Geotourism 1–2 (44–45) 2016: 27–44

http://dx.doi.org/10.7494/geotour.2016.44-45.27

Geotouristic values of the Gorce National Park and its surroundings (The Outer Carpathians, Poland)

Geoturystyczne walory Gorczańskiego Parku Narodowego i jego otoczenia (Karpaty Zewnętrzne, Polska)

Mateusz Szczęch[1], Marek Cieszkowski[1], Rafał Chodyń[1], Jan Loch[2]

[1]Jagiellonian University, Institute of Geological Sciences,
ul. Oleandry 2a,
30-063 Kraków;
e-mails: mateusz.szczech@uj.edu.pl, marek.cieszkowski@uj.edu.pl, rafal.chodyn@uj.edu.pl
[2]Gorce National Park,
Poręba Wielka 590, 34-735 Niedźwiedź;
e-mail: jan.loch@gorce.pn.pl

Abstract: *The Gorce Mountains are a picturesque range in the Polish sector of the Outer Carpathians. They are built with turbiditic deposits, representing sedimentary successions of the Krynica and Bystrica Subunits of the Magura Nappe, Late Cretaceous-Paleogene in age. In the Gorce Mts. the majority of lithostratigraphic divisions representing discussed subunits are very well exposed in numerous outcrops. The deposits of the Magura Nappe are folded, locally thrust, and cut by the strike-slip and oblique fault system. This nappe in the Gorce Mts. covers tectonically units of the Foremagura Group of Nappes, which crop out in two tectonic windows. From Rabka-Zdrój and Szczawa mineral waters are well known. Morphology of the Gorces Mts. is varied. A lot of rock tors occur there, as well as landslides, often extensive. Good localizations, varied geology, great land relief and rich live nature, as well as the highlander culture and monuments make the Gorce Mts. an area of high geotouristic potential.*

Key words: *Outer West Carpathians, Magura Nappe, Gorce Mts., geology, geomorphology, geotourism*

Treść: *Gorce są malowniczym pasmem w polskiej części Zachodnich Karpat Zewnętrznych. Są one zbudowane z turbidytowych, późnokredowo-paleogeńskich utworów reprezentujących osadowe sukcesje krynickiej i bystrzyckiej podjednostki płaszczowiny magurskiej. W Gorcach większość wydzieleń litostratygraficznych reprezentujących wspomniane podjednostki jest bardzo dobrze eksponowana w licznych odsłonięciach. Utwory płaszczowiny magurskiej są sfałdowane, lokalnie złuskowane i pocięte systemem poprzecznych i ukośnych uskoków. Płaszczowina magurska w Gorcach przykrywa tektonicznie jednostki przedmagurskiej grupy płaszczowin, które odsłaniają się w dwu tektonicznych oknach. W Rabce-Zdroju i w Szczawie wykorzystywane są wody mineralne. Rzeźba Gorców jest zróżnicowana. Występują tu liczne skałki oraz osuwiska, często rozległe. Dogodna lokalizacja, interesująca budowa geologiczna, wspaniała rzeźba tego pasma, bogata fauna i fora oraz dziedzictwo kulturalne miejscowej ludności wpływają na duży potencjał geoturystyczny Gorców.*

Słowa kluczowe: *Zachodnie Karpaty Zewnętrzne, płaszczowina magurska, Gorce, budowa geologiczna, geomorfologia, geoturystyka*

Introduction

The Gorce Mountains are one of the most beautiful and picturesque mountain ranges in the south of Poland, located about 60 km to the south of Cracow. The mountains are a part of the Beskidy Mountains range. The Gorces border Beskid Wyspowy Mts. from the north, while from the south, they slope gently towards the Orawa-Nowy Targ Basin, from where the majestic Tatra Mountains and Spisz-Gubałówka range can be seen (Fig. 1). The Gorce Mts. are bordered by the Dunajec valley from the east, separating them from the Beskid Sądecki, which creates a scenic ancedent type gorge (Zuchiewicz, 1978, 2010). From the West, the mountains border Orawa-Jordanów Foothills (Balon et al. 1995). The Gorce Mountains' height difference measured by Zuchiewicz (1995) on square polygons reaching 1 km^2 is 100 m at the margins, up to 350 m in the center of the massif. Characteristic for this range is the fact that there are the para-radial arrangement mountain ranges and valleys, radiating from the highest peak, the Turbacz Mt. (1310 m a.s.l.). Their varied and interesting geological structure makes the range picturesque and has a great influence on plentiful forms in morphology, i.e.: numerous rocks and rock outcrops (e.g. Fig. 2), waterfalls, landslides and, what is more, the caves (e.g. Cieszkowski 2004, 2005, 2006a; Cieszkowski et al. 2015a, b). As such, the Gorces Mts. are attractive for geotourists.

