GEOLOGICA CARPATHICA, APRIL 2016, 67, 2, 147–164 doi: 10.1515/geoca-2016-0010

The Upper Cretaceous Ostravice Sandstone in the Polish sector of the Silesian Nappe, Outer Western Carpathians

MAREK CIESZKOWSKI[1], ANNA WAŚKOWSKA[2], JUSTYNA KOWAL-KASPRZYK[1✉], JAN GOLONKA[2], TADEUSZ SŁOMKA[2], ANDRZEJ ŚLĄCZKA[1], PATRYCJA WÓJCIK-TABOL[1] and RAFAŁ CHODYŃ[1]

[1]Jagiellonian University, Institute of Geological Sciences, Oleandry 2a, 30-376 Kraków, Poland; marek.cieszkowski@uj.edu.pl, ✉justyna.kowal@uj.edu.pl, andrzej.slaczka@uj.edu.pl, p.wojcik-tabol@uj.edu.pl, rafal.chodyn@uj.edu.pl
[2]University of Science and Technology (AGH), Faculty of Geology, Geophysics and Environmental Protection, Al. Mickiewicza 30, 30-059 Kraków, Poland; waskowsk@agh.edu.pl, jgolonka@agh.edu.pl, tslomka@agh.edu.pl

(Manuscript received June 27, 2015; accepted in revised form December 8, 2015)

Abstract: The Ostravice Sandstone Member was identified and described as a lithostratigraphic unit in the Polish part of the Outer Carpathians. This division occurs in the lowermost part of the Godula Formation, is underlain by variegated deposits of the Mazák Formation or directly by the Barnasiówka and Lhoty formations, and overlain by the Czernichów Member of the Godula Formation. Domination by thick- and very thick-bedded sandstones, conglomeratic sandstones and conglomerates rich in calcareous clasts, mostly of the Štramberk-type limestones, is typical for the Ostravice Sandstone Member. These deposits are widespread between the Moravskoslezské Beskydy Mountains in the Czech Republic and the Ciężkowice Foothills in Poland. The documentation of the Ostravice Sandstone Member occurrence as well as the petrological, sedimentological features, and inventory of the carbonate clasts are presented here.

Key words: Outer Carpathians, Silesian Nappe, Late Cretaceous, Godula Formation, Ostravice Sandstone Member, lithostratigraphy, sedimentology, carbonate clasts.

Introduction

The Carpathians, one of the most important mountain ranges of the European Alpides, are divided into the Inner Carpathians and the Outer Carpathians domains (e.g. Książkiewicz 1962, 1965, 1972, 1977; Maheľ 1974; Cieszkowski et al. 1985; Ślączka & Kaminski 1998; Golonka et al. 2005, 2006 and references therein). The Outer Carpathians (with the exception of the Pieniny Klippen Belt) are also called the Flysch Carpathians because they are mainly composed of the flysch facies (turbidites) and they consist of a stack of nappes and thrust-sheets. The nappe succession in the Polish sector of the Outer Carpathians from the highest to the lowermost ones includes the Magura Nappe, Dukla Nappe and Foremagura group of nappes, Silesian Nappe, Subsilesian Nappe, Skole Nappe, and Stebnik and Zgłobice units (e.g. Książkiewicz 1962, 1965, 1972, 1977; Bieda et al. 1963; Geroch et al. 1967; Koszarski et al. 1974; Cieszkowski et al. 1985; Żytko et al. 1989; Lexa et al. 2000; Cieszkowski 2003; Golonka et al 2005, 2006, 2013a; Ślączka et al. 2006; Golonka & Waśkowska-Oliwa 2007 and papers cited therein).

The Silesian Nappe is one of the largest tectonic units of the Western Outer Carpathians (e.g. Roth & Matějka 1953; Andrusov 1959; Książkiewicz 1972, 1977; Eliáš 1979; Ślączka et al. 2006). It is composed of a continuous turbiditic sequence up to six thousands metres thick or occasionally more representing the Late Jurassic through to the Early Miocene (e.g. Cieszkowski 1992; Ślączka & Kaminski 1998; Ślączka et al. 2006; Picha et al. 2006; Cieszkowski et al. 2012b and papers cited therein). Numerous papers were devoted to the litho- and biostratigraphy of Cretaceous and Palaeogene deposits of the sedimentary succession present in the Silesian Nappe. Some of them proposed formalization of the Silesian Nappe's deposits according to the Polish Stratigraphic Code (Alexandrowicz et al. 1975; Racki & Narkiewicz 2006). A lithostratigraphy of the Upper Jurassic–Lower Cretaceous deposits of the Silesian Nappe in the Western part of the Outer Carpathians was proposed by a group of Polish and Czech geologists (Golonka et al. 2008). A proposal for the complete lithostratigraphy of the Upper Jurassic–Lower Miocene deposits representing the Silesian Nappe was prepared by Golonka et al. (2013a). These proposals were preceded by field research aimed at better identification and revision of the formalized lithostratigraphic units. The research enables the highlighting of some new facts, including the discovery that the Ostravice Sandstone described until now only from the Moravskoslezské Beskydy Mts. in the Czech Republic also occurs in the Polish sector of the Outer Carpathians (Fig. 1) and forms the lowermost member of the Godula Formation (Late Cretaceous in age). Sedimentation of these sandstones in the Silesian Basin marks the initiation of a new Late Cretaceous–Early Palaeogene stage of development of the Outer Carpathian domain (cf. Eliáš 2000; Picha et al 2006; Cieszkowski et al. 2009a).

This paper concerns the Ostravice Sandstones. The authors paid attention to the development, lithostratigraphic position, distribution and composition of these sandstones and their formal lithostratigraphy.

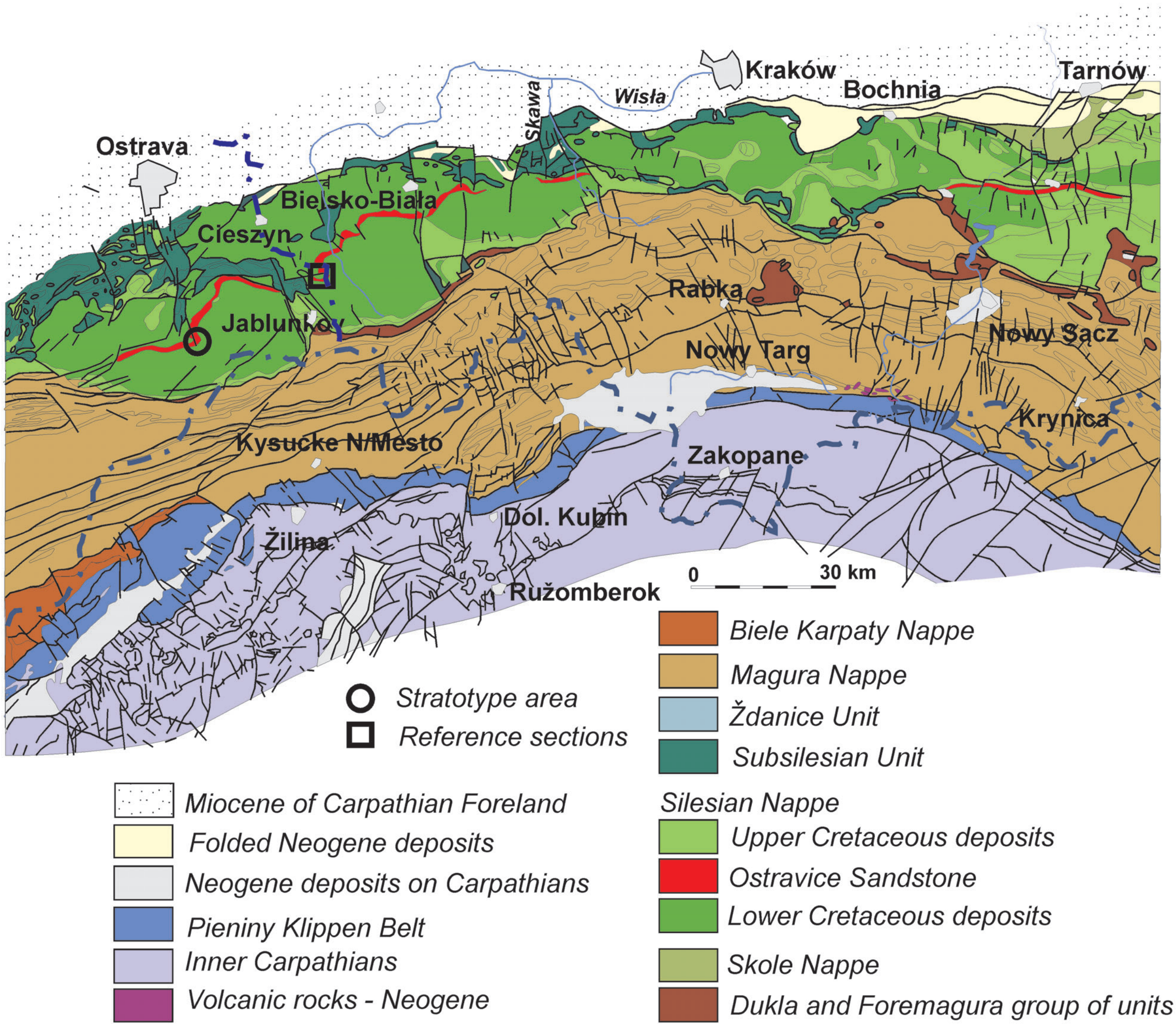


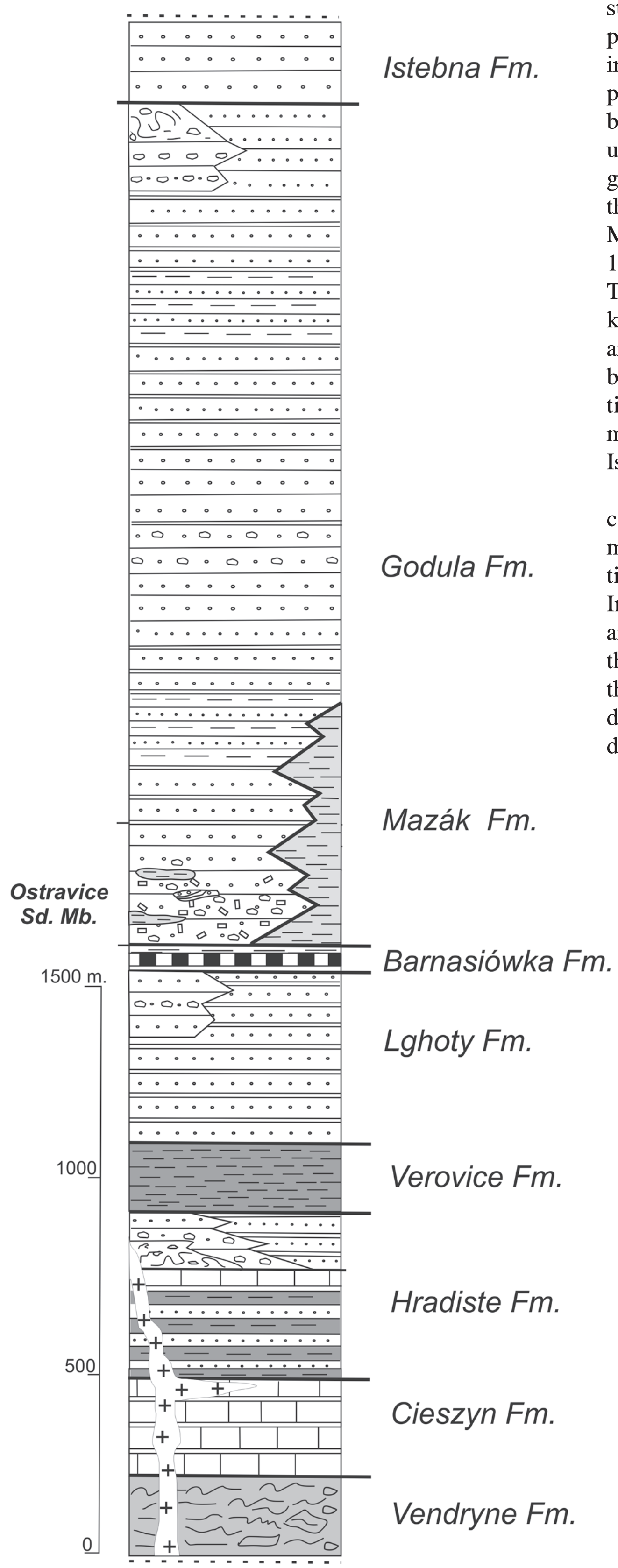
Fig. 1. Geological setting of the Ostravice Sandstone Member in the western sector of the Outer Carpathians (map after Lexa et al. 2000 – simplified).

