1. The breccia from the Wapiennik Quarry includes: the crinoidal limestone breccia and the pelitic limestone breccia. Both breccias differ in clast composition, but are incorporated into the same red limestone matrix.

2. The age of the breccias, as determined on the basis of foraminifera in the breccia matrix, is confined to the late Albian. This age determination is not consistent with the Callovian-Oxfordian age, proposed by Birkenmajer (1977).

3. The origin of the breccia is related to the submarine erosion of scarps, generated by synsedimentary tectonic activity of the Czorsztyn Swell during the late Albian. This event may be associated with the mid-Cretaceous Benkovo Phase.

4. The breccia from the Wapiennik Quarry has been known as the Wapiennik Breccia Member and attributed to the Czorsztyn Limestone Formation (Birkenmajer, 1977). The late Albian age of the breccia, as well as its lithology and micropalaeontological content, allowed us to suggest the attribution of the Wapiennik Breccia Member to the Chmielowa Formation.

Acknowledgements. Preliminary findings from this study were part of the MSc. thesis of A. Sobstyl (first author): “Origin and stratigraphy of the limestone breccia from the Wapiennik Quarry in Szaflary (Pieniny Klippen Belt)”, Faculty of Geology, University of Warsaw, 2008. This work was supported by the Faculty of Geology, University of Warsaw (M.S. & M.B., project No. BW 1837/2). The authors are grateful to the reviewers, dr M. Krobicki and dr hab. R. Aubrecht for their thorough review of the manuscript and to prof. A. Wierzbowski for helpful discussions and comments.

REFERENCES

ALEXANDROWICZ S. W. (1979) – Albian foraminifera of the Czorsztyn Series (Chmielowa Formation) of the Pieniny Klippen Belt. Ann. Soc. Geol. Pol., **49** (1–2): 182–157.

AUBRECHT R., KROBICKI M., SÝKORA M., MIŠÍK M., BOOROVÁ D., SCHLÖGL J., ŠAMAJOVÁ E. and GOLONKA J. (2006) – Early Cretaceous hiatus in the Czorsztyn Succession (Pieniny Klippen Belt, Western Carpathians): submarine erosion or emersion? Ann. Soc. Geol. Pol., **76**: 161–196.

AUBRECHT R., MÉRES Š., SÝKORA M. and MIKUŠ T. (2009) – Provenance of the detrital garnets and spinels from the Albian sediments of the Czorsztyn Unit (Pieniny Klippen Belt, Western Carpathians, Slovakia). Geol. Carpath., **60** (6): 463–483.

BĄK K., BĄK M., GASIŃSKI M. and JAMIŃSKI J. (1995) – Biostratigraphy of Albian to Turonian deep-water agglutinated foraminifera calibrated by planktonic foraminifera, radiolaria, and dinoflagellate cysts in the Pieniny Klippen Belt, Polish Carpathians. Proc. 4th Internat. Workshop on Agglutinated Foraminifera, Kraków, Poland, September 12–19, 1993. Grzybowski Foundation, Spec. Publ., **3**: 13–27.

BER A., CYMERMAN Z., GAŹDZICKI A., KROBICKI M., LEFELD J., LINDNER L., MARKS M., MATYJA B. A., OSZCZYPKO N., PSZCZÓŁKOWSKI A., UCHMAN A., WIERZBOWSKI A. and ŻYTKO K. (2008) – Karpaty. In: Tabela stratygraficzna polski (eds. R. Wagner *et al.*). Państw. Inst. Geol.

BIRKENMAJER K. (1952) – La question du Miocène marin de Podhale (in Polish with French summary). Rocz. Pol. Tow. Geol., **21**: 235–278.

BIRKENMAJER K. (1958) – Przewodnik geologiczny po pienińskim pasie skałkowym. Wyd. Geol., Warszawa.

BIRKENMAJER K. (1963) – Stratigraphy and palaeogeography of the Czorsztyn Series (Pieniny Klippen Belt, Carpathians) in Poland (in Polish with English summary). Stud. Geol. Pol., **9**.

BIRKENMAJER K. (1977) – Jurassic and Cretaceous lithostratigraphic units of the Pieniny Klippen Belt, Carpathians, Poland. Stud. Geol. Pol., **45**.

BIRKENMAJER K. (1979) – Przewodnik geologiczny po pienińskim pasie skałkowym. Wyd. Geol., Warszawa.

BIRKENMAJER K. (1986) – Stages of structural evolution of the Pieniny Klippen Belt, Carpathians. Stud. Geol. Pol., **88**: 7–32.

BIRKENMAJER K. and JEDNOROWSKA A. (1987) – Late Cretaceous foraminiferal biostratigraphy of the Pieniny Klippen Belt, Carpathians (Poland). Stud. Geol. Pol., **92**: 7–28.

CSONTOS L. and VÖRÖS A. (2004) – Mesozoic plate tectonic reconstruction of the Carpathian region. Palaeogeogr. Palaeoclimat. Palaeoecol., **210**: 1–56.

FROITZHEIM N., PLAŠIENKA D. and SCHUSTER R. (2008) – Alpine tectonics of the Alps and Western Carpathians. In: The Geology of Central Europe, Volume 2: Mesozoic and Cenozoic (ed. T. McCann): 1141–1232. Geol. Soc., London.

GALE A. S., KENNEDY W. J., BURNETT J. A., CARON M. and KIDD B. E. (1996) – The Late Albian to Early Cenomanian succession at Mont Risou near Rosans (Drôme, SE France): an integrated study (ammonites, inoceramids, planktonic foraminifera, nannofossils, oxygen and carbon isotopes). Cretaceous Res., **17**: 515–606.

