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GEOLOGY OF THE MAGURA NAPPE IN THE OSIELEC AREA WITH EMPHASIS ON AN EOCENE OLISTOSTROME WITH METABASITE OLISTOLITHS (OUTER CARPATHIANS, POLAND)

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Abstract: The Magura Nappe in the Polish sector of the Outer Carpathians consists of four tectonic subunits characterized by differing development of facies. From the south to the north, they include the Siary, Rača, Bystrica and Krynica subunits. The sedimentary succession in the Rača Subunit in the vicinity of the village of Osielec is composed of Campanian–Palaeogene flysch deposited in the Magura Basin. In this succession, the Middle Eocene Pasierbiec Sandstone Fm consists of thick-bedded sandstones and conglomerates with occasional intercalations of thin-bedded shale-sandstone flysch. Within the Pasierbiec Sandstone Fm at Osielec there is an olistostrome, rich in pebbles and cobbles of exotic rocks. In addition, large blocks of Neoproterozoic metabasites and boulders of Palaeogene organogenic limestones were found. The discovery of metabasites raised the possibility that the rocks in question could be evidence of supposed oceanic crust in the basement of the Magura sedimentary basin, because of the suggestion that they represent the Alpine orogenic cycle. This concept was abandoned when investigations of the absolute age of the metabasites gave a date of ca. 600 Ma. In the Osielec area, there are two tectonic thrust sheets in the Rača Subunit, namely the Osielczyk Thrust Sheet in the north and the Bystra Thrust Sheet in the south; they are folded and cut by a transverse system of strike-slip and oblique faults. The Osielczyk Thrust Sheet was overthrust northwards on to the Siary Subunit.

Key words: Magura Nappe, Rača Subunit, Late Cretaceous–Palaeogene, lithostratigraphy, tectonics, olistostrome, olistoliths, metabasite.

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INTRODUCTION

The idea of a detailed geological investigation of the Magura Nappe in the Babia Góra region, beginning in the vicinity of the village of Osielec, was motivated by the interesting presentations of the geological structure of this area by Książkiewicz (1958, 1966; and in Burtan and Szymakowska, 1966) and the very important study of fold tectonics of the Babia Góra region that was presented by Aleksandrowski (1985). A brief description of the Magura Fm sandstones, exposed in the quarry in the southern part of Osielec village, was presented by Cieszkowski (1985). The geology of Osielec village was presented by Wójcik and Rączkowski (1994), in the explanations to the Osielec Sheet of the Detailed Geological Map of Poland on a scale 1:50000, but in relation to the results of Książkiewicz did not make significant amendments. The geological interpretation by Książkiewicz, presented on the map edited by Burtan and Szymakowska (1966), was adopted in a new version of the Osielec Sheet (Książkiewicz *et al.*, 2017). The present authors were particularly interested in the tectonics of the so-called "Osielec Skiba" – "skiba" in Polish geological nomenclature is a large thrust sheet with a complex internal structure – and the lithostratigraphic position and sedimentary features of the Pasierbiec Sandstone, especially well developed there. These deposits had been mentioned by Uhlig (1888) and described first as sandstones rich in nummulites. Bieda (1946) described them under the name "Pasierbiec Sandstone" and determined their age as Middle Eocene on the basis of large foraminifera. During the course of studies of the Magura Nappe in the Beskid Makowski (Średni) and Beskid Żywiecki (Wysoki) ranges, investigations

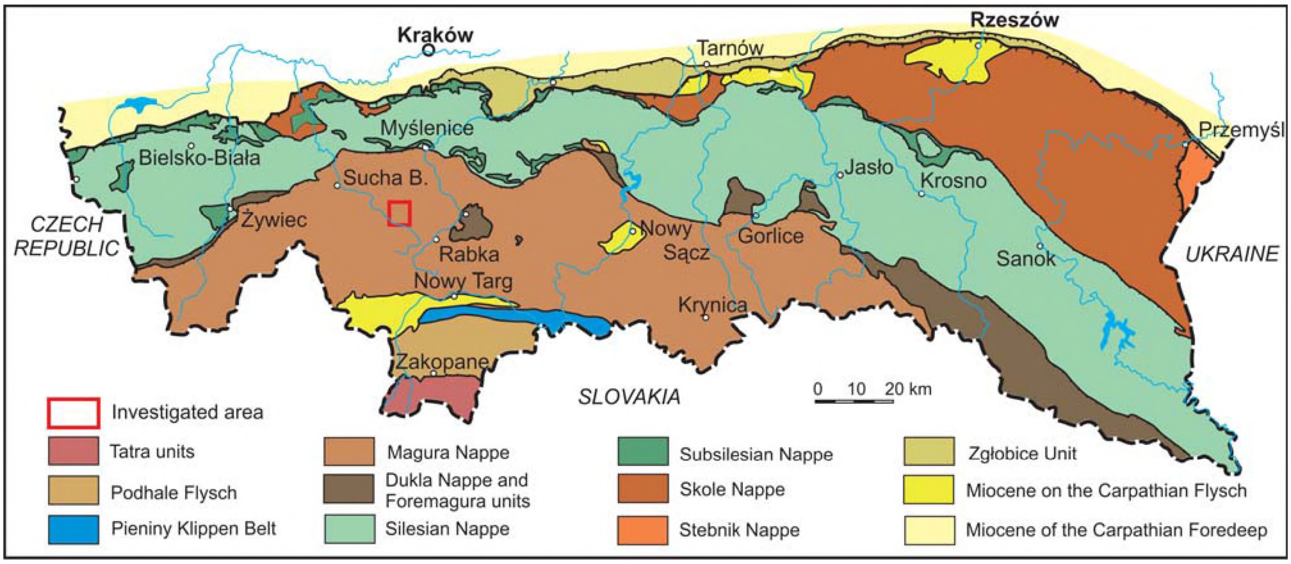

Fig. 1. Geological sketch map of the Polish sector of the Outer Carpathians, showing location of the study area (Chodyń and Cieszkowski based on Żytko *et al*., 1989, modified).

of the Pasierbiec Sandstone were continued by Książkiewicz (1948, 1951a, b, 1958, 1962, 1966) together with Sikora and Żytko (1956, 1960), Wieser (1966) and Bieda *et al.* (1967). In the Pasierbiec Sandstone Fm, a metabasite block was found at Osielec by Książkiewicz during geological mapping and then described in detail by Wieser (1952). Wieser considered it to be an albite amphibolite or a hornblende prasinite and regarded it as an ophiolite. Wieser's interpretation did not receive much comment in the geological literature until now; this occurrence of metabasites in the Carpathian flysch is unique and important and recently became a subject of discussion. As well, the presence of debris flow deposits and chaotically deformed flysch layers observed during preliminary field reconnaissance encouraged the present authors to expand existing geological knowledge about the Osielec area and to collect new data on the olistostromes and olistoliths, which have been systematically investigated in the Outer Carpathians for several years (e.g., Cieszkowski *et al.,* 2009, 2012; Waśkowska and Cieszkowski, 2014; Golonka *et al.*, 2015).

Geological studies at Osielec have been continued by geologists of the Jagiellonian University since 2009. Kysiak (2010a) pursued his master's thesis on the geology of Osielec (map in Fig. 1) and found new outcrops with large blocks of metabasite. The preliminary results of studies on these metabasite blocks and their geological position were presented at a number of conferences (Cieszkowski *et al.,* 2010, 2015b; Kysiak, 2010b). However, some geological problems in the Osielec area remained unresolved and Cieszkowski and Szczęch continued their field investigations, with special attention to detailed geological mapping. Together with Kysiak, they produced a new detailed geological map (Fig. 2). Remote sensing data were very helpful in the final interpretation of this map. At the same time, Wolska (see Anczkiewicz *et al*., 2016) examined petrological and geochemical aspects of the exotic rocks from Osielec.

GEOLOGICAL SETTING

Osielec village is located on the southern slopes of the Beskid Makowski Mts, on the Skawa river, between the towns of Jordanów and Maków Podhalański, about 60 km SSW of Kraków (Fig. 1). The location is geologically in the Outer Carpathians, also called the Flysch Carpathians (Maheľ, 1974; Książkiewicz, 1977a). The Flysch Carpathians consist of several nappes overthrust one upon another and all together transported over the Miocene deposits of the Carpathian Foredeep, on the southern margin of the North European Platform (Książkiewicz, 1972, 1977a; Golonka *et al*., 2003, 2005; Oszczypko, 2006; Ślączka *et al.,* 2006). In the Polish sector of the Outer Carpathians, the Magura Nappe is the largest among the flysch nappes (Książkiewicz, 1977a; Oszczypko, 1992, 2006; Golonka *et al.,* 2003). It is subdivided into four subunits (Koszarski *et al*., 1974; Cieszkowski *et al*., 1985; Oszczypko, 1992). Each subunit displays its own typical sedimentary sequence, Late Cretaceous to Palaeogene in age, which consists of several lithostratigraphic units. The sequences were deposited in different zones of the Magura Basin. From north to south, they are the Krynica, Bystrica, Rača and Siary subunits. Lithostratigraphic units in the Magura Nappe were partly formalized by Birkenmajer and Oszczypko (1989), Oszczypko (1992), and Oszczypko *et al.* (2005). Formalization of lithographic units of the northern zone of the Magura Nappe was proposed by Cieszkowski *et al.* (2006) and Golonka *et al.* (2013). In the area investigated, the Rača and Siary subunits are present. The "Osielec Skiba" (Książkiewicz 1958, 1966) of the Rača Subunit can be subdivided into two thrust sheets. The sedimentary successions in each of these thrust sheets are distinctly different (Fig. 3). In the northern thrust sheet, the Pasierbiec Sandstone Fm is more than 200 m thick and contains olistostromes with large metabasite olistoliths.