Ostravice Sandstone Member

Position of the Ostravice Sandstone Member within the Godula Formation

The Godula Formation is widespread in the Silesian Nappe in the western part of the West Outer Carpathians in Poland and the Czech Republic (e.g. Koszarski et al. 1959; Koszarski & Ślączka 1973; Ślączka 1986; Słomka 1995; Picha et al. 2006). It is composed of thick-, medium- and thin-bedded glauconitic sandstones with intercalations of grey shales. The presence of glauconite in sandstones is a characteristic feature important for distinguishing the Godula Formation. In the western part of the occurrence area, it reaches the impressive thickness of up to 2500 m or even almost 3000 m in the Moravskoslezské Beskydy Mts., 2000 m in the Beskid Śląski (in Czech: Slezské Beskydy) Mts, and about 1500 m in the Beskid Mały Mts. (Słomka 1995). North-east of the Beskid Mały Mts. the Godula Formation is thinning and interfingering with variegated shales of the Mazák Formation (Picha et al. 2006) (Fig. 2). Further to the east the thickness decreases to below 1000 m, and mostly ranges between 200 and 400 m. In the eastern part of the Polish Outer Carpathians this formation can be partly or completely replaced by variegated shales of the Mazák Formation ("Godula variegated shales") as in the Bystre thrust sheet in the Bieszczady Mts. (cf. Ślączka 1959). The Godula Formation was described firstly in the Silesian part of the Carpathians as the Godula Beds, which were divided into three parts: Lower, Middle, and Upper Godula Beds (e.g. Książkiewicz 1933; Burtanówna et al. 1937; Geroch et al. 1967; Unrug 1969; Burtan 1973; Koszarski & Ślączka 1973; Nowak 1973; Słomka 1995). In relation to this, Golonka et al. (2013a) following partly Burtan (1973) and Wójcik et al. (1996) proposed formal lithostratigraphy for the sedimentary sequence of the Silesian Nappe and suggested dividing the Godula Formation into a few lithostratigraphic members. The lower part of this formation should be divided into the Ostravice Sandstone Member which consists mainly of thick-bedded sandstones, and the Czernichów Member represented by fine-grained, thin- and medium-bedded sandstones intercalated with black or grey shales. The middle part, developed as thick-bedded sandstones with thin shaly intercalations, is called the Skrzyczne Member. The upper part named the Wisła Member consists of thin- and thick-bedded sandstones and green shales. Conglomerates in the upper part, which were called the Malinowska Skała Conglomerate Member (Burtan 1973), are widespread in the Beskid Śląski (Slezské Beskydy) Mts. and the Beskid Mały Mts. (e.g. Burtan 1973; Książkiewicz 1974; Słomka 1995). The age of the Godula Formation is estimated as the Turonian–Early Senonian time interval (Nowak 1973; Cieszkowski 1992; Słomka 1995; Ślączka & Kaminski 1998 and references therein), Turonian–Campanian/Maastrichtian boundary (Skupien & Mohamed 2008). The Godula Formation is underlain by the variegated shales of the Mazák Formation and overlain by the thick-bedded sandstones of the Istebna Formation.

Taking into consideration the above-mentioned facts, we can state that the Ostravice Sandstone Member is the lowermost lithostratigraphic sub-division of the Godula Formation. From the bottom it borders with the Mazák Formation. In many places the lower boundary of this member is erosive and the Ostravice Sandstone Member contacts directly with the Barnasiówka or even Lhoty formations. It is caused by the dynamic sedimentation of the sandy and conglomeratic deposits. From the top the Ostravice Sandstone Member borders the thin- and medium-bedded sandstone-shaly complex



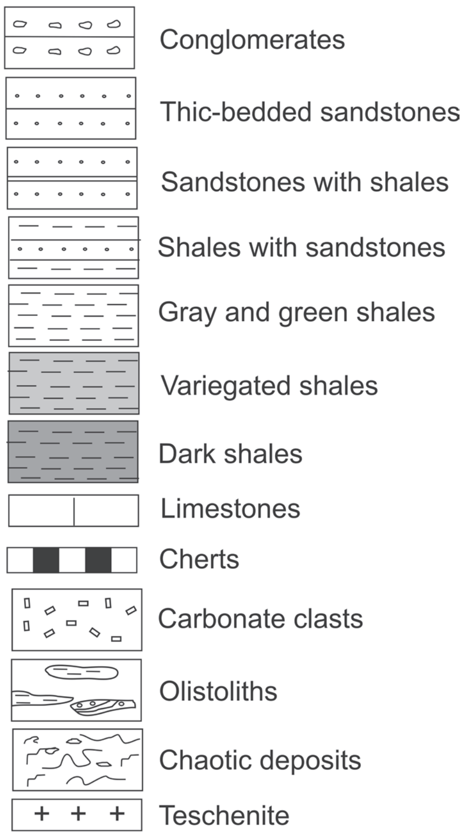


Fig. 2. Lithostratigraphic log of the Late Jurassic–Cretaceous sedimentary succession of the Silesian Nappe exposing the position of the Ostravice Sandstone Member within the Godula Formation.

of the Czernichów Member. In the Moravskoslezské Beskydy Mts. the transition between the Mazák Formation. and Ostravice Sandstone Member of the Godula Formation can be gradual and layers of sandstones rich in carbonate clasts could be interbedded with red shales (cf. Andrusov 1933). Anyway, the Ostravice Sandstone Member is widespread in the southern area of occurrence of the Godula Formation.

Name

The Ostravice Sandstone Member name was given after the Ostravice River in the Moravskoslezské Beskydy Mts., Frýdek-Místek District, Ostrava Province, Morava Land, Western Outer Carpathians, Czech Republic.

Czech name: ostravický pískovec v godulských vrstvách.

Polish name: ogniwo piaskowca ostrawickiego (shortened name: ogniwo ostrawickie).

Area of occurrence

The Ostravice Sandstone Member is widespread in the Outer Carpathians in the Silesian Nappe on the territory of the Czech Republic and Poland over a distance of about 300 km, from the surroundings of Ostravice village to the surroundings of Gromnik village. Its outcrops were noticed in the Moravskoslezské Beskydy Mts., Beskid Śląski (Slezské Beskydy) Mts., Beskid Mały Mts., and Wieliczka, Wiśnicz, Rożnów, and Ciężkowice foothills (Fig. 1).

Type section

The abandoned quarry called "Mazák Quarry" located in the Ostravice river valley, on the right bank of the river, near the tributary of Mazák Creek in Ostravice village (GPS coordinates: 49°32'25.9" N, 18°26'24.8" E), Frýdek-Místek District, Moravskoslezské Beskydy Mts., Czech Outer Carpathians, Morava Land, Czech Republic (Figs. 1, 3.1–3.5).

Reference section (proposed by authors)

Abandoned quarry in Ustroń-Poniwiec, town of Ustroń, Akacjowa Str., northern slope of Czantoria Mt., Beskid Śląski Mts., Cieszyn District, Upper Silesian Province, Poland (Figs. 1, 4).

Thickness

The member's thickness in the type section is about 60–120 m, but in the Moravskoslezské Beskydy Mts. even a 150–400 m complex of thick bedded sandstones located at the base of the Godula Formation is included in this division (Menčík in: Roth et al. 1962). East of the Beskid Mały Mts. the thickness of the Ostravice Sandstone Member is changeable but in general it decreases.

Dominant lithology

The Ostravice Sandstone Member is characterized by the dominant occurrence of 0.7–2.0 m thick sandstone layers. Thicker, amalgamated layers of up to 5 m also occur. The sandstone is medium- and coarse-grained, often conglomeratic (Figs. 3, 4, 5). Layers or lenses of fine conglomerate are not uncommon. Occasionally coarser conglomerate with pebbles or clasts of exotic rocks (3–7 cm, occasionally even up to 30 cm in size) occurs. In some layers limestone clasts of different sizes are so numerous that the rock takes on characteristics of sedimentary breccia. The thicker sandstone layers are usually massive, but in thinner layers parallel lamination occurs. In some cases dish structures can be noticed as well as flame structures (Fig. 6). The sandstone is more or less rich in glauconite, which causes its grey-greenish colour. In some parts of sections the thick-bedded sandstone deposits are intercalated with medium-bedded, medium- or fine-grained glauconitic sandstones with more or less clearly developed sequences of Bouma intervals, very typical for the facial type of "Godula sandstone". These are interbedded very rarely with grey-bluish marly or greenish clayey shales.

The sandstones and conglomerates are composed of monomineral grains as well as fragments of rocks. Bioclasts such as fragments of corals, echinoids, crinoids, fragments of crushed mollusk shells, and calcareous algae are also observable (Figs. 7.1, 7.2). Detritic material is matted with carbonate or carbonate-ferruginous cement.

The grains and pebbles are usually sub-rounded, but some of them are more or less angular, especially clasts of limestones, which indicates their short transport to the point from which they flowed in turbidity currents to the deep sedimentary basin. Some fragments of limestones reveal traces of synsedimentary erosion and redeposition, and they are allodapic limestones consisting of limestone clasts inherent in detrital, medium- or coarse-grained carbonate matrix of the same age as clasts.

In general composition, the sandstones described above are similar to these common within the whole section of the Godula Formation. However, a fundamental feature that allows us to easily distinguish the Ostravice Sandstone Member is the presence of numerous clasts of limestone in coarse-grained and conglomeratic sandstone. These whitish clasts, of different dimensions, are explicitly visible against the dark grey sandstone background (Figs. 3, 4).

The thick-bedded sandstones of the Ostravice Member contain large olistoliths of older turbiditic deposits known from the sedimentary succession of the Silesian Nappe. Their lateral size is from several metres up to 100 m or more, and thickness 3–10 m or even more. They are clearly visible only in big outcrops.

History

The Ostravice Sandstone (in Czech: ostravický pískovec) within the sedimentary succession of the Silesian Nappe was named and first described by Andrusov (1933) from Moravia — eastern part of the Czech Republic. Its name is connected with the name of the Ostravice River (Roth & Andrusov in: Andrusov & Samuel 1985, page 111) which has source in the Moravskoslezské Beskydy Mts. and flows through the nearby city of Ostrava. However, Andrusov (1933) did not

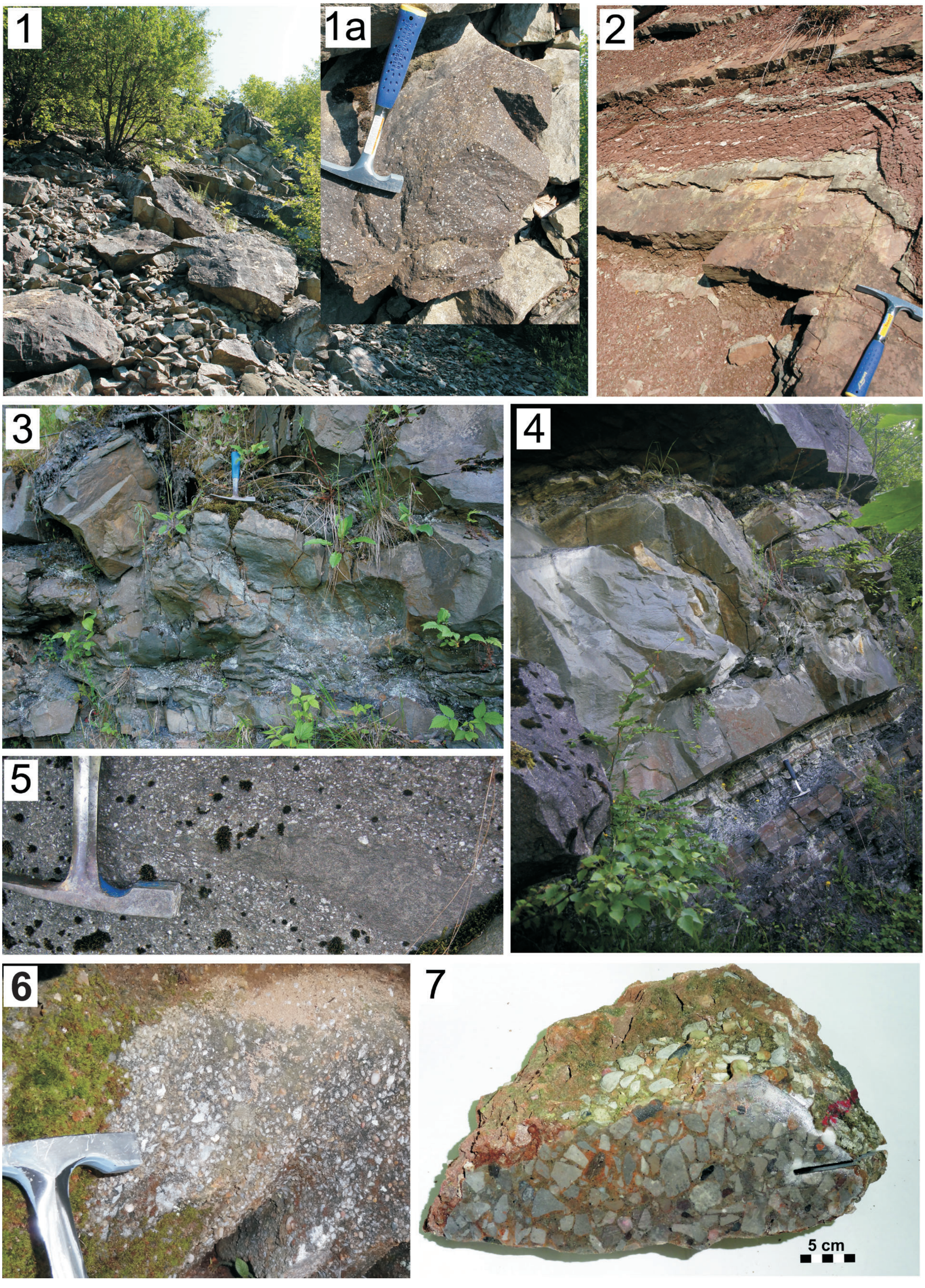


Fig. 3. Exposures of the Ostravice Sandstone Member and Mazák Formation in the Mazák Quarry, Moravskoslezské Beskydy Mts., Czech Republic (3.1–3.5). Outcrop in Porąbka, Beskid Mały Mts., Poland (3.6) and the sample of the conglomerate from this locality (3.7).