The Gorce Mts. consist of the unique variety of flysch deposits. These enriched the natural world protected by the Gorce National Park (GNP) (launched in 1981); which was created for protecting precious natural habitats, especially the untamed Carpathian Forest.

Fig. 1. Winter view of the Tatra Mts. and Orawa-Nowy Targ Basin, filling with fog visible from the southern slopes of the Gorce Mts., photo J. Loch • Zimowy widok z południowych stoków Gorców na Tatry i zasnutą mgłami Kotlinę Orawsko-Nowotarską, fot. J. Loch

Fig. 2. Cliff tors located on the northern slope of Kudłoń Mt., photo M. Szczęch • Baszta skalna znajdująca się na północnych stokach Kudłonia, fot. M. Szczęch

The geological attractions of the Gorce National Park and its surroundings are receiving a great deal of attention for their geological structure, which is presented in many science publications dealing with this type of study (e.g. Książkiewicz, 1958; Chrząstowski, 1971; Watycha, 1966, 1975, 1976; Sikora, Żytko, 1968; Burtan et al., 1976, 1978, 1992a, b, c; Burtan, Łydka, 1978; Paul, 1978, 1980; Cieszkowski et al., 1987, 1989; Zuchiewicz, Oszczypko, 1992; Oszczypko et al., 1991, 1999; Cieszkowski, 2006a, b, c; Cieszkowski et al., 1998, 1999a, 2015a, b), and in the geological (Unrug, 1969; Ślączka, Kamiński, 1998), as well as touristic (Cieszkowski, 2004) guidebooks. Moreover, the geotouristic attractions of the Gorce Mts. can be also found in some other publications (Cieszkowski, 2005, 2006b; Barmuta, 2011; Kucharska et al., 2013; Cieszkowski et al., 2015a, b).

Geological structure

The Gorce Mountains are located in a Polish sector of the West Outer Carpathians (Fig. 3), called also the Flysch Carpathians, because they mainly consist of flysch deposits (i.a. Książkiewicz, 1972, 1977; Cieszkowski et al., 1985; Cieszkowski, 2003; Oszczypko, 2004;; Ślączka et al., 2006). Flysch sediments were deposited during the late stages of the Jurassic up to the Early Miocene in some sedimentary basins, which are the part of the north Tethys. Basins were separated by the elevated structures which constitute geanticline ridges, often emerging above sea level. During the Miocene folding, the deposits, filling already mentioned basins, were folded, uprooted from their primary base, and removed in the form of nappes overthrust one on top of another. The developed nappes formed the current orogen of the Outer Carpthians, which were shifted towards the north and tectonically covered the Miocene deposits filling the Carpathian Foredeep. This occurred transgresive on the consolidated basement of the North-European Platform. The mentioned platform was subducted below the Inner Carpathians terrain. In the nappes, mainly deep-sea deposits can be found, while the mentioned above ridges and their slopes have been collapsed in the subduction processes.

The Magura Nappe is the southern structure, and it is the greatest nappe on the Polish sector of the Outer Carpathians (Fig. 3). It contacts tectonically with the most southerly structure of the Outer Carpathians, the Pieniny Klippen Belt on the south, while on the north, it is overthrust on the Dukla Nappe and on the tectonic units of the Fore-Magura Zone and together with them, on the Silesian Nappe. The Magura Nappe is divided into four facies-tectonic subunits. The Gorce Mts. are located within the two most southern subunits. One of these is the Krynica Subunit, which builds the southern part of the Gorce Mts., with the highest peaks: Turbacz (1310 m a.s.l.), Obidowiec (1106), Mostownica (1251), Gorc (1228), Kudłoń (1274), Kiczora (1282), Jaworzyna Kamienicka (1288), Lubań (1225). The second one is the Bystrica Subunit, which builds the northern parts of the range. At the northern foothills of the Gorce Mts., below the Magura Nappe, in the tectonic windows, the units of the Fore-Magura Zone emerged on the surface. They are represented by the Dukla Nappe and Grybów Nappe.

Stratigraphy

The facies of sedimentary series of the Magura Nappe are laterally varied. The facies change within Paleogene deposits overlapped from the south to the north as well as some tectonic features, which divided four facies-tectonic subunits in the Magura Nappe (e.g. Koszarski et al., 1974; Cieszkowski et al., 1985). The Krynica and Bystrica Subunits occurring in the Gorce Mts. on the Gorce National Park area and its surroundings flysch deposits represent the age interval from the uppermost Early Cretaceous to the Oligocene.