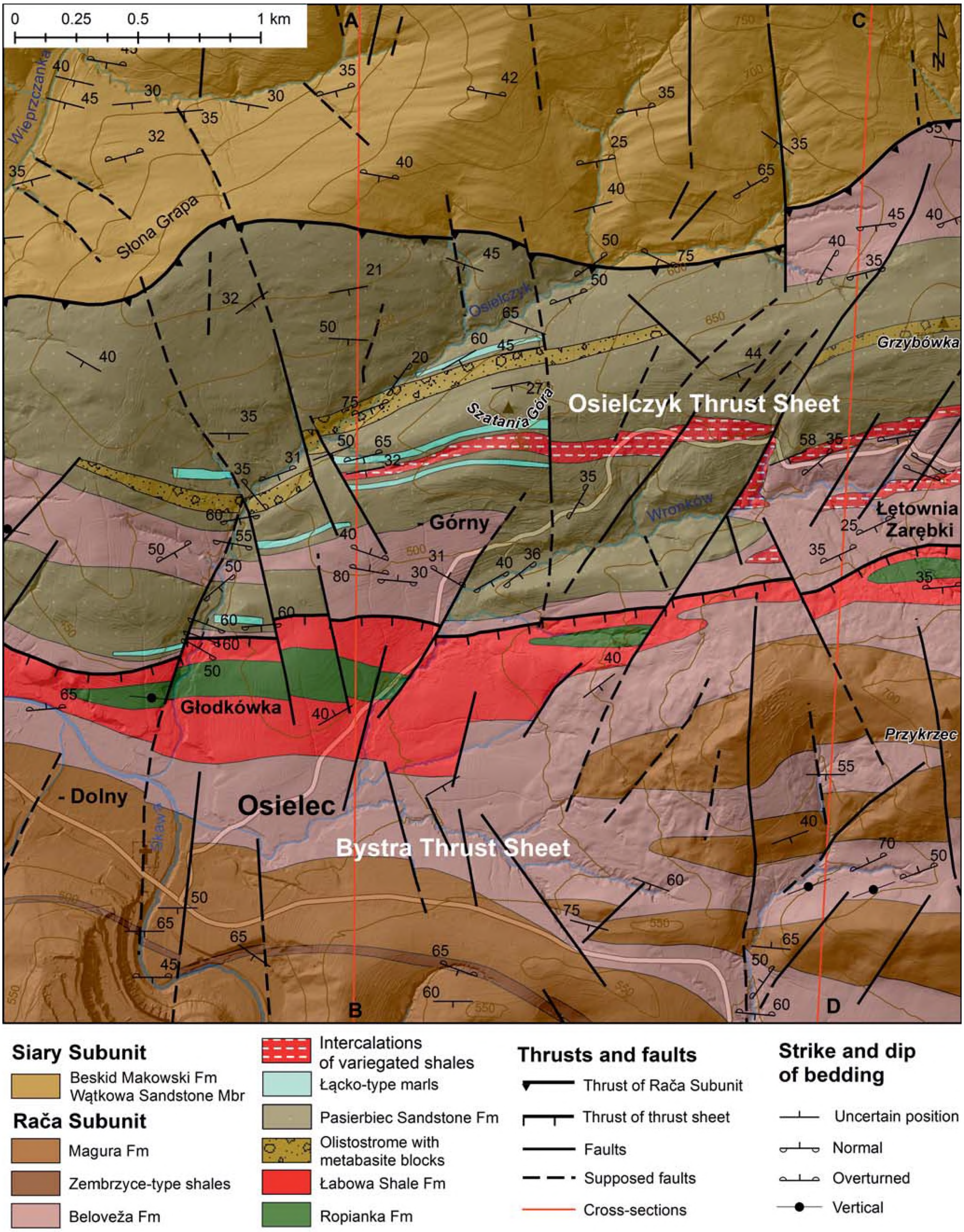

Fig. 2. Geological map of the study area.

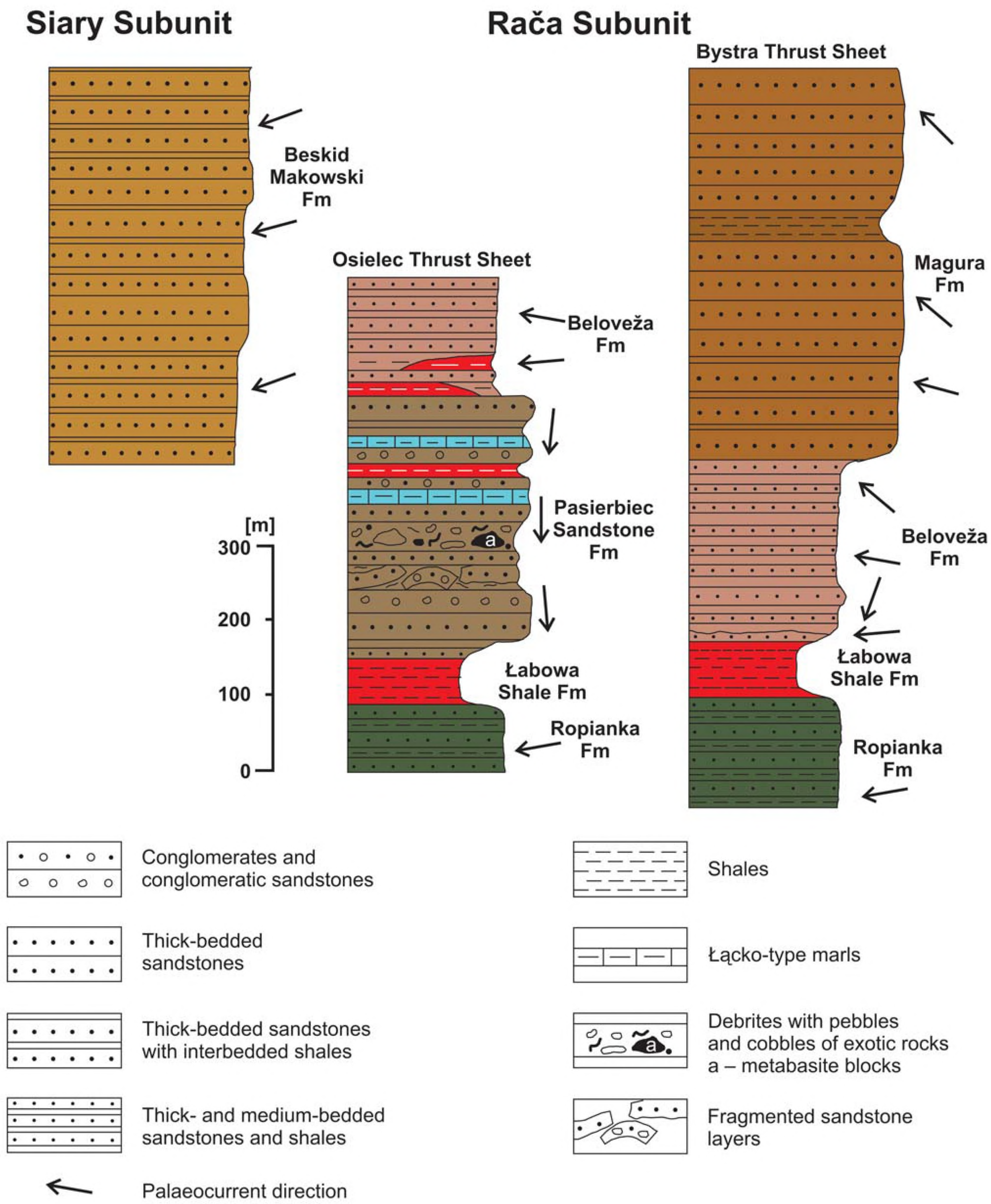

Fig. 3. Lithostratigraphic logs of the Magura Series in the study area.