explicitly write whether he named the sandstones after the Ostravice River or Ostravice village. However, it is apparent from the text that the second option is correct (cf. "...I call it Ostravice Sandstone because it has great extent near Ostravice..."). The described sandstone is exposed there in the quarry located in the Ostravice river valley near the tributary of Mazák Creek in Ostravice village. In the quarry the Ostravice Sandstone overlaid the Godula Variegated Shales, recently called the Mazák Formation (e.g. Picha et al. 2006; Golonka et al. 2013a). In Andrusov's (1933) description on page 196 we can find that the Ostravice Sandstone is developed as thick-bedded, 2–4 m thick, light grey or light greenish, fine- to coarse-grained, silicified glauconitic sandstone layers. Between these layers thin intercalations of strongly glauconitic muddy-sandstones and red clayey shales appear. Conglomeratic intercalations with frequent

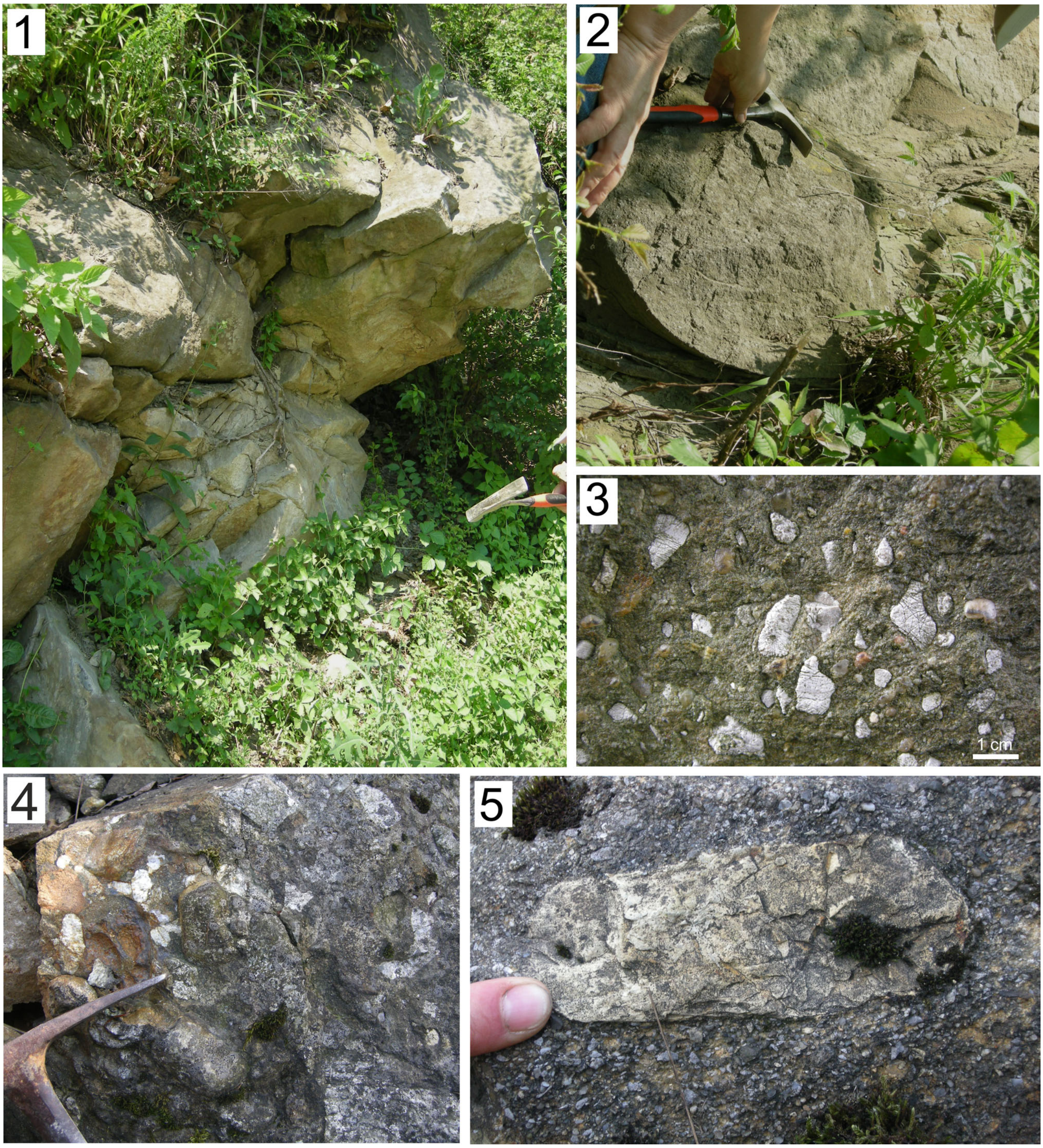


Fig. 4. Exposures of the Ostravice Sandstone Member in the Ustroń-Poniwiec Quarry as the proposed neostratotype. **1–2** — thick-bedded Ostravice Sandstone Member. **3–4** — whitish clasts of limestones explicitly visible against of the dark grey background. **5** — pebble of limestone in conglomerate.

pebbles of quartz and significant clasts of the Štramberk Limestone occur in the sandstones.

This characterization has been completed and partly extended. Matějka & Roth (1949) noted that the Ostravice Sandstone in the Ostravice river valley occurs within the Godula Variegated Shales (Beds) and is represented mainly by thick-bedded sandstone, discontinuous in many places. Menčík (in: Roth et al. 1962) included to this division a 150–400 m thick thick-bedded sandstone package occurring at the base of the Godula Beds in the S and SE surroundings of Třinec which laterally replaced the shaly Variegated Godula Beds. Eliáš (1995, 2000) also described the Ostravice Sandstone from the Outer Carpathians in Moravia and noted that they formed a prograding sedimentary fan beginning the new Late Cretaceous evolutionary stage of the Silesian Basin.

Roth & Andrusov (in: Andrusov & Samuel 1985) stated that the Ostravice Sandstone developed within the sedimentary succession of the Silesian Nappe and forms a lithostratigraphic division dominated by sandstones. In many places it overlays the Variegated Godula Beds, but also replaces them partly or completely. They described distinctive coarse and conglomeratic or even brecciated sandstones rich in limestone clasts as well as light glauconitic noncalcareous sandstones. The age of the sandstone was estimated as Cenomanian–Lower Turonian.

Some specimens of macrofossils were found in some clasts of sediments redeposited into the Ostravice Sandstone. The ammonite *Perisphinctes* sp. and remnants of corals (Andrusov 1933) were noticed in clasts of the Štramberk-type limestones, while in clasts of the Tešin-Hradište Beds (recently called Cisownica Member of the Hradište Formation) Early Cretaceous ammonite fauna was identified (Foldyna & Šuf 1964).

Picha et al. (2006) (page 111) mentioned that thick, coarse turbiditic sandstones and conglomerates representing the Ostravice Sandstone (*sensu* Andrusov 1933) interbed variegated pelagic and hemipelagic shaly deposits of the Mazák Formation (*sensu* Roth 1980). They noticed that the Mazák Formation was assigned by Hanzlíková (1973) to the Cenomanian age. Their figs. 17A and 17B present the stratigraphy and lithostratigraphic logs of Outer Carpathian units in the Czech Republic. The Ostravice Sandstone is marked there as an intercalation within the Mazák Formation.

The deposits of the Ostravice Sandstone Member were not mentioned in the Polish literature almost to this time, with the exception of a cursory consideration by Słomka (1995) who conducted extensive and detailed research into the development and sedimentological features of the Godula Formation in Poland and the Czech Republic. He studied the Ostravice Sandstone in its stratotype area in the Moravsko-slezské Beskydy Mts., and noticed the origin of a submarine fan formed by these sandstones at the foot of the north-western slope of the Silesian Ridge in the Late Cenomanian. The occurrence, lithology, some sedimentological features, and lithostratigraphic position of the Ostravice Sandstone in the Polish sector of Silesian Nappe between Ustroń and Tuchów area were briefly described by Cieszkowski et al. (2010). Next, the micropalaeontological data from limestone clasts from the Ostravice Sandstone in Poland were presented (Cieszkowski et al. 2011; Kowal et al. 2011). These sandstones were also mentioned in some publications considering the existence and origin of olistostromes and olistoliths in the Outer Carpathians (e.g. Cieszkowski et al. 2009a, 2012a, b). In a paper presenting the geology of the western part of Polish Outer Carpathians, Golonka et al. (2013a) proposed to recognize the Ostravice Sandstone as the lowermost member of the Godula Formation.

Though the name "Ostravice Sandstone" was not used in Polish geological publications, some geologists noticed that in the thick-bedded sandstone at the base of the Godula Formation in the Beskid Śląski Mts. (e.g. Ślączka and Kaminski 1998; Cieszkowski 2004; Cieszkowski et al. 2009b) or in the Beskid Mały Mts. (Książkiewicz 1951) clasts of limestones are abundant. Nowak (1957) in the Beskid Mały Mts. (river basin of Wielka Puszcza) from the lower part of the Godula Beds described conglomerates and sandstones composed mostly of quartz and clasts of the Cieszyn Limestone (which constitutes a distal, allodapic equivalent of the Štramberk-type limestones).

One of the best outcrops of the Ostravice Sandstone Member located in an abandoned quarry in Ustroń-Poniwiec was described in

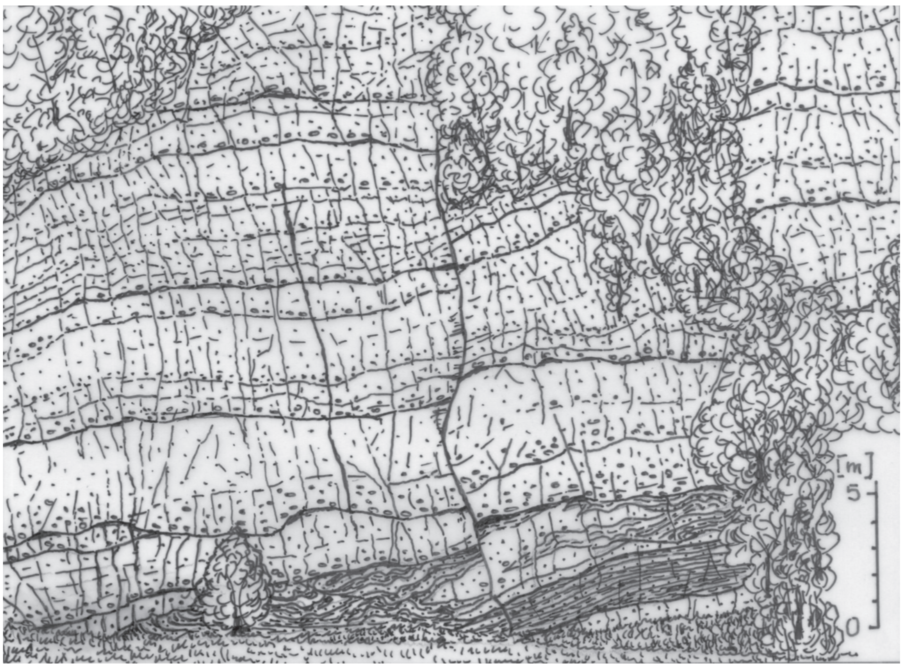


Fig. 5. The thick-bedded deposits of the Ostravice Sandstone Member in the Poniwiec Quarry (drawing by Marek Cieszkowski).