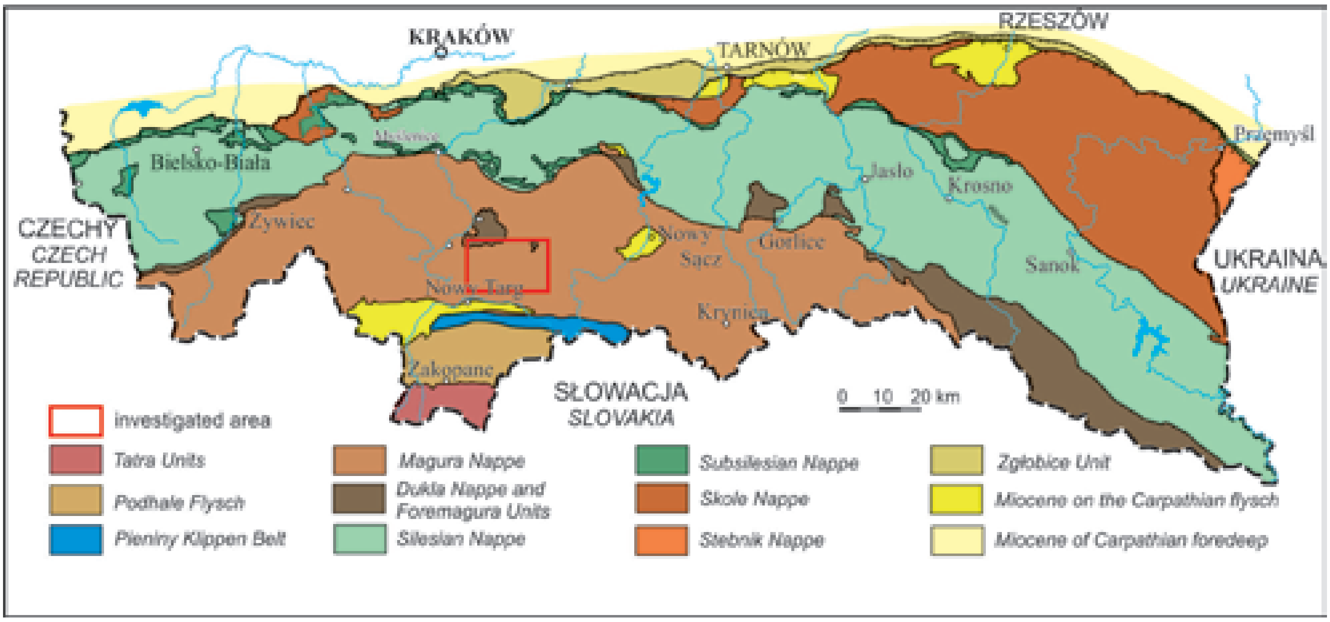

Fig. 3. Geological sketch of the Polish sector of the Carpathians with location of studied area (Cieszkowski 2006a, modified) • Szkic geologiczny polskiej części Karpat z lokalizacją badanego terenu (Cieszkowski 2006a, zmodyfikowany).