ANALYTICAL METHODS

The study area was investigated by using the traditional methods of geological mapping. The positions of all observation points, sampling sites and photographs were specified with the aid of a Global Positioning System (GPS) device and the data were stored in a geodata base. Remote sensing data were analysed using a high-resolution digital elevation model (DEM) by means of ArcMap10.3 software. It was especially helpful in areas covered by forest and

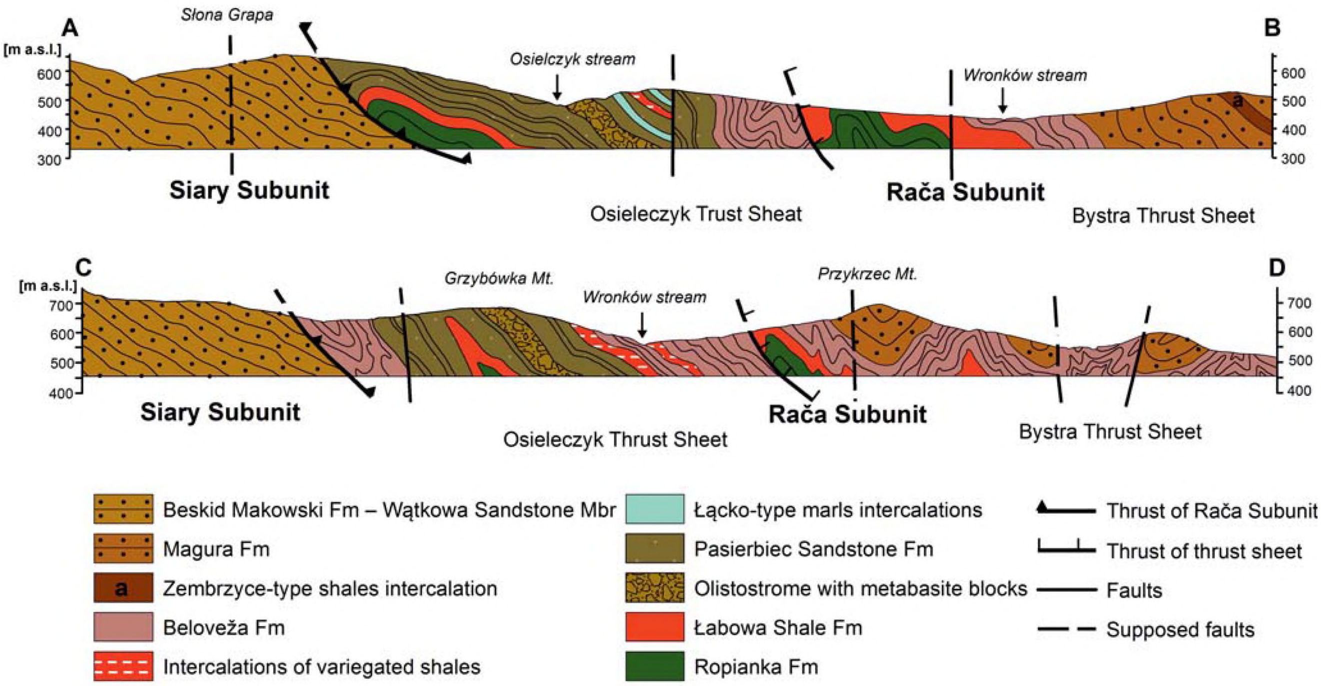

Fig. 4. Geological cross-sections of the Magura Nappe in the study area.

where the ground surface had not been modified by agriculture. In these places, the stratification is clearly visible on the DEM. Parts of faults and thrusts were detected on the DEM by applying morpholineament methods. Microscopic studies were performed using a NIKON YM-EPI Eclipse E600POL optical microscope. Microphotographic documentation was carried out with a CANON EOS 40D camera.

STRATIGRAPHY

In the vicinity of Osielec, the Rača and Siary subunits of the Magura Nappe are present (Figs 2–4). The Siary Subunit occupies only the northernmost part of study area and consists of the Late Eocene–Oligocene Wątkowa Sandstone Member of the Beskid Makowski Formation. The sedimentary succession of the Rača Subunit comprises five lithostratigraphic formations, Late Cretaceous to Palaeogene in age and mainly developed as a flysch facies. From the bottom to the top, they include the Ropianka Fm, the Łabowa Shale Fm, the Pasierbiec Sandstone Fm, the Beloveža Fm, and the Magura Fm (Fig. 3).

Ropianka Formation (Campanian–Palaeogene)

The Ropianka Formation, previously also known as the Inoceramian Beds (Fig. 5A), consists of thin- and medium-bedded sandstones, intercalated with shales. The sandstone layers are usually up to several centimetres and occasionally up to 50 cm thick. The sandstones are muscovitic, grey coloured, fine-grained, and in the thicker layers medium- to coarse-grained. Parallel lamination and cross-lamination, often convolute (Tbcde, $Tbc_{conv}de$ or Tcde Bouma sequences) are common, but in the medium- or thick-bedded layers, the lower part is massive and normally graded (Tabcde, $Tabc_{conv}de$). The sandstones are well sorted and mainly consist of quartz and muscovite, with the addition of feldspars, biotite and plant detritus, and occasionally rare glauconite. Muscovite, usually with an admixture of coalified plant detritus, is concentrated on the lamination surfaces. Grains are bounded with silica-carbonate cement. Current marks and trace fossils are present on the lower bedding surfaces. The former indicate palaeocurrents from the east. The shales, with thicknesses of a few to several centimetres, are represented by grey, light grey and greenish mudstones or muddy claystones. The grey-coloured shales are to different degrees marly and the greenish shales are noncalcareous. The shales are often rich in ichnofossils. At Osielec, the exposed thickness of the Ropianka Fm reaches about 100 m, as reported by Książkiewicz (1962). The Ropianka Fm in the Osielec and adjacent areas is dated as upper Late Cretaceous–Paleocene on the basis of foraminiferal assemblages (Jednorowska, 1966; Geroch *et al.*, 1967; Malata, 1981; Wójcik and Rączkowski, 1994).

Łabowa Shale Formation (Early–Middle Eocene)

The Łabowa Shale Formation (Fig. 5B) is developed as a complex of muddy or clayey variegated shales, mainly red and subordinately green. The proportion of the green shales increases and of intercalations of thin and very thin-bedded fine-grained greenish sandstones increase up the section. The shales of the Łabowa Shale Fm are massive when fresh, flaky and fissile when weathered. According to micropalaeontological data, the Łabowa Shale Fm at Osielec and in the adjacent areas is dated as latest Paleocene–Middle Eocene (Bieda, 1966; Jednorowska, 1966; Geroch *et al.*, 1967; Malata, 1981; Borysławski, 1985; Wójcik and Rączkowski,

Fig. 5. Outcrops of the deposits of the Magura Nappe in the study area. **A.** Ropianka Fm. **B.** Variegated shales of the Łabowa Shale Fm. **C.** Thick-bedded sandstones of the Pasierbiec Sandstone Fm with flute casts, showing a palaeocurrent direction from the north. **D.** Thick-bedded sandstones and conglomerates of the Pasierbiec Sandstone Fm. **E.** Chaotic olistostrome deposits with fragmented and disturbed, thick-bedded sandstones of the Pasierbiec Sandstone Fm. **F.** Thick-bedded Łącko Marl-like marls in the Pasierbiec Sandstone Fm. **G.** Sandstones and shales of the Beloveža Formation. **H.** Thick-bedded sandstones of the Magura Fm.

1994; Cieszkowski *et al.*, 2015b). In some papers, only Early Eocene taxa were observed (e.g., Bieda, 1966; Malata, 1981).

Beloveža Formation (Middle–Late Eocene)

The Beloveža Formation (Fig. 5G), previously called the Hieroglyphic Beds in this region (e.g., Książkiewicz, 1958, 1966), is dominated by a thin-bedded sandstone-shale succession. Usually, shales predominate over sandstones. The sandstones are grey-greenish, fine grained, thin-bedded, but up the section medium-bedded or single thick-bedded, fine-, medium- and rarely coarse-grained sandstones also occur. The sandstones show parallel, planar and subordinate ripple-cross-lamination. The Bouma intervals Tbcd and Tcd are common, but occasionally Tabcd also occurs. Small mechanoglyphs and trace fossils are common. The sandstones are composed mainly of quartz, with a low feldspar content and varying amounts of glauconite and muscovite. The cement is siliceous, siliceous-clayey or siliceous--carbonate. Shales are represented by grey-greenish, grey or dark grey-coloured, clayey or marly mudstones.