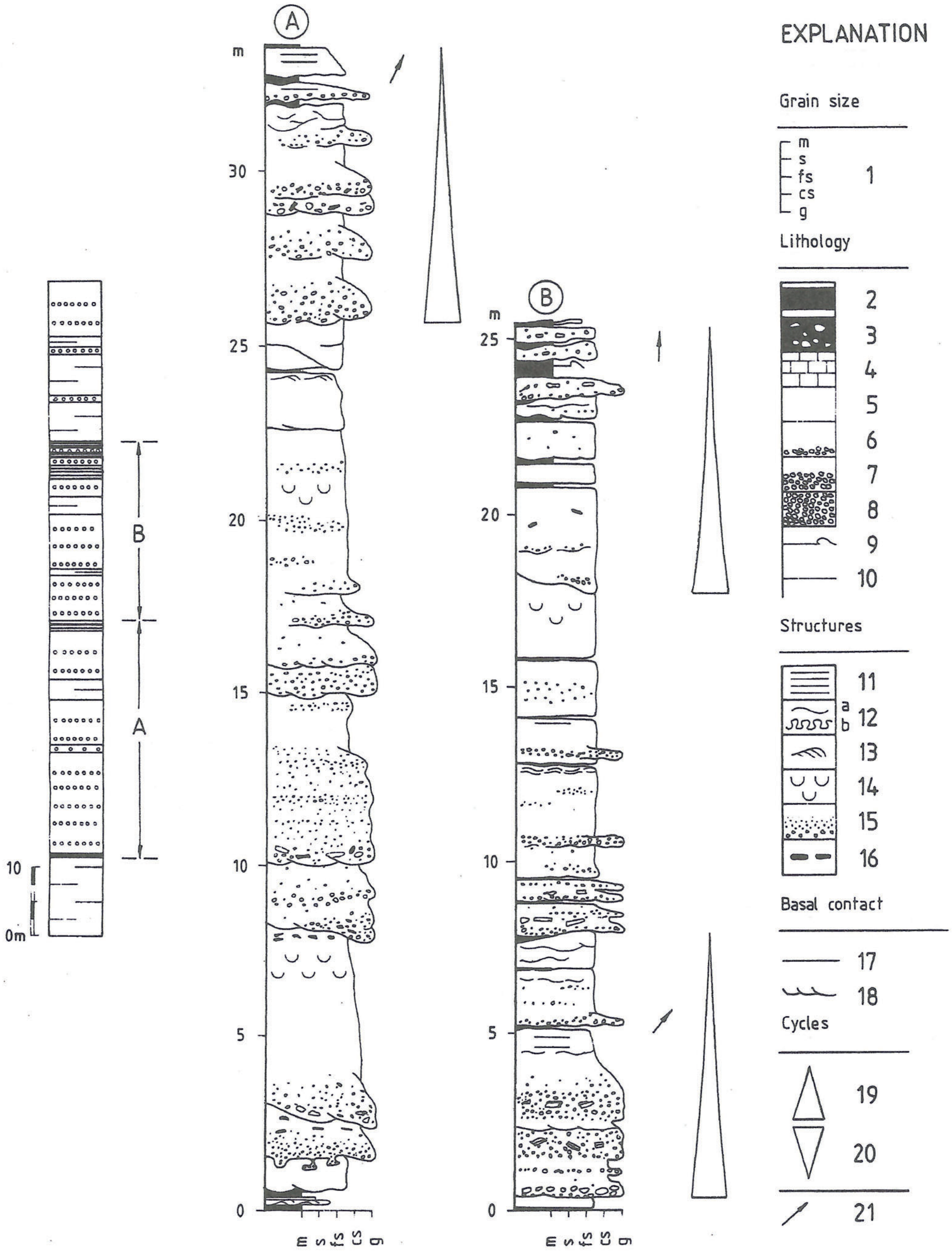


Fig. 6. Type I channel sequences in deposits of the Ostravice Sandstone Member in the Ustroń-Poniwiec Quarry section in the Beskid Śląski Mts. (after Słomka 1995, slightly modified). **1** — grain size: m - mud, s - silt, fs - fine sand, c- coarse sand, g- gravel. Lithology: **2** — shale; **3** — pebbly mudstone; **4** — micritic limestone; **5** — sandstone; **6** — conglomeratic sandstone; **7** — sandy conglomerates; **8** — conglomerates; **9** — thin, ripple-laminated sandstone beds (below 3 cm); **10** — thin, laminated and massive sandstone beds (below 3 cm); **11** — parallel lamination; **12a** — wavy lamination; **13** — through cross stratification; **14** — dish structures; **15** — graded bedding; **16** — shale and/or limestone clasts; **17** — flat, even sole; **18**— erosional and /or loaded sole. Cycles: **19** — positive cycle; **20** — negative (compensation) cycle; **21** — palaeocurrents directions.

some geological guidebooks. Ślączka and Kaminski (1998) described the Lower Senonian (Turonian–Lower Campanian) very thick-bedded sandstones of the lowermost part of the Godula Beds outcropping there. They pointed out that the large olistoliths of turbiditic deposits were derived from the Lower Cretaceous Lhoty Beds within the Godula sandstones and noticed that clasts of limestones belong to the distinctive components of these sandstones. Cieszkowski (2004) also emphasized these features of deposits visible in the Poniwiec Quarry. The sedimentological features of the Godula Formation were studied there by Słomka (1995). He presented lithological and sedimentological logs of the Godula Beds that cropped out in the quarry, and noticed the occurrence of limestone clasts in sandy conglomerates.

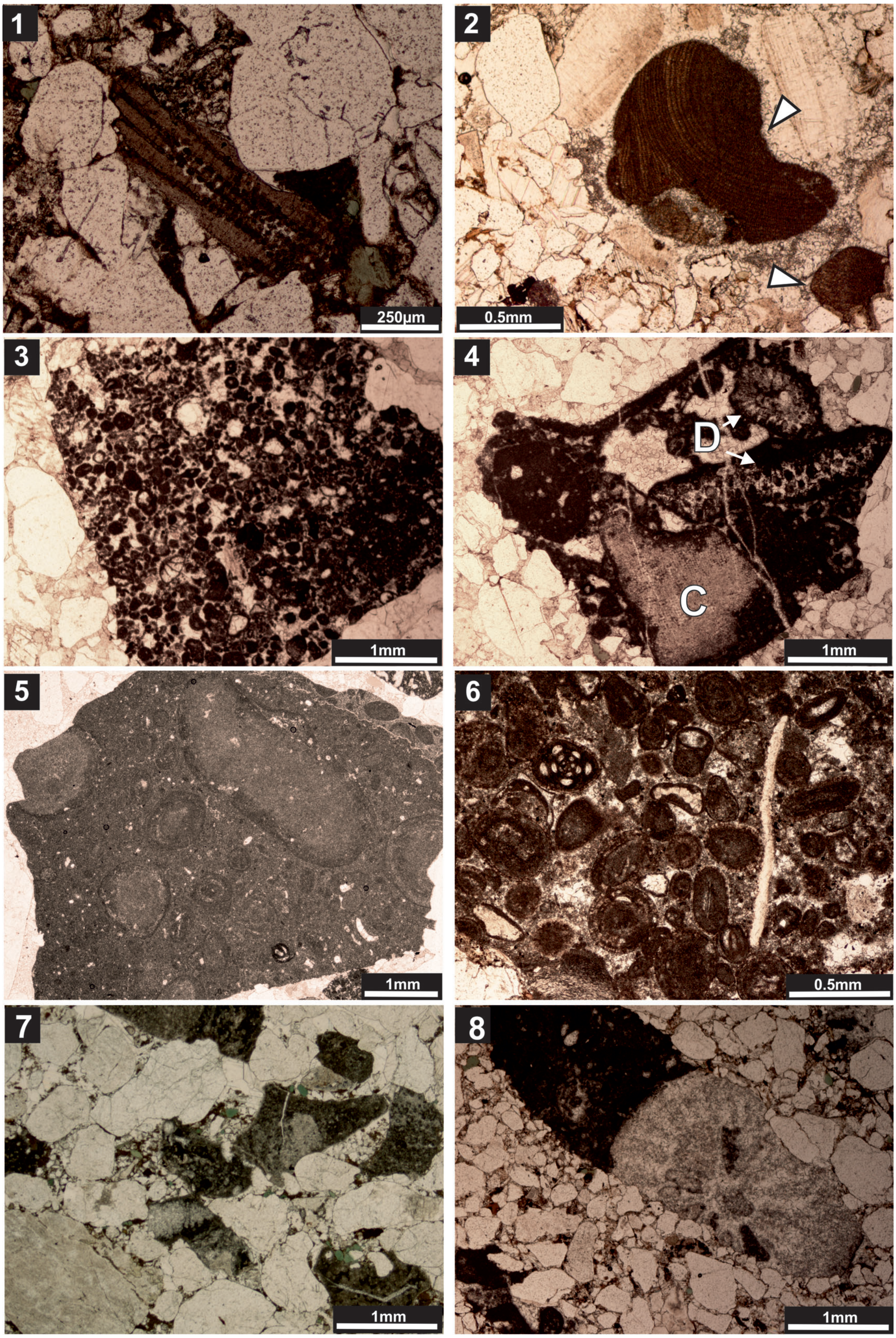


Fig. 7. Micrographs of calcareous clasts and bioclasts in sandstones and conglomerates of the Ostravice Sandstone Member: **1** — Echinoid spin; sample 18. **2** — Red algae Corallinaceae (arrows); sample UP3/3. **3** — Peloidal-bioclastic grainstone; sample OI/1. **4** — Limestone with peloids, Dasycladales algae fragments (D) and crinoid plate (C); sample OI/6. **5** — Oncoid wackstone; sample O/Po1. **6** — Ooid packstone; sample OII/1. **7** — Numerous poorly rounded limestone clasts (dark clasts); sample OIII/1. **8** — Fragment of limestone with coral; sample OII/2.

Cieszkowski at al. (2010) stated that Ostravice Sandstone occurs in the Ustroń-Poniwiec Quarry, but a more complete description of it was presented by Golonka et al. (2013b), who also stated that this quarry can be a good reference section for the Ostravice Sandstone Member.

Sedimentation, sedimentological features

Deposits of the Ostravice Sandstone Member from the Poniwiec Quarry in Ustroń are dominated by conglomeratic sandstone facies (SC) (Słomka 1995) in which the most common variety is medium-grained sandstone with up to 30 vol. % of pebble fraction (Fig. 6). The average size of pebbles does not exceed 3 cm although boulders (up to 30 cm across) were also encountered. Deposits of this member form very thick layers (locally over 5 m) with numerous distinct amalgamation surfaces. The bottoms of the layers are erosional or deformational whereas the tops are flat or wavy. The pebble fraction always accumulates close to the bottoms of the layers. Up the sequence, pebbles can form thin lenses or streaks (sSC subfacies — bedded conglomeratic sandstones) or are randomly scattered within the framework (mSC subfacies — massive conglomeratic sandstones). The roundness of pebbles is variable but sub-rounded grains predominate. In some layers, perfect examples of blow-type and droplet-type structures can be encountered. The conglomeratic sandstones facies is accompanied by sandstone facies (S), which shows very thick or thick layers with flat bottom surfaces. Blurred load casts are also present. The sandstone facies (S) includes two subfacies: massive sandstones (mS) and massive sandstones with bowl-types structures (mqS). Medium-bedded sandy conglomerates facies (CS) and sandstones with mudstones facies (SM) are rather scarce (Słomka 1995).

In the bottom part of the Ostravice Sandstone Member succession an olistolith can be observed as a few-metres-thick sliding wedge of mudstones with sandstones (MS facies) of the Lhoty Formation jammed within the Ostravice Sandstone Member (cf. Słomka 1995).

The mining operations carried on in the Obłaziec Quarry exposed a diverse succession of the Godula Formation (Fig. 8). In its bottom part several-metres-thick SM facies (sandstones with mudstones) can be observed. These are fine-, rarely medium-grained sandstones with graded bedding and parallel lamination. Sandstone beds show flat bottom and top surfaces. Thin interbeds of mudstones, thin to medium beds of micritic limestones with locally developed, poorly visible parallel laminations as well as very thin lensoidal intercalations of cross-laminated sandstones are common. Up the sequence, we observe very thick- to thick-bedded conglomeratic sandstones with a total thickness of nearly 40 metres. The qSC subfacies (conglomeratic sandstones with graded bedding) predominates (Słomka 1995), accompanied by the less frequent gLSC subfacies (conglomeratic sandstones with graded bedding transitional to laminated sandstones) and by thick-bedded, medium-grained, massive sandstones. The conglomeratic sandstones grade upward into a 4-metres-thick layer of SM facies (sandstones with mudstones). These are medium- to thick-grained (pebbles up to 50 cm across) sandstones with graded bedding, followed upward by laminated sandstones and less common diagonally bedded sandstones. Shale interbeds host lensoidal bodies of very fine-grained sandstones with ripplemarks. Up the sequence, the amount of shales increases.

Both successions described above represent the bottom portion of the Godula Formation in the Beskid Śląski Mts. These are typical channel sequences of the internal fan (Słomka 1995) developed as: thick and very thick layers of conglomeratic sandstones (SC facies), and massive sandstones (MS facies) accompanied by sandy conglomerates (CS facies) and sandstones with mudstones (SM facies, known only from the top part of the sequence). The upward-decreasing thickness of layers and grain size of sediments is clearly visible (Shanmugam & Moiola 1988; Słomka 1995).

Petrology

Thin-section investigations from samples taken from deposits of the Ostravice Sandstone Member reveal composition and sedimentary microstructures. Detrital material is texturally immature. The sizes of grains vary over a wide extent from 0.2 to 20 mm (extremely up to 10 cm). The majority of large clasts of the gravel fraction are poorly to well-rounded, whereas the background (grain size 0.5 mm in ave-rage) consists of angular grains. The sandy fraction framework consists of: quartz occurring as singular grains and polycrystalline aggregates; feldspar, mainly altered orthoclase, rarer plagioclase; mica (mainly muscovite plus minor amounts of biotite); glauconite; heavy minerals (abraded grains and euhedral crystals of rutile, tourmaline, zircon) (Fig. 9).

Gravel-sized grains appear separately, dispersed by finer material. There are quartz mono- and polycrystalline and pieces of rocks (intrusive and extrusive igneous rocks, metamorphic schists and gneisses as well as sedimentary rocks, e.g. sandstones, mudstones, cherts, limestones, and coal). Matrix occurs in minor amounts within interstitial spaces between the framework grains. Occasionally it is ferric. Detritus is cemented by crystalline calcite, which corrodes grain surfaces.