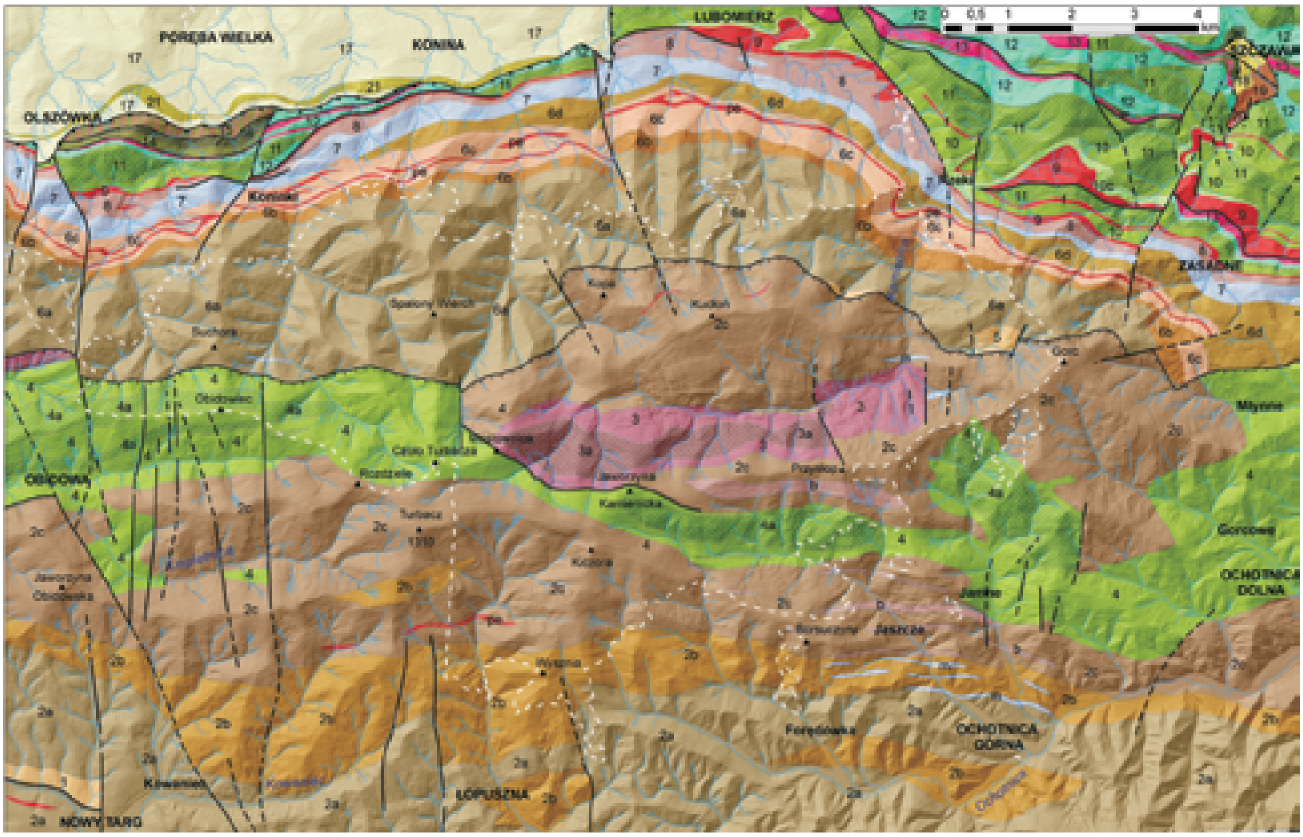

Fig. 4. Geological map of the investigated area (after Cieszkowski et al. 2015, modified): 1–4 Krynica Subunit: 1 – Malcow Formation , Oligocene; 2a – Magura Fm., Poprad Sandstone Member, thick-bedded sandstones, Late Eocene-Oligocene; 2b – Magura Fm., Kowaniec Mb., thick-bedded sandstones inercalated by thin-bedded sandstones, shales and Łącko-like marls, Middle Eocene; 2c – Magura Fm., Piwniczna Sandstone Mb., thick-bedded sandstone and conglomerate interbedded by thin-bedded sandstone and shales Beloveža-like facies; b – thin-bedded sandstone and shales Beloveža-like facies, Early and Middle Eocene; 3 – Zarzecze Fm., thin- and medium-bedded sandstone and shales Beloveža-like facies; 3a – Early Eocene, Zarzecze Fm., Krynica Sandstone Mb., thick-bedded sandstones and conglomerates, Early Eocene; 4 – Szczawnica Fm., thin- and medium-bedded sandstones and shales, Cretaceous-Paleocene; 4a – Szczawnica Fm., thick-bedded sandstones and conglomerates, Cretaceous-Paleocene. 5–16 Bystrica Subunit: 5 – Malcov Fm. thin- and medium-bedded sandstones and marly shales, Late Eocene-Oligocene; 6a – Magura Fm., Poprad Mb., thick-bedded sandstones, Late Eocene; 6b – Magura Fm., Trusiówka Mb., thick-bedded sandstones intercalated by thin-bedded sandstones and shales and Łącko-like marls, Late Eocene; 6c – Magura Fm., Mniszek Mb., thin-bedded sandstones and shales Beloveža-like facies; pe – variegated shales in different members; 6d – Middle and Late Eocene, Magura Fm., Maszkowice Mb., thick-bedded sandstones with intercalations of Łącko marls, Middle and Late Eocene; 7 – Żeleźnikowa Fm. and Bystrica Fm., thick-bedded Łącko marls and sandstones in Żeleźnikowa Fm. with thin-bedded sandstones and shales, Middle and Late Eocene; 8 – Beloveža Fm., thin- and medium-bedded sandstones and marly shales, Early Eocene; 9 – Łabowa Shale Fm., variegated shales, Early Eocene; 10 – Ropianka Fm. thin- and medium bedded sandstones and shales, Maastrichtian-Paleocene; 11 – Szczawina Fm., thick-bedded sandstones, Campanian-Maastrichtian; 12 – Białe Fm., thin- and medium-bedded sandstones, marls and limestones, Maastrichtian; 13 – Malinowa Shale Fm., variegated shales, Cognac; 14 – Thick-bedded Cretaceous sandstones; 15 – Poręba Górna Fm., chaotic flysch deposits, Late Cretaceous; 16 – Janień Fm., green spotted shales, Albian-Cenomanian. 17-21 Foremagura Group of Nappes: 17 – Krosno Beds, sandstones and shales Oligocene; 18 – Cergowa Beds, shales, sandstones and thick-bedded marls, Oligocene; 19 – Grybów Beds, shales, marls and sandstones, Oligocene; 20 – Rdzawka Beds, thin-bedded silicified sandstones and shales, Eocene? - Oligocene; 21 – Jaworzynka Beds, shales and sandstones, Late Cretaceous-Paleocene (olistholits?) • White dashed line – borders of Gorce National Park • Mapa geologiczna badanego terenu (za Cieszkowski et al. 2015, zmodyfikowana): 1–4 podjednostka krynicka: 1 – formacja malcowska, oligocen; 2a – formacja magurska, ogniwo piaskowców z Popradu, gruboławicowe piaskowce, późny eocen-oligocen; 2b – formacja magurska, ogniwo z Kowańca, gruboławicowe piaskowce przeławicone piaskowcami, łupkami i marglami typu łąckiego, środkowy eocen; 2c – formacja magurska, ogniwo piaskowców z Piwnicznej, gruboławicowe piaskowce i zlepieńce