In the thin- and medium-bedded sandstones of the Beloveža Fm, palaeocurrent directions from the east (azimuths about 260–265°) predominate, in accordance with the data from this region by Książkiewicz (1962). A single case of transport from the NNE was noted in an bed of glauconitic sandstone, about 0.9 m thick, in the eastern part of Osielec village. Książkiewicz (1962) reported palaeocurrent directions from the ESE in the uppermost part of the Beloveža Fm, where the first intercalations of thick-bedded sandstones typical of the Magura Fm were recorded. The Beloveža Fm is dated to the Middle–Late Eocene (Jednorowska, 1966; Książkiewicz, 1966, 1974; Geroch *et al.*, 1967; Malata, 1981; Borysławski, 1985; Wójcik and Rączkowski, 1994; Golonka and Waśkowska, 2012). Middle Eocene large foraminifera were described by Bieda (Bieda and Książkiewicz, 1958) from Osielec and from Wieprzec village neighbouring to Osielec in the west (Bieda, 1966). A Late Eocene assemblage of small calcareous foraminifera, also from Wieprzec, was determined by Blaicher (1961).

Pasierbiec Sandstone Formation (Middle Eocene)

The Pasierbiec Sandstone Formation (Fig. 5D) is a series of thick-bedded sandstones, conglomeratic sandstones and conglomerates, with occasional breccias, with intercalations of thin-bedded Beloveža Fm-like shale-sandstone deposits as well as occasional layers of marls, representing the Łącko (Zlin) Marl lithotype (Fig. 5F). This marl lithotype is mostly typical of the Bystrica Fm of the Bystrica Subunit (e.g., Oszczypko, 1991). At Osielec, the thick-bedded detrital deposits are represented by two lithotypes, which were considered in the past as separate lithostratigraphic units – the Pasierbiec Sandstone (in fact, sandstones and conglomerates) and the Osielec Sandstone. This second one was distinguished by Książkiewicz (1966) as a fine-grained variety of the Pasierbiec Sandstone.

The Pasierbiec Sandstone lithotype forms thick-bedded layers, 0.5–2.0 m, occasionally up to 3.0 m in thickness. The layers are normally graded, coarse-grained or conglomeratic at the base. There are also intercalations of coarser conglomerates with pebbles of exotic rocks, 2–10 cm in diameter and occasionally larger (Fig. 6A–D). The sandstones and conglomerates are polymictic (cf. Fig. 8A, B), composed mainly of quartz, transparent, smoky and milky, with an admixture of feldspar, some muscovite and glauconite. There are also different lithoclasts of limestones, cherts, red and green radiolarites, mudstones and claystones, granitoids, metabasites, amphibolitic and micaceous gneisses, phyllites as well as chloritic, sericitic and muscovitic schists. The components of the conglomerates are not weathered, and usually poorly rounded or angular, showing that the transportation of the clastic material was rather short-lived. In the coarse sandstones and fine conglomerates, large foraminifera (Fig. 6D, H), mainly nummulites, can rarely be observed. The cement of the sandstones and conglomerates is carbonate or silicic-carbonate.

Microscopic examination of the Pasierbiec Sandstone showed that these detrital deposits are medium- to coarse--grained, with the mean size of mineral grains from 0.2 mm to 0.5 mm (locally up to 0.9 mm). The grains are subrounded (after Pettijohn, 1975) and the sandstones are moderately to very poorly sorted (Fig. 8A, B).

Quartz is the dominant mineral. It commonly occurs as 'mosaic' and undulose grains (Fig. 8B). The feldspar grains (orthoclase perthite, plagioclase) occasionally are strongly altered (sericitized). Phyllosilicates fragments occur as flakes in subordinate amounts. Grains of white mica are more common than grains of chlorite and glauconite (Fig. 8A).

Lithoclast grains (Fig. 8) are represented mainly by metamorphic rocks, showing low- and medium-grade, regional metamorphism (gneisses, granitic gneisses, slates/phyllites, schists (Fig. 8B) and organogenic limestones (Fig. 8A). Lithoclasts of magmatic rocks (both felsic and mafic) also occur, including granites, metabasites, and volcanic rocks. Other rock fragments, namely siliceous rocks (Fig. 8B), mudstones, medium- and fine-grained sandstones, are less common. The Pasierbiec Sandstone displays predominantly the contact type of carbonate cement (Fig. 8A); locally the basal type of cement is also observed (Fig. 8B).

The Osielec Sandstone lithotype forms medium and thick beds. The sandstones are light grey and grey-greenish, fine- and medium-grained, especially characterized by a considerable amount of glauconite. Quartz predominates in the mineral composition of the sandstones, besides feldspar, muscovite and various admixture of glauconite, often in large grains. The sandstones are massive, but in the upper parts of beds, parallel lamination and/or cross-lamination often occur. In some beds, extensive convolute lamination is present.

In the Pasierbiec Fm, the sandstone beds form packages, which are from a few to a dozen metres thick. The sandstone layers of both lithotypes typical of the Pasierbiec Fm are intercalated with greenish shales, rarely with dark grey or brown shales. The thickest beds display amalgamation. Some sandstone packages consist of the Pasierbiec Sandstone lithotype and some of the Osielec Sandstone lithotype and combinations of both types. In some beds, the lower part consists of the Pasierbiec Sandstone lithotype and it passes up into the Osielec Sandstone lithotype. The

Fig. 6. Deposits of the Pasierbiec Sandstone Fm. **A–D.** Conglomerates and conglomeratic sandstones. **E.** Metabasite block (mb) within debrites (db). **F.** Organogenic limestone bolder. **G.** Tomasz Kysiak, next to metabasite blocks. **H.** Nummulites in fine conglomerate. **I.** Polished fragment of organogenic limestone rich in fossils

Fig. 7. View of the Osielec quarry with thick-bedded sandstones of the Magura Fm.

sandstone packages are intercalated with flysch packages, which are 2–8 m thick and developed in Beloveža Fm-like facies. Locally, thick-bedded sandstones, usually of the Osielec sandstone lithotype, 0.5–1.2 m in thickness, are intercalated with the Łącko Marl lithotype (Fig. 5F), 1.5–3.0 m thick, which usually passes toward the top into massive, light grey marlstone. Książkiewicz (1966) noticed brown cherts with radiolarians at the top of some marls of this type.

In the thick-bedded sandstones of the Pasierbiec Sandstone Fm at Osielec, several measurements of palaeocurrent directions indicate supply of the clastic material from the north (see Fig. 3), as noted by Książkiewicz (1962). In the Rača Subunit, in the north-eastern part of the adjacent Beskid Żywiecki mountain range, palaeocurrent directions from the N, NNW and NW were recorded, while in the Siary Subunit located to north of investigated area, palaeocurrent directions from the N are present (Książkiewicz 1962). Studies of large foraminifers from Osielec and the villages of Wieprzec and Łętownia to the east allowed the determination of a Middle Eocene age for the Pasierbiec Sandstone Fm (Bieda and Książkiewicz, 1958; Bieda, 1966). Similar ages were obtained from investigations of small foraminifera (Jednorowska, 1966; Malata, 1981; Cieszkowski *et al.*, 2015b).

Magura Formation (Late Eocene–Oligocene)

The Magura Formation (Fig. 5H) consists of massive, thick-bedded sandstones, usually interbedded with thin shale layers. The sandstones, representing the micaceous Magura Sandstone lithotype, are characterized by beds dominantly 0.5–2.0 m thick, locally amalgamated and up to 5.0 m thick. The sandstones are grey, light grey or grey-bluish when fresh, fine- and medium-grained, occasionally coarse-grained in the lower parts of beds. Usually, they are massive and poorly sorted in the lower parts. The top parts of beds are commonly parallel-laminated or cross-laminated, rarely wavy-laminated; the Bouma intervals Ta_0bc, Ta_0c, Ta_1bc, and Ta_1bcd may be present. In some thick sandstones beds, large-scale cross-bedding was observed. Load casts are present occasionally in the basal parts of beds. Also trace fossils, mostly *Scolicia*, were found. The sandstones are composed of quartz, feldspar, muscovite, chlorite, occasional biotite, and lithoclasts of mica schists, crumbs of igneous rock, quartzite and carbonate rocks in places. Quartz is the main component and muscovite is enriched on lamina surfaces, often with variable amounts of plant detritus; the sandstones contain also clasts of pelitic rocks and occasionally grains of coal. The cement is carbonate, silica-carbonate with an admixture of clayey or ferrous material. The sandstones are interbedded with shales and thin packages of thin-bedded sandstones and shales, 0.5–2.0 m thick. The shales are made up of mainly grey-greenish or brownish carbonates, to a lesser extent mudstones and sandy mudstones. In the lower part of the Magura Formation, shale intercalations are more frequent and thicker. There are also single layers of shales, up to 1 m thick. In the southern part of the Osielec village, there is a complex of thick-bedded massive, grey, grey-greenish marly mudstone shales interbedded with sandstones, several tens of metres thick; they are similar to strata that are characteristic for the Zembrzyce Shale Member facies, known from the Siary Subunit of the Magura Nappe. The sandstones are medium- and thick-bedded, grey or grey-greenish, fine- and medium-grained; in macroscopic view, they are similar to the thick-bedded sandstones described above. They are composed of quartz, feldspars, muscovite and glauconite. For this lithotype, a high frequency of glauconite is typical. In the southern part of the village Osielec, the Magura Formation builds up the highest peaks and is very well exposed in the large Osielec quarry, located on the eastern slope of Łysa Góra Mt. (Fig. 7). Flute and groove casts at the bottom of the layers indicate a transport direction of the material from the SE and ESE. In the lowermost part of the formation, where thin intercalations of shale-sandstone packages similar to these of the Beloveža Fm and shale layers similar to those of the Zembrzyce Member of the Beskid Makowski Fm occur, there is evidence of palaeotransport from the E. In the Beskid Żywiecki mountain range, directions from the SE and ESE, and occasionally from the S and E predominate (Książkiewicz, 1962). In the lower part of the Magura Fm in Osielec Quarry, the microfauna studied by Malata (see Cieszkowski, 1985) indicated a Late Eocene age. Other micropalaeontological investigations of foraminifera and calcareous nannoplankton point to the Late Eocene, but in some cases possibly the Oligocene (Jednorowska, 1966; Geroch *et al.*, 1967; Wójcik and Rączkowski, 1994). The Oligocene age of the Magura Fm finally was confirmed by the investigation of nannoplankton from the nearby quarry at Tenczyn (Oszczypko-Clowes, 2001).