Granites are phaneritic, medium-grained rocks consisting of ca. 70 % alkali feldspar, 25 % quartz, and minor amounts of biotite. The feldspar grains tend to be between 0.5–1 mm in size on average. They occur generally as colourless anhedral grains. Dusty alteration is visible. Orthoclases damaged by speckled sericite replacement represent the majority of feldspars. Only minor amounts of albite have been observed as discrete twinned grains. The quartz is clear and unaltered with sweeping extinction under crossed nicols. The quartz grains tend to be between 1–3 mm in size on average, though smaller grains are common, often aggregated. The quartz grains have anhedral habit. There are intergrowths with the orthoclase grains. The biotite is brown with single cleavage. It shows subhedral flaky habit. Numerous dark spots in biotite, called pleochroic haloes, are developed around small zircon inclusions. Chlorite represents a common product of biotite alteration.

Strongly altered basalt reveals an amygdaloidal structure (Fig. 9). The matrix originally composed of augite, plagioclase, and olivine is entirely changed. Olivine is replaced by serpentine with admixture of iron ores and chalcedony, which in turn are replaced by carbonates. Vesicles are filled with chlorite, quartz, chalcedony and calcite.

Another type of extrusive igneous rocks is characterized by well-developed trachytic structure. Parallel lying feldspar plates (1 mm length) are embodied in the feebly developed matrix, consisting of the plagioclase mixed with quartz and pyroxene (often replaced by chlorite). Hematite occurs as reddish pigment.

The metamorphic rock assemblage contains quartzite, schists and gneisses (Fig. 9). Quartzitic rocks reveal granoblastic or porphyroblastic structure. The parallel texture is due to more abundant biotite, dispersed in bands or lenticular quartz aggregates enveloped by fine-grained quartz. Mica schists are a medium grained rock of homeoblastic and thin schistose structure. The rock is composed of quartz, biotite, and rarer muscovite. Quartz is xenoblastic and usually flattened. Micas are present in thin flakes and parallel aggregates, arranged separately or in layers often wavy deformed. Sericite-chlorite schists are fine-grained, phyllitic rocks. Porphyroblasts of plagioclase are enveloped by chlorite-sericite or quartz-albite aggregate. Gneisses are medium-grained, heteroblastic rocks, of intermediate texture between massive and schistose. Biotite, which does not form continuous layers, is corroded and intergrown with muscovite. Orthoclase occurs in somewhat larger grains. Quartz shows cataclasis.

Sedimentary rock clasts are represented by the following lithotypes: fine-grained, quartzitic sandstones; dark, non-calcareous mudstones; clayey shales; cherts composed of chalcedony stuff with recrystallized, circular tests (radiolarian, sponge) therein; limestones. Sandstones and shales represent recycled turbiditic deposits.

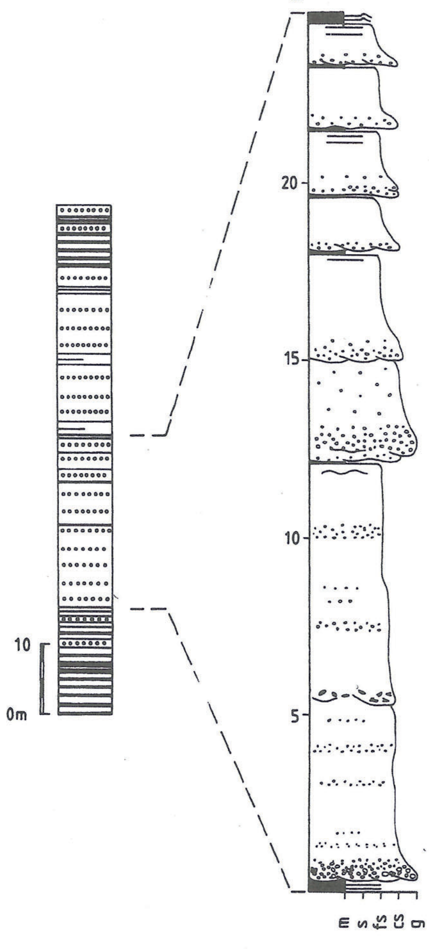


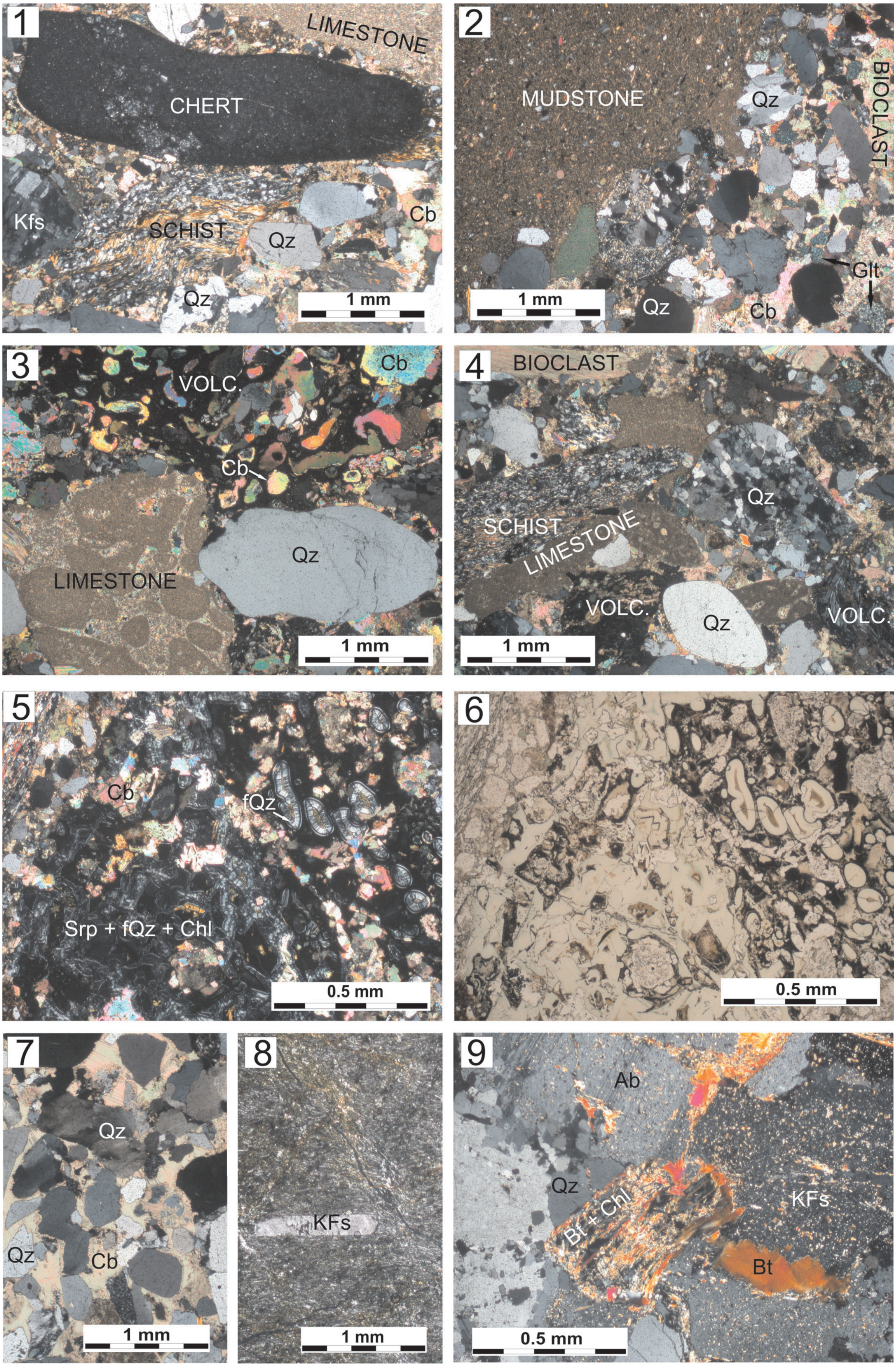
Fig. 8. Type I channel sequences in deposits of the Ostravice Sandstone Member in the Wisła-Obłaziec Quarry section in the Beskid Śląski Mts. (after Słomka 1995, slightly modified). Explanation like in Fig. 6.

Carbonate clasts

Fragments of light coloured limestones constitute the most characteristic component of deposits of the Ostravice Sandstone Member (Figs. 3, 4, 7). The carbonate clasts were studied in detail in thin sections. The analysed clasts are poorly rounded and measure from less than 1 mm to several centimetres, mostly 1–5 mm.

It is possible to recognize such types of limestones as bioclastic wackstone, oncoid wackstone, bioclastic-peloid wackstone and packstone, peloid packstone, peloid-bioclastic grainstone, ooid grainstone, ooid-bioclastic grainstone, lithoclastic-bioclastic grainstone. Boundstone microfacies are difficult to state with regard to the small size of limestone fragments, but a lot of calcareous clasts that could constitute fragments of microbial deposits were observed. Fragments of calcareous sponges and corals are also found, which may indicate the presence of some reefs formed by these groups of organisms in the source area. These limestones represent diversified deposits of the inner carbonate platform, platform margin, slope of platform, and probably also deeper shelf.

Identified fossils indicate the latest Jurassic–earliest Cretaceous (mainly Tithonian-Berriasian) age of the limestones (Kowal et al. 2011). The most important for the age determination are calpionellids, most of which are poorly preserved, but some can be precisely identified: *Calpionella alpina* Lorenz (Fig. 10.1), *Calpionella elliptica* Cadisch (Fig. 10.2), *Crassicollaria parvula* Remane (Fig. 10.3), *Calpionellopsis oblonga* (Cadisch) (Fig. 10.4), *Tintinnopsella carpathica* (Murgeanu et Filipescu) (Fig. 10.5). Foraminifera occurring in these clasts are mostly typical for the carbonate platform environments, and are known from the Štramberk-type limestones, as well as from the Cieszyn Limestone Formation (e.g. Olszewska 2005; Ivanova & Kołodziej 2010). Among them miliolids are the most common (e.g. *Moesiloculina* cf. *histri* (Neagu) (Fig. 10.6), *Ophthalmidium* sp., *Rumanoloculina* sp.), as well as foraminifera of the genus *Andersenolina*, especially *Andersenolina alpina* (Leupold) (Fig. 10.7), *Andersenolina elongata* (Leupold) (Fig. 10.8), *Andersenolina delphinensis* (Arnaud-Vanneau, Boisseau & Darsac) (Fig. 10.9). Other important foraminiferal taxons recognized in the thin sections are: *Mohlerina basiliensis* (Mohler) (Fig. 10.10), *Protopeneroplis ultragranulata* (Gorbatchik) (Fig. 10.11), *Troglotella incrustans* Wernli & Fookes (Fig. 10.12), *Haghimashella arcuata* (Haeusler), *Uvigerinammina uvigeriniformis* (Seibold & Seibold) (Fig. 10.13),


1
LIMESTONE
CHERT
Kfs
SCHIST
Qz
Cb
Qz
1 mm
2
MUDSTONE
Qz
BIOCLAST
Glt
Qz
Cb
1 mm
3
VOLC.
Cb
Cb
Qz
LIMESTONE
1 mm
4
BIOCLAST
SCHIST
LIMESTONE
Qz
VOLC.
Qz
VOLC.
1 mm
5
Cb
fQz
Srp + fQz + Chl
0.5 mm
6
0.5 mm
7
Qz
Qz
Cb
1 mm
8
KFs
1 mm
9
Ab
Qz
Bt + Chl
KFs
Bt
0.5 mm

and foraminifera of the genera *Arenobulimina, Bullopora, Dobrogelina, Gaudryina, Glomospira, Lenticulina, Melathrokerion, Nautiloculina, Neotrocholina, Paleogaudryina, Reophax, Spirillina, Trocholina*, *Textularia.* In some clasts calcareous dinoflagellate cysts were noticed: *Colomisphaera minutissima* (Colom), *Committosphaera ornata* (Nowak) (Fig. 10.14), *Cadosina fusca fusca* Wanner (Fig. 10.15), *Crustocadosina semiradiata semiradiata* (Wanner) (Fig. 10.16), *Colomisphaera* sp. In the thin sections, other microfossils typical for the Upper Jurassic and Lower Cretaceous deposits of carbonate platforms and slopes of platforms also appear: *Crescentiella morronensis* (Crescenti) — a very common microfossil, recently interpreted as nubecularid foraminifera incrusted by cyanobacteria (Senowbari-Daryan et al. 2008); *Globochaete alpina* Lombard — planktonic green alga; problematic alga *Thaumathoporella parvovesiculifera* (Raineri); polychaetes *Terebella lapilloides* Münster; microproblematica *Koskinobulina socialis* Cherchi et Schroeder; "Bacinellid" fabric. Fragments of macrofossils occur in many clasts, especially fragments of calcareous green algae of the order Dasycladales, bryozoan colonies, brachiopods, bivalves, calcareous sponges, and corals. Moreover spines of siliceous sponges, radiolarians, calcimicrobes, echinoderms elements, shells of gastropods, and ostracods were noticed.

The age, fossils, and microfacies of the studied limestone clasts indicate that they correspond to the Upper Jurassic–Lower Cretaceous exotic limestones, mostly shallow-water, platform deposits — so-called Štramberk-type limestones, which commonly occur in deposits of the Outer Carpathians (see e.g. Książkiewicz 1951; Morycowa 1968; Cieszkowski 1992; Kołodziej 2015) and are compared with the Štramberk Limestone from Moravia (Czech Republic) (e.g. Eliáš & Eliášová 1984). Clasts of mudstones, often with calpionellids probably represent deeper facies of the latest Jurassic and earliest Cretaceous.