przeławicone cienkoławicowymi paskowcami i łupkami typu beloweskiego; b – cienkoławicowe paskowce i łupki typu beloweskiego, wczesny i środkowy eocen; 3 – formacja z Zarzecza, cienko- i średnioławicowe piaskowce i łupki, facja typu beloweskiego, wczesny eocen; 3a – formacja z Zarzecza, ogniwo piaskowców krynickich, gruboławicowe piaskowce i zlepieńce, wczesny eocen; 4 – formacja szczawnicka, cienko- i średnioławicowe piaskowce i łupki, kreda-paleocen; 4a – formacja szczawnicka, gruboławicowe piaskowce i zlepieńce, kreda-paleocen. 5–16 podjednostka bystrzycka: 5 – formacja malcowska, cienko- i średnioławicowe piaskowce i łupki margliste, późny eocen-oligocen; 6a – formacja magurska, ogniwo piaskowców z Popradu, gruboławicowe piaskowce, późny eocen; 6b – formacja magurska, ogniwo z Trusiówki, gruboławicowe piaskowce przeławicone cienkoławicowymi piaskowcami, łupkami i marglami typu łąckiego, późny eocen; 6c – formacja magurska, ogniwo z Mniszka, cienkoławicowe piaskowce i łupki typu beloweskiego; pe – łupki pstre w różnych jednostkach; 6d – formacja magurska, ogniwo z Maszkowic, gruboławicowe piaskowce z ławicami margli łąckich, środkowy i późny eocen; 7 – formacja żeleźnikowska i formacja bystrzycka, gruboławicowe margle łąckie i piaskowce w formacji żeleźnikowskiej z cienkoławicowymi piaskowcami i łupkami, środkowy i późny eocen; 8 – formacja beloweska, cienko- i średnioławicowe piaskowce i łupki margliste, wczesny eocen; 9 – formacja łupków z Łabowej, łupki pstre, wczesny eocen; 10 – formacja ropianiecka, cienko- i średnioławicowe piaskowce i łupki, mastrycht-paleocen; 11 – formacja ze Szczawiny, gruboławicowe piaskowce, kampan--mastrycht; 12 – formacja z Białego, cienko- i średnioławicowe piaskowce, margle i wapienie, mastrycht; 13 – formacja łupków z Malinowej, łupki pstre, koniak; 14 – kredowe gruboławicowe piaskowce; 15 – formacja z Poręby Górnej, chaotyczne utwory fliszowe, późna kreda; 16 – formacja z Jasienia, zielone łupki plamiste, alb-cenoman. 17–21 jednostki grupy przedmagurskiej: 17 – warstwy krośnieńskie, piaskowce i łupki, oligocen; 18 – warstwy cergowskie, łupki, piaskowce i gruboławicowe margle, oligocen; 19 – warstwy grybowskie, łupki, margle i piaskowce, oligocen; 20 – warstwy z Rdzawki, cienkoławicowe skrzemionkowane piaskowce i łupki, eocen?-oligocen; 21 – warstwy z Jaworzynki, łupki i piaskowce, późna kreda-paleocen (olistolit?). Biała przerywana linia – granica Gorczańskiego Parku Narodowego

The geological structure of the Magura Nappe in the western part of Gorce Mts., especially lithostratigraphic sections and their divisions, as well as tectonics were described by Burtan, Paul and Watycha (Watycha, 1963, 1966; Burtan et al., 1976, 1978; Paul, 1978, 1980). The lithostratigraphic divisions of the Krynica and Bystrica Subunits of the Magura Nappe were formalized by Oszczypko and partly by cooperating authors (Birkenmajer, Oszczypko, 1989; Oszczypko, 1991; Oszczypko et al., 2005). Some additions to the accepted formal division were offered by Cieszkowski (Cieszkowski, Olszewska, 1986; Cieszkowski, 2006a, b; Uchman, Cieszkowski, 2008a, b). A list of the actual geology of the Magura Nappe in the Gorce National Park and its surroundings area has developed on the base of detailed field studies and mapping (Figs 4, 5).