OLISTOSTROME

At Osielec, the olistostrome is well exposed. It occurs in the lower part of the Pasierbiec Sandstone Fm (Figs 3, 4) and extends to the east at the nearby village of Tokarnia (Cieszkowski *et al.*, 2015a). It displays features described by Flores (1959), who defined an olistostrome as a subaquatic sedimentary body, consisting of extraclasts represented by fragments (olistoliths), embedded in a finer-grained matrix (see later additions by other authors, e.g., Görler, 1968; Abbate *et al.*, 1970, 1981; Hoedemaeker, 1973; Richter, 1975; Naylor, 1981). This is a synorogenic olistostrome (Ricci Lucchi, 1986; Lucente and Pini, 2008), as are most olistostromes discussed in the literature. It also shows features of an endolistostrome that contains fragments of local sediments as well as those of an allolistostrome, containing exotic olistoliths derived from the basement rocks, uplifted and exposed at the margin of the basin (cf. e.g., Raymond, 1978). The first genetic type represents a chaotic complex, which consists of fragmented, disrupted sandstone layers and crumpled shales in between them (Fig. 5E). The sandstones within the olistostrome belong to the Pasierbiec and Osielec sandstone lithotypes. At the top of the olistostrome, a debrite occurs. It consists of a sandy-gravel matrix, with numerous shale clasts and pebbles, boulders and blocks of different exotic rocks and minerals, e.g., granitoids, micaceous schists, quartz, limestones, marls, and glauconitic sandstones. Among them are blocks of metabasite (Fig. 6E, G), 0.5–3.5 m in diameter. Moreover, ellipsoidal boulders of Early Palaeogene organogenic limestones, up to 0.7 m long, were found (Fig. 6F). They contain algae, bryozoans, small molluscs, corals, small and large foraminifera, mainly nummulites, as well as debris of echinoids (Fig. 6I).

According to Leszczyński and Malata (2002), the Siary Subzone in the Palaeogene was characterized by a significant deepening caused by subsidence, which resulted in the formation of a trough, whereas in the Rača Subzone, a morphological elevation caused by the formation of an accretionary prism took place. This situation explains the limited occurrence of the Pasierbiec Sandstone Fm in the Siary Subunit as well as in the northernmost part of the Rača Subunit and its absence in the southern part of Rača Subunit. The clastic deposits of the Pasierbiec Sandstone Fm were transported from the north into the filling trough, but further transport of the material to the south was blocked by a morphological elevation in the Rača Subzone.

The composition of sandstones, conglomerates and debrites of the Pasierbiec Sandstone Fm gives some information about the structure of the source area of the ridge, which bounded the Magura Basin in the north. The core of ridge was built up of crystalline rocks of metabasites, granitoides, granitic gneisses, gneisses, phyllites and micaceous schists, as well as some volcanic rocks. The basement was covered by sedimentary rocks represented by some siliceous rocks, cherts, radiolarites and various limestones, including Mesozoic limestones with *Saccocoma* and Palaeogene organogenic limestones. The latest were deposited on a shelf, where the large foraminifera common in the Pasierbiec Sandstone Fm could live. The Pasierbiec Sandstone Fm contains also clasts and olistoliths of older rocks, known from the Magura Nappe succession. Their presence is connected with synsedimentary tectonic movements, which facilitated submarine erosion of the sediments on the bottom of the basin. These movements also triggered submarine slumps, which are evidenced in the lower part of the Pasierbiec Sandstone Fm. A somewhat similar scenario of a formation with submarine slumps and other olistostrome deposits was described by De Ruig and Hubbard (2006) from a deep-sea channel belt in the molasse foreland basin, located north of the Eastern Alps in Austria.

METABASITE PETROGRAPHY

The metabasite investigated is a medium-grained rock, dark green or green black in colour, showing a massive texture. The rock is in places strongly dynamically altered and shows irregular pale green or pale yellow green zones, up to 5 cm thick, which consist of macroscopically visible neogenic minerals, such as chlorite, epidote and calcite.

Microscopic studies of thin sections showed that cataclastic and mylonitic structures were formed in dynamically deformed parts of the metabasite. The phenomena of crushing mineral crystals, reduction of their size and abnormal optical properties of rock-forming minerals were observed. In undeformed parts of the rock, some relics of primary poikiloblastic structure occur, where plagioclase and amphibole are the main rock-forming minerals. Plagioclase is represented by subhedral albite, characterized by multiple twinning of albite and undulose extinction (Fig. 8C). The central parts of albite crystals are filled with small grains of the neogenic epidote and zoisite. In the specimens studied, traces of metamorphic deformation were observed. In the deformed parts of the metabasite blocks (Fig. 8D), albite crystals are crushed and strongly altered into aggregates of muscovite flakes. Amphiboles are represented by olive