Age

The Ostravice Sandstone Member occurs in the lowermost part of the Godula Formation. The sedimentation of the Lower Godula Beds started from the Early Turonian (e.g. Nowak 1963; Bieda et al. 1963; Geroch et al. 1967; Koszarski & Ślączka 1973; Hanzlíková 1973; Menčík et al. 1983; Słomka 1995; Olszewska 1997 and references therein), only its eastern part was connected with the early Senonian (Słomka 1995). The foraminiferal assemblages from the Ostravice Sandstone Member are usually very poor, but in some samples they are stratigraphically diagnostic and indicate the Turonian Uvigerinammina jankoi biozone (zone after Geroch & Nowak 1984; Olszewska 1997). The occurrence of the index taxon *Uvigerinammina jankoi* Majzon in the Carpathians is estimated to the Turonian–Campanian range (e.g. Geroch & Nowak 1984; Olszewska 1997 and references therein) and is recently observed even in the Cenomanian. The lower boundary of the Ostravice Sandstone Member is synonymous with the age of the directly underlying the Barnasiówka Radiolarian Shale Formation. Bąk et al. (2001 and references therein), according to the integrating radiolarian and foraminiferal data, indicated the earliest Turonian age of the uppermost part of the Barnasiówka Formation. The radiolarian assemblages have been classified to the lower part of the Alievium superbum zone (biozone after O'Dogherty 1994), while in the foraminiferal assemblages the first appearance of *Uvigerinammina jankoi* Majzon was noticed (Bąk et al., 2001).

The sedimentation of the deposits of the Ostravice Sandstone Member probably took place only in the Turonian. The preliminary results from the poor foraminiferal assemblages derived from the upper part of this member are not stratigraphically diagnostic. The occurrence of single specimens of *Uvigerinammina jankoi* Majzon is noticed here. On the basis of micropalaeontological analysis Słomka (1995) suggested the Turonian or possibly Turonian–Coniacian age for the overlying Middle Godula Beds. Thus, the superposition of the Lower Godula Beds, containing in their lower part the Ostravice Sandstone Member, indicates the Turonian age. This aspect is now being studied in detail.

Studied locations

Moravskoslezské Beskydy Mountains

In the Moravskoslezské Beskydy Mts. the Godula Formation reaches record thicknesses of up to 2500 m or even more than 3000 m (Eliáš 1979). It is underlain by the variegated shales of the Mazák Formation. The Ostravice Sandstone Member makes up the basal, several dozen metres thick part of the Godula Formation. The sandstone layers are thick, usually 2–4 m, intercalated occasionally with thin- or medium-bedded glauconitic fine-grained sandstones and grey non-calcareous shales. Sandstones are coarse-grained or conglomeratic, rich in clasts of limestones, so that they partly represent a kind of sedimentary breccia. A representative outcrop of the Mazák Formation and the Ostravice Sandstone Member is exposed in the Mazák Quarry in Ostravice village (Roth 1980). Pieces of magmatic rocks typical for the teschenite association, black cherts, and clasts of shales tens of centimetres in size typical for the Lower Cretaceous Hradište Formation, were found within the sandstones. These clasts include the Early Cretaceous fauna (Foldyna & Šuf 1964) with *Lamellaptychus didayi* (Coquand), *Salfeldiella* cf. *guettardi* (Raspail), aucellids shells, juvenile forms of snails, as well as flora *Zamites göpperti* Schenk, *Baiera* cf. *cretosa* Schenk. Turbidites consisting of thin- and medium-

◄

Fig. 9. Microstructures of coarse-grained sandstones and conglomerates of the Ostravice Sandstone Member. **1–4** — Texturally immature conglomerate, clasts of gravel fraction are rounded, grains of psammite are angular. Matrix fills up interstitial spaces of the framework. **5–6** — Clast of altered mafic volcanic rock with amygdaloidal structure. **7** — Quartzitic arenite with corrosive carbonate cement. **8** — Clast of trachyte. **9** — Granite exotic. Images under crossed nicols, excluding 6 taken using parallel nicols, transmitted light. Abbreviations (after Whitney and Evans, 2010): Ab – albite, Bt – biotite, Cb – carbonate minerals, Chl – chlorite, Glt – glauconite, Kfs – K feldspar, Qz – quartz, Qz – fibrous quartz = chalcedony, Srp – serpentinite.

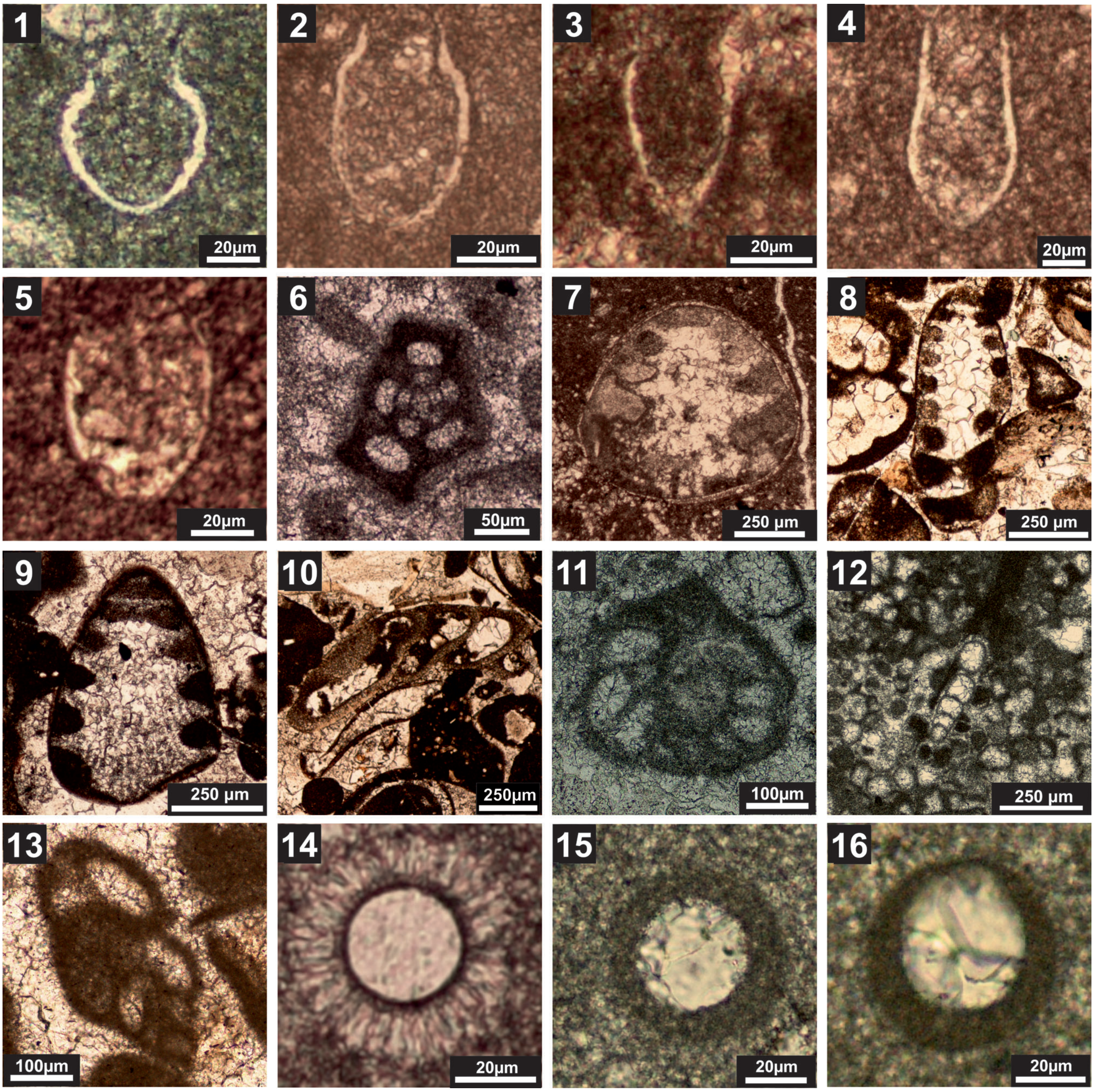


Fig. 10. Micrographs of selected microfossils from clasts of the Upper Jurassic and Lower Cretaceous limestones: **1** — *Calpionella alpina* Lorenz; sample O/Po2. **2** — *Calpionella elliptica* Cadisch; sample OIV/1. **3** — *Crassicollaria parvula* Remane; sample OI/8. **4** — *Calpionellopsis oblonga* (Cadisch); sample OIV/1. **5** — *Tintinnopsella carpathica* (Murgeanu & Filipescu); sample OIV/1. **6** — *Moesiloculina* cf. *histri* (Neagu); sample OII/1. **7** — *Andersenolina alpina* (Leupold); sample OIV/1. **8** — *Andersenolina elongata* (Leupold); sample O/Br. **9** — *Andersenolina delphinensis* (Arnaud-Vanneau, Boisseau & Darsac); sample O/Br. **10** — *Mohlerina basiliensis* (Mohler); sample O/Br. **11** — *Protopeneroplis ultragranulata* (Gorbatchik); sample O/PoB. **12** — *Troglotella incrustans* Wernli & Fookes; sample O/Po1. **13** — *Uvigerinammina uvigeriniformis* (Seibold & Seibold); sample OV/1. **14** — *Committosphaera ornata* (Nowak); sample OI/5. **15** — *Cadosina fusca fusca* Wanner; sample O/Po2. **16** — *Crustocadosina semiradiata semiradiata* (Wanner); sample O/Po2.

bedded glauconitic sandstones and grey shales typical for the Godula Formation occur above the Ostravice Sandstone Member. In some publications (e.g. Roth 1980; Picha et al 2006) the Ostravice Sandstone was described as a member within the Mazák Formation, but others claim that this sandstone is directly overlaid by shaly-sandstone turbidites typical for the Godula Formation.

The name “Mazák Formation” was taken from the Mazák Quarry but this quarry is also important as a part of the typical (stratotype) exposures of the Ostravice Sandstone Member.

Beskid Śląski (Slezské Beskydy) Mountains.

In the Beskid Śląski (Slezské Beskydy) Mts. the Godula Formation reaches the thickness of up to 2500 m or more.

Here the Godula beds were first described in details by Burtanówna et al. (1937), and then divided into three parts: Lower, Middle, and Upper Godula beds and included in the Godula Formation created firstly in the Silesian part of the Carpathians as the Godula Beds (cf. Unrug 1969; Burtan 1973; Nowak 1973). Golonka et al. (2013a) following Burtan (1973), Wójcik et al. (1996) and Cieszkowski et al. (2010) proposed a new formal lithostratigraphy of the Godula Formation with a few lithostratigraphic members (see above). In the Beskid Śląski (Slezské Beskydy) Mts. the Ostravice Sandstone Member is exposed in the northern foothills of this mountain range in Nýdek, Ustroń, Brenna, and the southern suburbs of Bielsko-Biala. It lies directly on the top of the Lhoty Formation and is covered by the shaly-sandstone Czernichów Member. The variegated shales of the Mazák Formation have not been noticed at its base there. The Ostravice Sandstone Member is well outcropped in the Ustroń-Poniwiec abandoned quarry and its surroundings (Figs 4, 5, 6). Now this position is proposed as a parastratotype of the discussed member (Golonka et al. 2013a, b). In that place coarse-grained and conglomeratic sandstones as well as conglomerates are rich in clasts of carbonate rocks dominated by the Štramberk-type limestones. Clast dimensions range from a few millimetres up to several centimetres, and the largest are more than 20 cm in size (Ślączka & Kaminski 1998; Cieszkowski 2004; Cieszkowski at al. 2009a, b). Large olistoliths of the deposits represented by the Lhoty and Verovice formations are exposed within the thick- and very thick-bedded sandstones (Ślączka & Kaminski 1998; Cieszkowski 2004; Cieszkowski at al. 2009a,b; Golonka et al. 2013b).

Beskid Mały Mountains

In the Beskid Mały Mts. the Godula Formation is up to 1500 m thick (Słomka 1995) or more in the western part. The Ostravice Sandstone Member is found in the western part of this mountain ridge in the basal part of the Godula Formation. Sedimentation of the Godula Formation began there with a complex of thick- and very thick-bedded sandstones. In some places they overlie variegated shales of the Mazák Formation. In the eastern part of the Beskid Mały Mts. the Ostravice Sandstone Member has not been found. A thin level of variegated shales and a complex of calciturbidites, described by Książkiewicz (1951) as siliceous marls Turonian–Coniacian in age, called the Kaczyna Marls occurs there at the base of the Godula Formation (cf. Cieszkowski et al. 2001, 2003; Uchman & Cieszkowski 2008). Thick-bedded sandstones without clasts of carbonates occur in the lower part of the Godula Formation in the section at Rzyki village overlying a shaly complex several tens of metres thick. Small outcrops of deposits typical for this member appear in the Puszcza Wielka stream at Porąbka village (Fig. 3.6).