Krynica Zone

The Szczawnica Formation (Fig. 6A, B) in the section of the Magura Nappe in the Krynica Zone in the Gorce Mts. starts from the uppermost Late Cretaceus sandstone-shale deposits. In former literature, this formation was called Inoceramian Beds or Nowy Targ Beds (Watycha, 1963, 1975, 1976). The formation is built with thin- and medium-bedded sandstone-shale flysch. The sandstones are steel grey, muscovite, with cross and parallel lamination, often convoluted, composed of quartz and muscovite. The shales, often marly, are grey or greenish-grey. Within the formation, there are thick-bedded micaceous sandstones, conglomeratic sandstones or fine conglomerates.

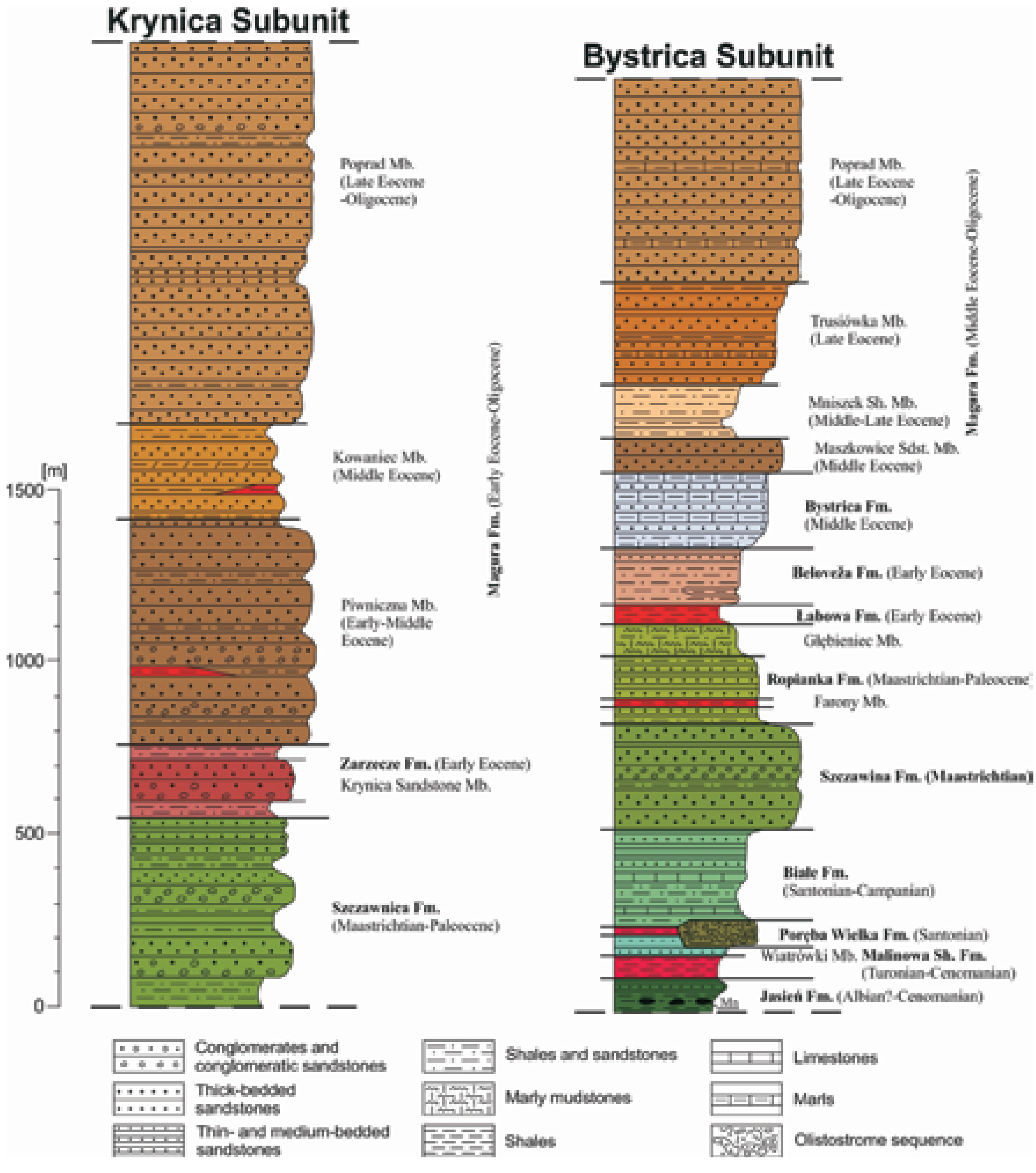

Fig. 5. Lithostratigraphic logs of the Magura Series in the Gorces Mts. • Profile litostratygraficzne serii magurskiej w Gorcach