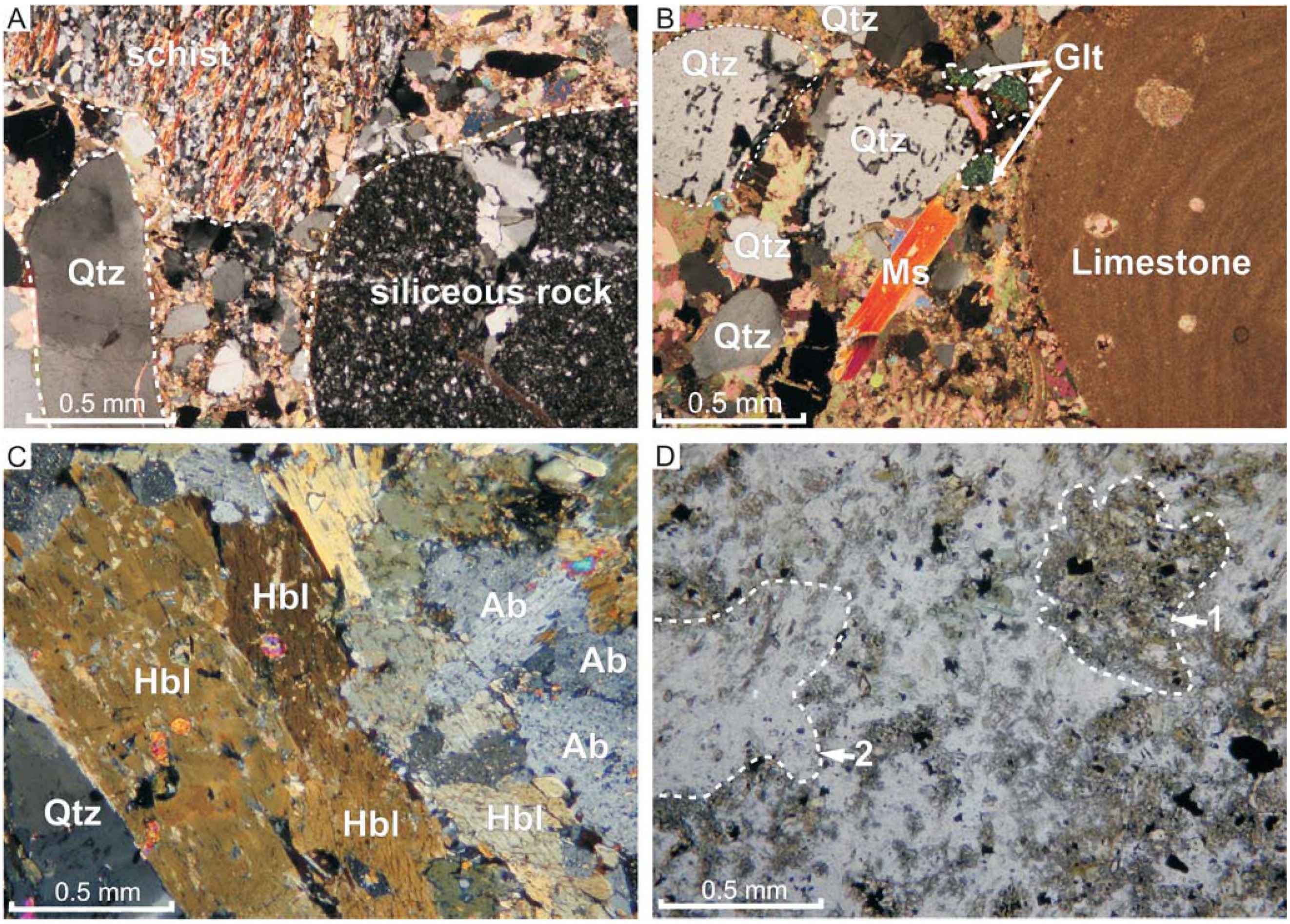

Fig. 8. Microscopic imagines of the studied rocks. **A.** Osielec Sandstone lithotype (sample no. Os-pas 12) – grain of quartz (Qtz) and lithoclasts of schist and siliceous rock. Cross-polarized light. **B.** Osielec Sandstone lithotype (sample no. Os-pas 4) – grains of quartz (Qtz) and glauconite (Glt), white mica flake (Ms) and limestone lithoclast. Cr ossed polars. **C.** Metabasite (sample no. OGK 1/1a/1) – crystals of amphibole (hornblende Hbl) and albite (Ab). Cross-polarized light. **D.** Metabasite (sample no. OGK 1/1b/1). Deformed zone consists of (1) pseudomorphosis after mafic minerals (amphiboles) filled by fine-grained aggregate of epidote, chlorite and opaque minerals and (2) neogenic albite with fine-grained sericite flakes and epidote/zoisite crystals. Plane-polarized light.

hornblende, which shows strong pleochroism from yellow green to olive green in colour. Hornblende tends to form elongated crystals, altered to different degrees, and partially replaced by aggregates of secondary epidote, sphene, chlorite and opaque minerals (Fig. 8D). Accessory minerals are represented by apatite, ilmenite and rare zircon. Petrologically, the metabasite studied can be determined as a cataclasytic amphibolite. The blocks of metabasite are cut by calcite veinlets, containing pyrite and chalcopyrite. Preliminary investigations of its absolute age give a date of ca. 600 Ma (Anczkiewicz *et al.*, 2016), which means that these igneous rocks were formed in Neoproterozoic times during the Cadomian Orogeny. In general, the results of microscopic research of this rock correspond with the results obtained by Wieser (1952), though according to suggestions by Książkiewicz (1977b), the data for determination of the metabasite as an ophiolite are insufficient. The metabasite could have been created by metamorphism and cataclasis of a gabbro or gabbro-diorite (cf. Wieser, 1952), therefore sometimes it was described as "gabbro" (e.g., Cieszkowski *et al.*, 2010; Kysiak, 2010b; Anczkiewicz *et al.*, 2016).

TECTONICS

In the Osielec area, the Siary and the Rača subunits of the Magura Nappe occur (Figs 2, 4). In the southern and central part of the village, within the Rača Subunit, Książkiewicz (1966) distinguished the tectonic unit called the "Osielec Skiba". He noticed significant differences between the geological structure of the northern and the southern limbs of this "skiba". Detailed investigations of the authors presented in this paper show that in fact the "Osielec Skiba" consists of two distinctly different thrust sheets: the southern Bystra Thrust Sheet and the northern Osielczyk Thrust Sheet (Fig. 4). In the northern part of the Osielczyk Thrust Sheet, the Grzybówka Anticline is northwardly overthrown. Its core is built up of the Pasierbiec Sandstone Fm and limbs of the Beloveža Fm and variegated shales. The northern, tectonically reduced limb is thrusted over the Wątkowa Sandstone Mb of the Siary Subunit. To the south of the thrust sheet, the irregularly formed Wronków Syncline is filled in general with the Beloveža Fm. Another local anticline built up of Pasierbiec Sandstone Fm occurs NW of the hamlet of

Głodkówka. In the Wronkówka Syncline, strata of the Beloveža Fm are locally disharmonically refolded. The Bystra Thrust Sheet is overthrust on to the Osielczyk Thrust Sheet from the south. In the frontal part of the Bystra Thrust Sheet, the Głodkówka Anticline appears. It is built up of the Ropianka and Łabowa Shale formations in the core and of the Beloveža Fm in the southern part. In the south-eastern part of the area, south of the Głodkówka Anticline, there exist three smaller, irregular folds of the Przykrzec Fold Group, with W-E-oriented synclines, composed of sandstones of the Magura Fm and anticlines made up of the Beloveža Fm. In the anticlines, the strata of the Beloveža Fm are disharmonically refolded (Fig. 4). Toward the west, these folds steeply decline. In the southwestern part of the study area, the regular Łysa Mount Syncline is located, with an axis oriented WNW-ESE. In its northern limb, sandstone beds of the Magura Fm are dipping to the south at angles of 45–65°. In the Osielec area, the fold structures and thrust sheets of the Magura Nappe are cut by a transverse system of strike-slip and oblique faults, oriented mainly N–S, NNW–SSE and NNE–SSW, and also close to NW–SE and NE–SW (Fig. 2). The majority of the faults are observable over a distance of less than 2 km. One of the longest is a fault located at Osielec Dolny, which influences the S–N course of the Skawa River and the lower reaches of Osielczyk Stream. Another distinct S–N-oriented fault is observable in the south-eastern part of Osielec village. This anticlockwise transcurrent fault displaces the fold axes of the Przykrzec Fold Group. Another SW–NE-oriented fault runs west of the mountain Grzybówka and it is traced over 2 km.

CONCLUSIONS

The area around Osielec is one of the most interesting areas in the Outer Carpathians, where the geology of the Magura Nappe is best exposed. The area provides the best insight into the lithostratigraphic and sedimentological development of the sedimentary succession of the Rača Subunit as well as into the tectonics of this region.

Of particular importance is the Pasierbiec Sandstone Fm, which consists of the Pasierbiec Sandstone and the Osielec Sandstone lithotypes. Both of these lithotypes and also alternate in the same formation, in accordance with the previous data of Książkiewicz (1966). Therefore, their separation as lithostratigraphic units is not recommended. The petrological composition of the Pasierbiec Sandstone Fm sandstones and conglomerates is very diverse and includes clasts and pebbles of different igneous, metamorphic and sedimentary rocks.

In the Pasierbiec Sandstone Fm, an olistostrome was observed. The rocks represent debris flow and submarine slump deposits, containing different clasts and olistoliths. Large blocks of metabasites, unique in the Outer Carpathians, were found. Preliminary investigations revealed their Cadomian age and traces of metamorphism, probably referable to the Variscan orogeny. The transport directions measured indicate that the coarse clastic material was derived from the north. Its source area was located on the Grybów (Fore-Magura) Ridge, which separated the Magura Basin from the Dukla Basin during the Palaeogene.

Studies on the structure of the "Osielec Skiba" thrust sheet described by Książkiewicz (1966) showed that it consists of two tectonic elements: the Osielczyk Thrust Sheet and the Bystra Thrust Sheet. There are significant differences in the development of the sedimentary successions in these thrust sheets. For example, the southern extent of the Pasierbiec Sandstone Fm is limited to the Osielczyk Thrust Sheet and it does not exist in the Bystra Thrust Sheet (Figs 3, 4). This demonstrates the considerable development of the thrust of the Bystra Thrust Sheet on to the Osielczyk Thrust Sheet, considerably more than 1 km.

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REFERENCES

Abbate, E., Bortolotti, V. & Passerini, P., 1970. Olistostromes and olistoliths. *Sedimentary Geology*, 4: 521–557.

Abbate, E., Bortolotti, V. & Sagri, M., 1981. An approach to olistostrome interpretation. In: Ricci Lucchi, F. (ed.), *Excursion Guidebook with Contributions on Sedimentology of some Italian Basins. International Association of Sedimentologists, 2nd European Regional Meeting*. International Association of Sedimentologists, Bologna, pp. 165–185.

Aleksandrowski, P., 1985. Structure of the Mt. Babia Góra region, Magura Nappe, Western Outer Carpathians: an interference of West and East Carpathian fold trends *Annales Societatis Geologorum Poloniae*, 55: 375–422. [In Polish, with English summary.]