Rożnów Foothills

In the Rożnów Foothills, the Ostravice Sandstone Member was noticed in Czchów and its surroundings in the southern limb of the Czchów Anticline. The Godula Formation is up to 800 m or more thick there (Cieszkowski 1992). Its base consists of a several tens of metres thick complex of the Ostravice Sandstone Member Sandstones rich in carbonate clasts. The biggest clasts reach up to 10 cm or even occasionally 15 cm. Thin- or medium-bedded shaly-sandstone turbidites are developed above the Ostravice Sandstone Member. In the uppermost part of the section thick-bedded, coarse-grained or conglomeratic sandstones that steeply pass into the thick-bedded sandstones of the Istebna Formation arrive. The Godula Formation is underlain by red shales of the Mazák Formation. Red or variegated shales form occasionally thin intercalations within the Godula Formation. The sandstones of the discussed member were used in the Middle Ages to build some Gothic buildings in Czchów town. It is possible to see them in the walls of the defensive tower, which is located on a small hill composed of the Ostravice Sandstone, and the walls of the Gothic church in the town centre. Clasts of the Štramberk-type limestones from a few millimetres up to 12 cm, as well as separate algal fragments, pieces of corrals or echinoids can be seen in the sandstones used in walls. Part of the market is also paved with slabs of these sandstones. It is interesting that the presence of deposits from the Ostravice Sandstone Member in Czchów was first noticed in the walls, and following these findings, the authors (Waśkowska and Cieszkowski) started looking for them in the field.

Ciężkowice Foothill

The easternmost locality of the Ostravice Sandstone Member was noticed east of the Biała Dunajcowa River. The sandstone crops out here in the core of the Rzepienniki Anticline in the surroundings of Gromnik village and in the Brzanka-Liwocz Anicline in the surroundings of Ryglice village. The cores of these anticlines are composed of deposits of the Mazák and Godula formations and limbs of the Istebna, Ciężkowice, Hieroglyphic, and Krosno formations. The Godula Formation is developed here as thin- and medium-bedded glauconitic sandstones and grey shales passing up the section to the medium- and thick-bedded sandstones and shales. At the top of the section, thick-bedded, coarse-grained, and conglomeratic sandstones occur. They are somewhat similar to the Istebna sandstone facies, but with noticeable amounts of glauconite. Thick-bedded, conglomeratic sandstones of the Ostravice Sandstone Member rich in carbonate clasts occur at the base of this complex. The Godula Formation is underlain by red shales of the Mazák Formation, but interbeddings of variegated shales also occur within the middle part and top of the section. The thickness of the Godula Formation in the Rzepienniki Anticline is estimated as 200–250 m and in Brzanka–Liwocz up to 400 m.

Discussion

The Ostravice Sandstone has been known as a lithostratigraphic unit of the Silesian Nappe since 1933 (Andrusov 1933), and later was commonly used by Czech geologists in the area of the Moravskoslezské Beskydy Mts., the West Outer Carpathians in the Czech Republic (e.g. Matějka & Roth 1949; Roth et al. 1962; Andrusov & Samuel 1985; Eliáš

1995, 2000; Picha et al. 2006 and papers cited therein). When describing this division, the author paid special attention to its lithological development and clearly noticeable individuality among the other Upper Cretaceous deposits of the Silesian Nappe. Then the Ostravice Sandstone was classified as a facies within the Mazák Formation (Roth 1980; Menčík et al. 1983).

The Ostravice Sandstone also occurs in the Polish sector of the Outer Carpathians and belongs to the same lithosome as that known from the Moravskoslezské Beskydy Mts. The lithostratigraphic position, age, lithology, mineral composition, and sedimentological features of these deposits are the same in the Czech Republic and Poland. Their lithological features clearly distinguish this unit from the other sandstones of the Godula Formation. This observation was initially provided by Słomka (1995). Field investigations found that this lithotype is widespread in the Polish sector of the Outer Carpathians ad its outcrops continue eastward from the Beskid Śląski (Slezské Beskydy) Mts. through the Beskid Mały Mts., Wieliczka and Rożnów Foothills, several kilometres east of the Biała River. Therefore, this unit has regional range. Thanks to its unique diagnostic lithological features, the Ostravice Sandstone is easy to distinguish and map out. These thick-bedded sandstone deposits represent a characteristic sandstone lithotype rich in carbonate rocks clasts mainly of the Štramberk-type. They form the sandstone complex in the lowermost part of the Godula Formation with well-defined upper and lower limits. Clearly visible diagnostic features are well-marked in both the vertical and lateral directions within the Ostravice Sandstone supporting the previous observations distinguishing it as a separate lithostratigraphic unit within the Godula Formation. Therefore, the present authors propose treating this lithological unit as a lithostratigraphic member within the Godula Formation. The definition and description of the proposed member fit the rules described in the Stratigraphic Codes (Alexandrowicz et al. 1975; Racki & Narkiewicz 2006).

The structure of the Ostravice Sandstone Member lithosome formed by its lithostratigraphic position, petrographic composition, and sedimentological features is important for understanding the history of sedimentation within the Silesian Basin as well as for reconstruction of the Silesian Ridge, which was destroyed during the orogenic process in the West Outer Carpathians. The changes of sedimentary regime, which contributed to the origin of the Ostravice Sandstone Member and the entire Godula Formation, began a new stage in the Cretaceous evolution of the Carpathian basins. The geotectonic reorganization of the Outer Carpathian basins took place at the beginning of the Late Cretaceous. The Silesian Basin *sensu stricto* was separated during this reorganization from the widespread proto-Silesian Basin, which existed at least from the Late Jurassic.

Conclusions

The deposits described in the Czech Republic as the Ostravice Sandstone of the Silesian Nappe continue eastward to the Polish sector of the Outer Carpathians.

The authors distinguish these deposits as a lithostratigraphic member — the Ostravice Sandstone Member of the Godula Formation. This member is developed in the lowermost part of the Godula Formation. The bottom of the Ostravice Member borders the variegated shales of the Mazák Formation, and at the top it is overlain by the Czernichów Member of the Godula Formation.

The Ostravice Sandstone Member is developed as thick-bedded sandstones and conglomerates. The sandstones are composed of quartz, glauconite, feldspar, muscovite, as well as lithoclasts of magmatic, metamorphic and sedimentary rocks. The presence of numerous carbonate clasts represented mainly by the Uppermost Jurassic-Lowest Cretaceous Štramberk-type limestones is a characteristic feature which clearly distinguishes this member.

In general, the age of the Ostravice Sandstone Member is estimated as Turonian.

The discussed member is widespread in the Moravskoslezské Beskydy Mts. in the West Outer Carpathians in the Czech Republic and continues eastward through to the Beskid Śląski (Slezské Beskydy) Mts. and Beskid Mały Mts., as well as the Wieliczka, Wiśnicz, Rożnów, Ciężkowice foothills in Poland.

Acknowledgements: Thanks are addressed to Barbara Olszewska for helpful discussion about microfossils, as well as to reviewers – Jacek Rajchel, Miroslav Bubík and Petr Skupien for constructive comments on the manuscript. This research has been financially supported by Ministry of Science and Higher Education/National Centre of Sciences grant no. NN307 249733, and AGH grant no. 11.11.140.173.

References

Alexandrowicz W., Birkenmajer K., Burchart J., Cieśliński S., Dadlez R., Kutek J., Nowak W., Orłowski S., Szulczewski M. & Teller L. 1975: Principles of Polish stratigraphical classification, terminology and nomenclature. *Instr. i metody badań geol.* 33, 1–63 (in Polish).

Andrusov D. 1933: Brief information on geology of Moravian-Silesian Carpathians. *Věst. Stát. Geol. Úst. ČSR* 9, 194–199 (in Czech).

Andrusov D. 1959. Geology of Czechoslovakian Carpathians. II. *Vyd. SAV*, Bratislava, 1–375 (in Slovak with German and Russian summary).

Andrusov D. & Samuel O. (Eds) 1985: Stratigraphic dictionary of the Western Carpathians. Part 2 L–Z. *GÚDŠ*, Bratislava, 1–359 (in Slovak).

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). *Ann. Soc. Geol. Pol.* 71, 2, 75–103.

Bieda F., Geroch S., Koszarski L., Książkiewicz M. & Żytko K. 1963: Stratigraphie des Carpathes externes polonaises. *Bull. Inst. Geol.* 181, 5–174.

Burtan J. 1973: Explanation to detailed geological map of Poland 1:50,000. Wisła Sheet. *PIG,* Warszawa, 1–37.

Burtanówna J., Konior K. & Książkiewicz M. 1937: Carte geologique des Karpates de Silesie. *PAU, Wyd. Śląskie*, Kraków, 1–104 (in Polish with French summary).

Cieszkowski M. 1992: Michalczowa zone: a new unit of Fore-Magura zone, Outer Carpathians, South Poland. *Kwart. AGH*

Geol. 18, 1–2, 1–125 (in Polish with English summary).

Cieszkowski M. 2003: The Outer Carpathians Thrustbelt. In: Golonka J. & Lewandowski M. (Eds.): Geology, Geophysics, Geothermics and Deep Structure of the West Carpathians and their Basement. Part 3. International Workshop, Zakopane, Poland, 2003. *Publ. of the Inst. of Geophysics, Polish Academy of Sciences, Warszawa,* Monographic vol. M-28, 363, 107–110.

Cieszkowski M. 2004: Stop 3. Ustroń, abandoned quarry. Field trip. The 11-th Meeting of the Petrology Group of the Mineralogical Society of Poland. Ustroń, October 14–27, 2004. *Mineral. Soc. Pol., Spec. Pap.* 24, 427–428.

Cieszkowski M., Ślączka A. & Wdowiarz S. 1985: New data on structure of the Flysch Carpathians. *Przegl. Geol.* 33, 6, 313–333.

Cieszkowski M., Gedl E., Ślączka A. & Uchman A. 2001: Stop C2 — Rzyki village. In: Cieszkowski M. & Ślączka A. (Eds.): Silesian & Subsilesian units. 12th Meeting of the Association of European Geological Societies & LXXII Zjazd Polskiego Towarzystwa Geologicznego, Field Trip Guide. *PGI*, Kraków, 115–118.

Cieszkowski M., Gedl E. & Uchman A. 2003: Field Trip Western Carpathians: Kraków–Lanckorona Castle–Inwałd–Roczyny–Rzyki–Kraków, Stop 3. Zagórnik-Rzyki villages. In: Ber A. & Alexandrowicz Z. (Eds): Geological Heritage Concept, Conservation and Protection Policy in Central Europe — International Conference, Cracow, Poland, October 3–4, 2003. Abstracts and Field Trip Guide-Book. *PGI*, Warszawa, 86–91.

Cieszkowski M., Golonka J., Krobicki M., Ślączka A., Waśkowska A. & Wendorff M. 2009a: Olistoliths within the Silesian Series and their connections with evolutionary stages of the Silesian Basin. *Kwart. AGH Geol.* 35, 2/1, 13–21 (in Polish with English summary).

Cieszkowski M., Golonka J., Krobicki M., Ślączka A., Oszczypko N., Waśkowska A. & Wendorff M. 2009b: The Northern Carpathian plate tectonic evolutionary stages and origin of olistolithes and olistostromes. *Geodin. Acta* 22, 1–3, 101–126.

Cieszkowski M., Golonka J., Kowal J., Mika M. & Waśkowska A. 2010: Ostravice Sandstones in Poland (Outer West Carpathians, Silesian Nappe). ESSE-WECA Conference, Bratislava, December 2–3. *Miner. Slovaca* 42, 4, 508.

Cieszkowki M., Kowal J. & Olszewska B. 2011: Limestone clasts from the Upper Cretaceous Sandstones of Silesian Series (Western Outer Carpathians, Poland) — micropaleontological case study. In: Boorova D. (Ed.): 12. Česko-Slovensko-Poľská Paleontologická Konferencia, Bratislava 20.–21. októbra 2011. *Zborník príspevkov. Konferencie–Sympózia–Semináre*, ŠGÚDŠ, Bratislava, 88–89.

Cieszkowski M., Golonka J., Kowal J., Ślączka A., Waśkowska A. & Wendorff M. 2012a: Early Cretaceous dark shale olistholits and Upper Jurassic–Early Cretaceous carbonate clasts as indicators of activity of the Silesian Basin's southern margin (Outer Carpathians, Poland). In: 29th IAS Meeting of Sedimentology, Schladming, Austria, 10th–13th September 2012, Abstract book, 415.

Cieszkowski M., Golonka J., Ślączka A. & Waśkowska A. 2012b: Role of the olistostromes and olistoliths in tectonostratigraphic evolution of the Silesian Basin in the Outer West Carpathians. *Tectonophysics* 568–569, 248–265.

Eliáš M. 1979: Facies and paleogeography of the Silesian unit in the western part of the Czechoslovak flysch Carpathians. *Věst. Ústř. Úst. Geol*. 54, 6, 327–339.

Eliáš M. 1995: Sedimentology of the Mazák Beds and the Ostravice Sandstone (Godula Beds). *Zprávy o geol. výzkumech v roce 1994*, *ČGS* 44–45 (in Czech).

Eliáš M. 2000: Relation between Pustevny Sandstone and Malinovska Skala Sandstone (Godula Formation) in the Beskydy Mts. *Geol. výzkumy na Moravě a ve Slezsku v roce 1999* 7, 64–66 (in Czech with English abstract).