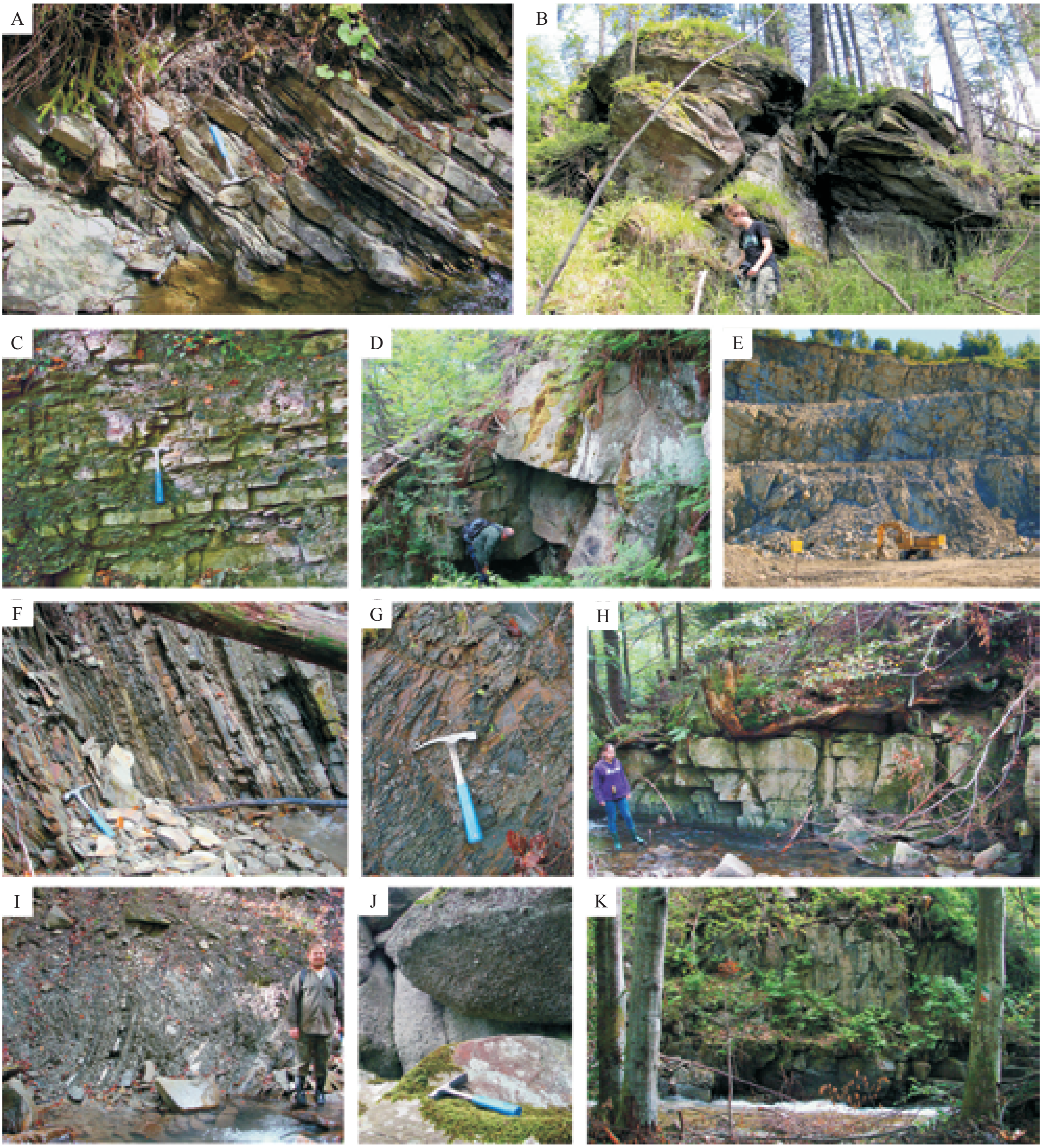

Fig. 6. Outcrops of deposits representing the Krynica Subunit: A – medium-bedded flysch of the Szczawnica Fm.; B – forming tors thick-bedded sandstones of the Szczawnica Fm.; C – thin-bedded flysch of the Zarzecze Fm.; D – thick-bedded sandstones of the Krynica Sandstone Mb. of the Zarzecze Fm. with cave entrance; E – thick-bedded sandstones of the Poprad Sandstone Mb. of the Magura Fm.; F – thin- and medium-bedded sandstone-shale flysch of the Kowaniec Mb. of the Magura Fm.; G – thick layer of shale of the of the Kowaniec Mb. of the Magura Fm.; H – thick-bedded sandstones of the Kowaniec Mb. of the Magura Fm.; I – thin- and medium shale – sandstone of the Beloveža-like flysch within Piwniczna Sandstone Mb.; J – coarse-grained sandstone and fine conglomerates of the Piwniczna Sandstone Mb.; K – forming rock wall thick-bedded sandstone of the Kowaniec Mb. of the Magura Fm. in Łopuszna stream valley; photo M. Szczęch • Odsłonięcia utworów reprezentujących podjednostkę krynicką: A – średnioławicowy flisz formacji szczawnickiej; B – skałka uformowana w gruboławicowych piaskowcach formacji szczawnickiej; C – cienkoławicowy flisz formacji z Zarzecza; D – gruboławicowe piaskowce ogniwa piaskowców krynickich formacji z Zarzecza z wejściem do jaskini; E – gruboławicowe piaskowce ogniwa piaskowców z Popradu formacji magurskiej; F – cienko- i średnioławicowy piaskowcowo-łupkowy flisz ogniwa z Kowańca formacji magurskiej; G – gruba ławica łupkowa w ogniwie z Kowańca formacji magurskiej; H – gruboławicowe ogniwo z Kowańca formacji magurskiej; I – cienko- i średnioławicowy flisz piaskowcowo-łupkowy typu beloweskiego w ogniwie piaskowców z Piwnicznej; J – gruboziarniste piaskowce i zlepieńce ogniwa piaskowców z Piwnicznej; K – ściana skalna zbudowana z piaskowców ogniwa z Kowańca formacji magurskiej w dolinie potoku Łopuszna; fot. M. Szczęch

The thick-bedded sandstones complex was considered by Sikora, and Żytko (1968) as an equivalent of the Szczawina Sandstone, whereas Oszczypko (1991) described similar deposits in Sądecki Beskid as sandstones and conglomerates from Życzanów. The deposits of this formation in the west part of Gorce Mts. occur in the range from Stare Wierchy and Obidowiec, through Mostownica to Ochotnica Górna.