Anczkiewicz, R., Cieszkowski, M., Szczęch, M., Ślączka, A. & Wolska, A., 2016. Ophiolite from Osielec – Magura Nappe, Outer Carpathians, Poland – a new approach to the problem. In: Šujan, M. (ed.), *Environmental, Structural and Stratigraphical Evolution of the Western Carpathians: 10th ESSE WECA Conference, 10th ESSEWECA Conference 1st – 2nd December 2016, Bratislava, Slovakia, Abstract Book.* Comenius University in Bratislava, Bratislava, pp. 9–10.

Bieda, F., 1946. La stratigraphie du Flysch des Karpates centrales polonaises basée sur les grands Foraminiferes. *Annales Societatis Geologorum Poloniae*, 16: 1–54. [In Polish, with French summary.]

Bieda, F., 1966. Duże otwornice eocenu serii magurskiej okolic Babiej Góry. In: Książkiewicz, M. (ed.), *Przewodnik XXXIX Zjazdu Polskiego Towarzystwa Geologicznego, Babia Góra 2-5 czerwca 1966.* Wydawnictwa Geologiczne, Warszawa: pp. 60–69. [In Polish.]

Bieda, F., Jednorowska, A. & Książkiewicz, M., 1967. Stratigraphy of the Magura series around Babia Góra. *Biuletyn Instytutu Geologicznego*, 211: 293–324.

Bieda, F. & Książkiewicz, M., 1958. On the age of the Babia Góra sandstone. *Kwartalnik Geologiczny*, 2: 841–853. [In Polish, with English summary.]

Birkenmajer, K. & Oszczypko, N., 1989. Cretaceous and Paleogene lithostratigraphic units of the Magura Nappe, Krynica

Subunit, Carpathians. *Annales Societatis Geologorum Poloniae*, 59: 145–181.

Blaicher, J., 1961. Zone with calcareous microfauna in the Upper Eocene of the Magura series (Flysch Carpathians). *Biuletyn Instytutu Geologicznego*, 166: 5–59. [In Polish, with English summary.]

Borysławski, A., 1985. Stop 17: Tokarnia. In: Birkenmajer, K. (ed.), *Main Geotraverse of the Polish Carpathians (Cracov – Zakopane). Guide to Excursion. Carpatho-Balcan Geological Association XIII Congress, Cracow, Poland 1985*. Geological Institute, Poland, pp. 44–45.

Burtan, J. & Szymakowska, F., 1966. *Szczegółowa Mapa Geologiczna Polski 1:50000, arkusz Osielec* (wydanie tymczasowe). Wydawnictwa Geologiczne, Warszawa. [In Polish.]

Cieszkowski, M., 1985. Stop 20: Osielec quarry. In: Birkenmajer, K. (ed.), *Main Geotraverse of the Polish Carpathians (Cracow – Zakopane). Guide to excursion. Carpatho-Balkan Geological Association XIII Congress Cracow, Poland 1985.* Geological Institute, Poland, pp. 47–48.

Cieszkowski, M., Golonka, J., Kowal-Kasprzyk, J., Szczęch, M. & Waśkowska, A., 2015a. Eocene olistostrome in the northern zone of the Magura Nappe in Tokarnia village (West Outer Carpathians, Poland). In: *Abstracts, 31st IAS Meeting of Sedimentology, 22-25 June, 2015, Krakow, Poland.* Polish Geological Society, Kraków, p. 123.

Cieszkowski, M., Golonka, J., Kasprzyk-Kowal, J., Szczęch, M. & Waśkowska, A., 2015b. Lithological and micropalaeontological data of the Pasierbiec Sandstone Formation in the Rača Subunit of the Magura Nappe (Outer Carpathians, Poland). In: Bubík, M., Ciurej, A. & Kaminski, M. A. (eds), *Abstracts Book and Excursion Guide. 16th Czech – Slovak-Polish Palaeontological Conference and 10th Polish Micropalaeontological Workshop. Grzybowski Foundation Special Publication*, 21: 24–25.

Cieszkowski, M., Golonka, J., Krobicki, M., Ślączka, A., Oszczypko, N., Waśkowska, A. & Wendorff, M., 2009. The Northern Carpathians plate tectonic evolutionary stages and origin of olistoliths and olistostromes. *Geodynamica Acta*, 22: 1–26

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

Cieszkowski, M., Golonka, J., Waśkowska-Oliwa, A. & Chrustek, M., 2006. Geological structure of the Sucha Beskidzka – Świnna Poręba region (Polish Flysch Carpathians). *Geologia, Kwartalnik AGH*, 23: 155–201. [In Polish, with English summary.]

Cieszkowski, M., Kysiak, T., Ślączka, A. & Wolska, A., 2010. Olistoliths of gabbro from Osielec (Magura Nappe, Outer Carpathians, Poland). In: *ESSE WECA Conference: Environmental, Structural and Stratigraphical Evolution of the Western Carpathians. Bratislava, 4.–5. 12. 2008. Geovestník, Mineralia Slovaca*, 42: 507–508.

Cieszkowski, M., Ślączka, A. & Wdowiarz, S., 1985. New data on structure of the flysch Carpathians. *Przegląd Geologiczny*, 33: 313–333.

De Ruig, M. J. & Hubbard, S.M., 2006. Seismic facies and reservoir characteristics of a deep-marine channel belt in the molasse foreland basin, Puchkirchen Formation, Austria. *AAPG Bulletin*, 90: 735–752.

Flores, G., 1959. Evidence of slump phenomena (olistostromes) in areas of hydrocarbon exploration in Sicily. *Proceedings 5th World Petroleum Congress, Sect. 1, pap. 13, Roma.* Xxx, pp. 259–275.

Geroch, S., Jednorowska, A., Książkiewicz, M. & Liszkowa, J., 1967. Stratigraphy based upon microfauna in the Western Polish Carpathians. *Biuletyn Instytutu Geologicznego*, 221: 185– 283. [In Polish, with English summary.]

Golonka, J., Aleksandrowski, P., Aubrecht, R., Chowaniec, J., Chrustek, M., Cieszkowski, M., Florek, R., Gawęda, A., Jarosiński, M., Kępińska, B., Krobicki, M., Lefeld, J., Lewandowski, M., Marko, F., Michalik, M., Oszczypko, N., Picha, F., Potfaj, M., Słaby, E., Ślączka, A., Stefaniuk, M., Uchman, A. & Żelaźniewicz, A., 2005. The Orava Deep Drilling Project and post-Palaeogene tectonics of the Northern Carpathians. *Annales Societatis Geologorum Poloniae*, 75: 211–248.

Golonka, J., Borysławski, A. & Paul, Z., 1979. Mapa Geologiczna Polski 1:200000, arkusz Bielsko-Biała. Instytut Geologiczny, Warszawa. [In Polish.]

Golonka, J., Krobicki, M., Oszczypko, N., Ślączka, A. & Słomka, T., 2003. Geodynamic evolution and paleogeography of the Polish Carpathians and adjacent areas during Neo-Cimmerian and preceding events (Late Triassic–earliest Cretaceous). In: McCann, T. & Sainton, A. (eds), Tracing tectonic deformation using the sedimentary record. *Geological Society, London, Special Publications*, 208: 137–158.

Golonka, J., Krobicki, M., Waśkowska, A., Cieszkowski, M. & Ślączka, A., 2015. Olistostromes of the Pieniny Klippen Belt, Northern Carpathians. *Geological Magazine*, 152: 269–286.

Golonka, J., Ślączka, A., Waśkowska, A., Krobicki, M. & Cieszkowski, M., 2013. Budowa geologiczna zachodniej części Karpat zewnętrznych. 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.* Państwowy Instytut Geologiczny - Państwowy Instytut Badawczy, Warszawa, pp. 11–62. [In Polish.]

Golonka, J. & Waśkowska, A., 2012. The Beloveža Formation of the Rača Unit in the Beskid Niski Mts. (Magura Nappe, Polish Flysch Carpathians) and adjacent parts of Slovakia and their equivalents in the western part of the Magura Nappe; remarks on the Beloveža Formation – Hieroglyphic Beds controversy. *Geological Quarterly*, 56: 821–832

Görler, K. & Reuter, K., 1968. Enstehung und Merkmale der Olistostrome. *Geologische Rundschau*, 57: 484–514.

Hoedemaeker, P., 1973. Olisthostromes and other delapsional deposits, and their occurrence in the region of Moratalla (Province of Murcia, Spain). *Scripta Geologica*, 19: 1–207.

Jednorowska, A., 1966. Zespoły małych otwornic w warstwach jednostki magurskiej rejonu Babiej Góry i ich znaczenie stratygraficzne. In: Książkiewicz, M. (ed.), P*rzewodnik XXXIX Zjazdu Polskiego Towarzystwa Geologicznego, Babia Góra 2-5 czerwca 1966.* Wydawnictwa Geologiczne, Warszawa, pp. 71–90. [In Polish.]