GASIŃSKI M. (1988) – Foraminiferal biostratigraphy of the Albian and Cenomanian sediments in the Polish part of the Pieniny Klippen Belt, Carpathian Mountains. Cretaceous Res., **9**: 217–247.

GOLONKA J., KROBICKI M., OSZCZYPKO N., ŚLĄCZKA A. and SŁOMKA T. (2003) – Geodynamic evolution and palaeogeography of the Polish Carpathians and adjacent areas during Neo-Cimmerian and preceding events (latest Triassic–earliest Cretaceous). In: Tracing Tectonic Deformation Using the Sedimentary Record (eds. T. McCann and A. Saintot). Geol. Soc., London, Spec. Publ., **208**: 138–158.

JAWORSKA M. (2000) – Microfacies, stratigraphy and sedimentary environment of Jurassic ammonitico rosso facies of the Czorsztyn and Niedzica Successions in the Pieniny Klippen Belt in Poland (in Polish). Unpubl. Ph. D. thesis Inst. Geol., Warsaw University.

JUREWICZ E. (1997) – The contact between the Pieniny Klippen Belt and Magura Unit (the Małe Pieniny Mts.). Geol. Quart., **41** (3): 315–326.

JUREWICZ E. (2005) – Geodynamic evolution of the Tatra Mts. and the Pieniny Klippen Belt (Western Carpathians): problems and comments. Acta Geol. Pol., **55** (3): 295–338.

KENNEDY W. J., GALE A. S., LEES J. A. and CARON M. (2004) – The Global Boundary Stratotype Section and Point (GSSP) for the base of the Cenomanian Stage, Mont Risou, Hautes-Alpes, France. Episodes, **27** (1): 21–32.

KROBICKI M., POPRAWA P. and GOLONKA J. (2006) – Early Jurassic–Late Cretaceous evolution of the Pieniny Klippen Basin indicated by tectonic subsidence analysis. In: Paleotectonic Evolution of the Outer Carpathian and Pieniny Klippen Belt Basin (eds. N. Oszczypko, A. Uchman and E. Malata). Inst. Nauk Geol. Uniw. Jagiellońskiego, Kraków.

KSIĄŻKIEWICZ M. (1972) – Budowa geologiczna Polski. Volume 4. Wyd. Geol., Warszawa.

MIŠÍK M. (1979) – Sedimentologické a microfaciálne štúdium jury bradla vršateckého hradu (neptunické dajky, biohermný vývoy oxford). Západné Karpaty, sér. Geológia, **5**: 7–56.

PLAŠIENKA D. (2002) – Early stages of tectonic evolution of the Pieniny Klippen Belt. Geolines, **14**: 75–78.

PLAŠIENKA D. (2003) – Dynamics of Mesozoic pre-orogenic rifting in the Western Carpathians. Mitteilungen der Österreichischen Geologischen Gesellschaft, **93**: 79–98.

PLAŠIENKA D., GRECULA P., PUTIŠ M., KAVÁČ M. and HOVORKA D. (1997) – Evolution and structure of the Western Carpathians: an overview. In: Geological Evolution of the Western Carpathians (eds. P. Grecula, D. Havorka and P. Putiš). Miner. Slovaca-Monograph, Bratislava.

PREMOLI S. I. and VERGA D. (2004) – Practical manual of Cretaceous planktonic foraminifera. International School on Planktonic Foraminifera, 3 E Course: Cretaceous. Universities of Perugia and Milan, Tipografia Pontefelcino, Perugia, Italy.

ROBASZYŃSKI F. and CARON M. (1995) – Foraminifers planctoniques du Crétacé: commentaire de la zonation Europe-Méditerranée. Bull. Soc. Géol. France, **166** (6): 681–692.

SIDORCZUK M. (2005) – Middle Jurassic ammonitico rosso deposits in the northwestern part of the Pieniny Klippen Belt in Poland and their paleogeographic importance; a case study from Stankowa Skała and Wapiennik Quarry in Szaflary. Ann. Soc. Geol. Pol., **75**: 273–285.

SOBSTYL A., SIDORCZUK M. and BARSKI M. (2009) – Wapiennik Breccia Member (Pieniny Klippen Belt, Poland) – is it really Jurassic? Jurassica VIII, Vršatec, Slovakia, October 9–11, 2009. Geol. Kwart. AGH, **35** (3/1): 99 –100.

WIERZBOWSKI A. (1994) – Late Middle Jurassic to Earliest Cretaceous stratigraphy and microfacies of the Czorsztyn Succession in the Spisz area, Pieniny Klippen Belt, Poland. Acta Geol. Pol., **44** (3–4): 223–249.

WIERZBOWSKI A., JAWORSKA M. and KROBICKI M. (1999) – Jurassic (Upper Bajocian–Lowest Oxfordian) ammonitico rosso facies in the Pieniny Klippen Belt, Carpathians, Poland: its fauna, age, microfacies and sedimentary environment. Stud. Geol. Pol., **115**: 7–74.

WIERZBOWSKI A., REHÁKOVÁ D. and KROBICKI M. (2006) – Stop B3.16 – Rogoża Klippen – ammonite coquinas (Thitonian–Berriasian): ammonites, brachiopods, and microfossils. In: Jurassic of Poland and Adjacent Slovakian Carpathians (eds. A. Wierzbowski *et al*.): 117–126. Field trip guidebook of 7th Internat. Congress on the Jurassic System, September 6–18, Kraków, Poland.