Eliáš M. & Eliášová H. 1984: Facies and palaeogeography of the Jurassic in the western part of the Outer Flysch Carpathians in Czechoslovakia. *Sbor. Gel. Vd*, *Geol.* 39, 105–170.

Foldyna J. & Šuf J. 1964: A note about conglomerates in the fossil pothole of the Ostravice layers. *Sbor. Věd. Prací Vys. Školy Báň. Ostrava* 10, 1–2, 185–189 (in Czech).

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 Symposium International Sur Les Foraminifères Benthiques: Pau (France), 11–15/4/1983. *Elf Aquitaine*, 225–239.

Geroch S., Jednorowska A., Książkiewicz M. & Liszkowa J. 1967: Stratigraphy based upon microfauna in the Western Polish Carpathians. *Biul. Inst. Geol.* 211, 2, 185–282.

Golonka J. & Waśkowska-Oliwa A. 2007: Stratigraphy of the Polish Flysch Carpathians between Bielsko-Biała and Nowy Targ. *Kwart. AGH Geol.* 33, 4/1, 5–28 (in Polish with English summary).

Golonka J., Krobicki M., Matyszkiewicz J., Olszewska B., Ślączka A. & Słomka T. 2005: Geodynamics of ridges and development of carbonate platform within the Carpathian realm in Poland. *Slovak Geol. Mag*. 11, 5–16.

Golonka J., Gahagan L., Krobicki M., Marko F., Oszczypko N. & Ślączka A. 2006: Plate Tectonic Evolution and Paleogeography of the Circum-Carpathian Region. In: Golonka J. & Picha F. (Eds.): The Carpathians and their foreland: Geology and hydrocarbon resources. *AAPG Memoir* 84, 11–46.

Golonka J., Vašíček Z., Skupien P., Waśkowska-Oliwa A., Krobicki M., Cieszkowski M., Ślączka A. & Słomka T. 2008: Litostratygraphy of the Upper Jurassic and Lower Createaceous deposits of the western part of the Outer Carpathians (discussion proposition). *Geologia* 34, 3/1, 9–31.

Golonka J., Ślączka A., Waśkowska A., Krobicki M. & Cieszkowski M. 2013a: Geology of western part of the Outer Carpathians. In: Krobicki M. & Feldman-Olszewska A. (Eds): Abstrakty referatów i posterów. Przewodnik do wycieczek. V Polska *Konferencja* Sedymentologiczna *POKOS* 5'*2013*. Głębokomorska sedymentacja fliszowa, Sedymentologiczne aspekty historii basenów karpackich. Żywiec, 16–19.05.2013. *PGI-NRI*, Warszawa, 11–62 (in Polish).

Golonka J., Cieszkowski M. & Słomka T. 2013b: Poniwiec. In: Krobicki M. & Feldman-Olszewska A. (Eds): Abstrakty referatów i posterów. Przewodnik do wycieczek. V Polska *Konferencja* Sedymentologiczna *POKOS* 5'*2013*. Głębokomorska sedymentacja fliszowa, Sedymentologiczne aspekty historii basenów karpackich. Żywiec, 16–19.05.2013. *PGI-NRI*, Warszawa, 341–345 (in Polish).

Hanzlíková E. 1973: Foraminifers of the variegated Godula Member in Moravia (Cenomanian–Turonian). *Sbor. Geol. Věd*, *Paleont*. 15, 119–184.

Ivanova D. & Kołodziej B. 2010: Late Jurassic-Early Cretaceous foraminifera from Štramberk-type limestones, Polish Outer Carpathians. *Stud. Univ. Babes-Bolyai, Ser. Geol.* 55, 2, 3–31.

Kołodziej B. 2015: Geological context and age of the Štramberk-type limestones from the Polish Outer Carpathians: an overview. *Neues Jahr. Geol. Paläont. Abhand*. 276, 2, 173–179.

Koszarski J., Sikora W. & Wdowiarz S. 1974: The flysch Carpathians. In: Maheľ M. (Ed.): Tectonics of the Carpathian-Balkan Regions. *ŠGÚDŠ*, Bratislava, 180–197.

Koszarski L., Nowak W. & Żytko K. 1959: Notes on the age of the Godula Beds (Carpathians Flysch) (preliminary report). *Kwart. Geol*. 3, 1, 127–151 (in Polish with English summary).

Koszarski L. & Ślączka A. 1973: Cretaceous: Outer (Flysch) Carpathians. In: Sokołowski S. (Ed.): Geology of Poland, 1(2).

Wyd. Geol., Warszawa, 647–660 (in Polish).

Kowal J., Cieszkowski M. & Olszewska B. 2011: Micropaleontological data of limestone clasts from the Upper Cretaceous Ostravice Sandstones (Silesian Nappe, Western Outer Carpathians, Poland). In: Bąk M., Kaminski M.A. & Waśkowska A. (Eds): Integrating Microfossil Records from the Oceans and Epicontinental Seas. 8th Micropaleontological Workshop MIKRO 2011 and Annual TMS Foram/Nannoplankton Group Meeting. Kraków, 27.06–30.06. 2011. AGH, UJ. *Grzybowski Found. Spec. Publ.* 17, 102–103.

Książkiewicz M. 1933: Beitrag zur Kenntnis der mittleren Kreide der Godula-Decke in den West-Karpaten. *Rocz. Pol. Tow. Geol.* 9, 88–95 (in Polish with German summary).

Książkiewicz M. 1951: Explanations to the General Geological Map of Poland 1:50,000, Wadowice Sheet. *Wyd. Geol.*, Warszawa, 1–283 (in Polish).

Książkiewicz M. (Ed.) 1962: Geological atlas of Poland. Stratigraphic and facial problems. Cretaceous and early Tertiary in the Polish External Carpathians. Fasc. 13. *Inst. Geol.*, Warszawa.

Książkiewicz M. 1965: Les cordilleres dans les mers cretaces et paléogènes des Carpathes du Nord. *Bull. Soc. Géol. France* 7, 75–97.

Książkiewicz M. 1972: Geology of Poland. Vol. 4. Part 3. Carpathians. *Wyd. Geol.*, Warszawa, 1–228 (in Polish).

Książkiewicz M. 1974: Detailed Geological Map of Poland 1:50,000. Sucha Beskidzka Sheet. *Wyd. Geol.*, Warszawa (in Polish).

Książkiewicz M. 1977: The tectonics of the Carpathians. In: Pożaryski W. (Ed.): Geology of Poland. Vol. IV. Tectonics. *Wyd. Geol.*, Warszawa, 476–620.

Lexa J., Bezák V., Elečko M., Mello J., Polák M., Potfaj M. & Vozár J. (Eds.) 2000: Geological map of the Western Carpathians and adjacent areas, 1:500,000. *Ministry of Environment of the Slovak Repub., GSSR,* Bratislava.

Maheľ M. (Ed.) 1974: Tectonics of the Carpathian-Balkan Regions. Explanations to the Tectonic Map of the Carpathian-Balkan Regions and their Foreland. *ŠGÚDŠ*, Bratislava, 1–455.

Matějka A. & Roth Z. 1949: Compte rendu des levés géologiques exécutés dans les envirous de Rožnov (Moravie orientale). *Věst. Ústř. Úst. Geol.* 24. 125–130.

Menčík E. et al. 1983: Geology of the Moravskoslezské Beskydy Mountains and Podbeskydská Pahorkatina Hilly Country. *ÚÚG*, Praha, 1–304 (in Czech, with English summary).

Morycowa E. 1968: Sur les calcaires exotique a Madréporaires dans les Lac Rożnów (Carpathes polonaises de Flysch). *Ann. Soc. Geol. Pol.* 38. 19–32 (in Polish with French summary).

Nowak W. 1957: The Silesian series in the basin of the river Wielka Puszcza (Beskid Mały, Western Carpathians). *Kwart. Geol.* 1, 3–4, 513–540 (in Polish with English summary).

Nowak W. 1963: The Globotruncana at the lower part of the lower Godula sandstones in Ustroń, Śląsk Cieszyński. *Kwart. Geol.* 7, 4, 714–715 (in Polish with English summary).

Nowak W. 1973: Outer (Flysch) Carpathians. In: Sokołowski S. (Ed.): Geology of Poland. Part I. Vol. 2. Mesozoic. *Wyd. Geol.*, Warszawa, 389–408, 464–469.

O'Dogherty L. 1994: Biochronology and paleontology of mid-Cretaceous radiolarians from Northern Apennines (Italy) and Betic Cordillera (Spain). *Mém. Géol.* 21, 1–415.

Olszewska B. 1997: Foraminiferal biostratigraphy of the Polish Outer Carpathians: a record of basin geohistory. *Ann. Soc. Geol. Pol*. 67, 2–3, 325–337.

Olszewska B. 2005: Microfossils of the Cieszyn Beds (Silesian Unit, Polish Outer Carpathians) — a thin section study. *PGI Spec. Pap.* 19, 1–58.

Picha F.J., Stranik Z. & Krejčí O. 2006: Geology and Hydrocarbon Resources of the Outer Western Carpathians and Their Foreland, Czech Republic. In: Golonka J. & Picha F.J. (Eds): Carpathians and Their Foreland: Geology and Hydrocarbon Resources. *AAPG Memoir* 84, 49–175.

Racki G. & Narkiewicz M. (Eds.) 2006: Polish principles of stratigraphy. *PIG*, Warszawa, 1–77 (in Polish).

Roth Z. et al. 1962: Explanation to the Synoptic Geological Map of ČSSR 1:200,000, M-34-XIX, Ostrava. *ÚÚG*, Praha, 1–292 (in Czech).

Roth Z. 1980: The stratigraphy of the Godula Group of the Moravskoslezske Beskydy Mountains in the light of deep boreholes. *Věst. Ústř. Úst. Geol.* 55, 2, 75–84 (in Czech with English summary).

Roth Z. & Matějka A. 1953: The pelosiderites of the Moravosilesian Beskydy, their historical importance, geological occurrence, petrographical and chemical nature, and their origin. *Geotechnika* 16, 1–110 (in Czech with English summary).

Senowbari-Daryan B., Bucur I.I., Schlagintweit F., Săsăran E. & Matyszkiewicz J. 2008: *Crescentiella*, a new name for *"Tubiphytes" morronensis* CRESCENTI, 1969: an enigmatic Jurassic–Cretaceous microfossil. *Geol. Croat.* 61, 2–3, 185–214.

Shanmugam G. & Moiola R.J. 1988: Submarine fans: characteristics, models, classification, and reservoir potential. *Earth Sci. Rev*. 24, 6, 383–428.

Skupien P. & Mohamed O. 2008: Campanian to maastrichtian palynofacies and dinoflagellate cysts of the Silesian Unit, Outer Western Carpathians, Czech Republic. *Bull. Geosci.* 83, 2, 207–224.

Słomka T. 1995: Deep-marine siliciclastic sedimentation of the Godula Beds, Carpathians. *Prace Geol. PAN, Kraków* 139, 1–132 (in Polish with English extend summary).

Ślączka A. 1959: Stratigraphy of the Silesian series of the Bystre slice (to the South of Baligród). *Biul. Inst. Geol.* 131, 202–260 (in Polish with English summary).

Ślączka A. (Ed.) 1986: Atlas of paleotransport of detrital sediments in the Carpathian-Balkan Mountain System. Part II: Cenomanian-Senonian. *Hung. Geol. Inst., Budapest*.

Ślączka A. & Kaminski M.A. 1998: A guidebook to excursions in the Polish Flysch Carpathians. *Grzybowski Found. Spec. Publ*. 6, 1–171.

Ślączka A., Kruglov S., Golonka J., Oszczypko N. & Popadyuk I. 2006: Geology and hydrocarbon resources of the Outer Carpathians, Poland, Slovakia and Ukraine: general geology. In: Golonka J. & Picha F.J. (Eds): The Carpathians and their foreland: geology and hydrocarbon resources. *AAPG Memoir* 84, 221–258.

Uchman A. & Cieszkowski M. 2008: Stop 2 — Rzyki — Siliceous Marl and lowermost part of the Godula Beds: ichnology of the calcareous turbidites. Post-Congress field trip B — the Carpathian Flysch. In: Pieńkowski G. & Uchman A. (Eds): Ichnological sites of Poland, the Holly Cross Mountains and the Carpathian Flysch. The Pre-Congres and Post-Congres Field Trip Guide Book. The Second International Congress of Ichnology, Cracow, Poland, August 29–September 8, 2008. *PGI*, 104–109.

Unrug R. (Ed.) 1969: Geological guidebook to the western Flysch Carpathians. *Wyd. Geol.*, Warszawa, 1–260 (in Polish).

Wójcik A., Kopciowski R., Malata T., Marciniec P. & Nescieruk P. 1996: Proposition of the division of lithostratigrapthic units of the Polish Outer Carpathians. In: Przewodnik 57 Zjazdu Pol. Tow. Geol., Szczyrk, 6–9 czerwca 1996. *PTG*, Kraków, 209–215 (in Polish).

Żytko K., Zając R., Gucik S., Ryłko W., Oszczypko N., Garlicka I., Nemčok J., Eliáš M., Menčík E. & Stráník Z. 1989: Map of the tectonic elements of the Western Outer Carpathians and their foreland. In: Poprawa D. & Nemčok J. (Eds.): Geological Atlas of the Western Outer Carpathians. *PIG*, Warszawa.