Koszarski, J., Sikora, W. & Wdowiarz, S., 1974. The flysch Carpathians. In: Mahel', M. (ed.), *Tectonics of the Carpathian-Balkan Regions, Explanations to the Tectonic Map of the Carpathian-Balkan Regions and their Foreland.* Štátny geologický ústav Dionýza Štúra, Bratislava, pp. 180–197.

Książkiewicz, M., 1948. Stratigraphy of the Magura series north of the Babia Góra (Western Carpathians). *Biuletyn Państwowego Instytutu Geologicznego*, 48: 1–35. [In Polish, with English summary.]

Książkiewicz, M., 1951a. *Objaśnienia arkusza Wadowice. Ogólna mapa geologiczna Polski 1:50000.* Państwowy Instytut Geologiczny, Warszawa, 283 pp. [In Polish.]

Książkiewicz, M. (Ed.), 1951b. *Regionalna geologia Polski, T. 1.*

Karpaty, Z. 1. Stratygrafia. Polskie Towarzystwo Geologiczne, Kraków, 206 pp. [In Polish.]

Książkiewicz, M., 1958. Stratygrafia serii magurskiej w Beskidzie Średnim. Stratigraphy of the Magura series in the Średni Beskid (Carpathians). *Biuletyn Instytutu Geologicznego*, 135: 43–82. [In Polish, with English summary.]

Książkiewicz, M. (ed.), 1962. *Geological Atlas of Poland. Stratigraphic and Facial Problems. Fasc. 13 - Cretaceous and Early Tertiary in the Polish External Carpathians. 1:600000.* Instytut Geologiczny, Warszawa.

Książkiewicz, M., 1966. Geologia region babiogórskiego. *Przewodnik XXXIX Zjazdu Polskiego Towarzystwa Geologicznego, Babia Góra 2–5 czerwca 1966.* Wydawnictwa Geologiczne, Warszawa, pp. 5–58. [In Polish.]

Książkiewicz, M., 1972. Karpaty. In: *Budowa geologiczna Polski, T. 4. Tektonika, Część 3.* Wydawnictwa Geologiczne, Warszawa, 228 pp. [In Polish.]

Książkiewicz, M., 1974. *Objaśnienia do Szczegółowej Mapy Geologicznej Polski w skali 1:50 000, ark. Sucha Beskidzka.* Wydawnictwa Geologiczne, Warszawa. [In Polish.]

Książkiewicz, M., 1977a. The tectonics of the Carpathians. In: Pożaryski, W. (ed.), *Geology of Poland, Volume IV, Tectonics, The Alpine Tectonic Epoch*. Geological Institute. Wydawnictwa Geologiczne, Warszawa, pp. 476–620.

Książkiewicz, M., 1977b. Hypothesis of plate tectonics and the origin of the Carpathians. *Annales Societatis Geologorum Poloniae*, 47, 3: 329–353. [In Polish, with English summary.]

Książkiewicz, M., Rączkowski, W. & Wójcik, A., 2017. *Szczegółowa Mapa Geologiczna Polski 1:50000, arkusz Osielec (M-34-76D).* Państwowy Instytut Geologiczny.

Kysiak, T., 2010a. *Geology of Magura Nappe in Surroundings of Osielec.* Unpublished MSc Thesis. Jagiellonian University, Institute of Geological Sciences, Kraków, 69 pp. [In Polish, with English abstract.]

Kysiak, T., 2010b. Gabbro exotic rocks from the Rača Subunit of the Magura Nappe, West Outer Carpathians, Poland. *1-st Students International Geological Conference. Abstracts. 16-19 April 2010.* Kraków, Poland. Polish Geological Society, Kraków, pp. 28.

Leszczyński, S. & Malata, E., 2002. Sedimentary conditions in the Siary Zone of the Magura Basin (Carpathians) in the late Eocene–early Oligocene. *Annales Societatis Geologorum Poloniae*, 72: 201–239.

Lucente, C. C. & Pini, G. A., 2008. Basin-wide mass-wasting complexes as markers of the Oligo–Miocene Foredeep-accretionary wedge evolution in the Northern Apennines, Italy. *Basin Research*, 20: 49–71.

Maheľ, M. (ed.), 1974. *Tectonics of the Carpathian-Balkan Regions, Explanations to the Tectonic Map of the Carpathian-Balkan Regions and their Foreland.* Štátny geologický ústav Dionýza Štúra, Bratislava, 454 pp.

Malata, E., 1981. The stratigraphy of the Magura Nappe in the western part of the Beskid Wysoki Mts., Poland base on the microfauna. *Biuletyn Instytutu Geologicznego*, 331: 103–116. [In Polish, with English summary.]

Naylor, M. A., 1981. Debris flow (olistostromes) and slumping on a distal passive continental margin: the Palombini limestone-shale sequence of the Northern Apennines. *Sedimentology*, 28: 837–852.

Oszczypko, N., 1992. Late Cretaceous through Paleogene evolution of Magura Basin. *Geologica Carpathica*, 43: 333–338.

Oszczypko, N., 2006. Late Jurassic-Miocene evolution of the Outer Carpathian fold-and-thrust belt and its foredeep basin (Western Carpathians, Poland). *Geological Quarterly*, 50: 169–194.

Oszczypko, N., Malata, E., Bąk, K., Kędzierski, M. & Oszczypko-Clowes, M., 2005. Lithostratigraphy and biostratigraphy of the Upper Albian-Lower/ Middle Eocene flysch deposits in the Bystrica and Rača subunits of the Magura Nappe; Western Carpathians (Beskid Wyspowy and Gorce ranges, Poland). *Annales Societatis Geologorum Poloniae*, 75: 27–69.

Oszczypko, N., Ślączka, A., Oszczypko-Clowes, M. & Olszewska, B., 2015. Where was the Magura Ocean? *Acta Geologica Polonica*, 65: 319–344.

Oszczypko-Clowes, M., 2001. The nannofossil biostratigraphy of the youngest deposits of the Magura Nappe (east of the Skawa River, Polish Flysch Carpathians) and their palaeoenvironmental conditions. *Annales Societatis Geologorum Poloniae*, 71: 139–188.

Pettijohn, F. J., 1975. *Sedimentary Rocks*. Harper & Row, New York, 628 pp.

Raymond, L. A., 1978. A classification of melanges and broken formations (abstract). *Geological Society of America, Abstracts with Programs*, 10: 143.

Ricci Lucchi, F., 1986. The Oligocene to Recent foreland basins of the Northern Apennines. In: Allen, P. A., Homewood, P. (eds.), *Foreland Basins. International Association of Sedimentologists, Special Publication*, 8: 105–140. Oxford.

Richter, D., 1975. Olisthostrom, olistholith, olisthothrymma and olisthoplaka as criteria of gravitational mass movements and resedimentation in geosynclinal areas. *Bollettino Servizio Geologico d'Italia*, 96: 371–417.

Sikora, W. & Żytko, K., 1956. Stratigraphy of the Magura Series in Beskid Wyspowy on the Żywiec sheet. *Przegląd Geologiczny*, 10: 469–471. [In Polish].

Sikora, W. & Żytko, K., 1960. Geology of the Beskid Wysoki Range south of Żywiec (Western Carpathians). *Biuletyn Instytutu Geologicznego*, 141: 61–204.

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

Uhlig, V., 1888. Ergebnisse geologischer Aufnahmen in den westgalizischen Karpathen. *Jahrbuch der Kaiserlich-Königlichen Geologischen Reichsanstalt*, 38: 85–264.

Waśkowska, A. & Cieszkowski, M., 2014. Biostratigraphy and depositional anatomy of a large olistostrome in the Eocene Hieroglyphic Formation of the Silesian Nappe, Polish Outer Carpathians. *Annales Societatis Geologorum Poloniae*, 84: 51–70.

Wieser, T., 1952. The ophiolite from Osielec. *Annales Societatis Geologorum Poloniae*, 21 (for 1951): 319–327. [In Polish, with English summary.]

Wieser, T., 1966. Z petrografii regionu Babiej Góry. In: Książkiewicz, M. (ed.), *Przewodnik XXXIX Zjazdu Polskiego Towarzystwa Geologicznego, Babia Góra, 2–5 czerwca 1966.* Wydawnictwa Geologiczne, Warszawa, pp. 91–100. [In Polish.]

Wójcik, A. & Rączkowski, W., 1994. *Objaśnienia do szczegółowej mapy geologicznej Polski 1:50 000. Arkusz Osielec (1015).* Państwowy Instytut Geologiczny, Warszawa, 63 pp. [In Polish.]

Żytko, K., Gucik, S., Ryłko, W., Oszczypko, N., Zając R., Garlicka, I., Nemčok, J., Eliáš, M., Menčík, E., Dvořák, J., Straník, Z., Rakús, M. & Matejovska, O., 1989. Geological map of the Western Outer Carpathians and their foreland without Quaternary formations. In: Poprawa, D. & Nemčok, J. (eds), *Geological Atlas of the Western Outer Carpathians.* Polish Geological Institute.