The Zarzecze Formation (Fig. 6C) represents the early Eocene. There are deposits of thin-bedded, rhythmic flysch, which are reminiscent of the deposits of the Beloveža Formation (see below) from the Bystrica Subunit. In the Zarzecze Formation, the thick-bedded sandstones and conglomerates were divided as the Krynica Sandstone Member (Fig. 6D). In the petrographic composition, there is a big amount of quartz and lithoclasts of micaceous shists, phyllites, greenstones, gneisses and marbles, granitoids, granite-gneiss, quartzites, lydites, silicified mudstones, clayey shales, limestones and dolomites as well.

The Magura Formation in the western part of the Gorce Mts. is of upper Eocene-Oligocene age. It is dominated by thick-bedded sandstones, which represent the lithotype of the Magura Sandstone distinguished by Paul (1868) in Oravská Magura Mts. in Slovakia. The thickness of the sandstone layers is 0.5–2 m, and of the composed layers, amalgamated, is up to 8 m. The fresh sandstones are greyish-blue, calcareous, but the weathered ones are grey-yellow, medium- and coarse-grained, conglomeratic in places. In the petrographic composition of the Magura Sandstone lithotype, it is clear that quartz dominates, but there are also feldspars, muscovite, lithoclast of granitoids, gneisis, micaceous shists, volcanites, quartzites and carbonate rock, limestones and Triassic dolomites. The distinctive in macroscopic feature of the described sandstones is the presence of the red quartzites and volcanites, as well as pink quartz and feldspar.

In the Gorce Mts. in the Krynica Zone, the Magura Formation was divided into three members: the Piwniczna Sandstone Member (Fig. 6J), primarily described as Jaszcze or Turbacz Beds, a compound of thick- and very thick-bedded sandstones, and also fine conglomerates in some places with the thin Beloveža Beds-like flysch (Fig. 6I). Occurring higher, from the Middle-Eocene, the Kowaniec Member is a compound of thick-bedded sandstone (Fig. 6H, K), with thick-fissile shales or thin-bedded Hieroglyphic Beds-like flysch (Fig. 6F) and occasional Łącko Marl layers or thick packages of shales (Fig. 6G). The Poprad Sandstone Member is the youngest. It consists of almost entirely thick-bedded sandstones. The deposits of the Magura Formation build the massif of Turbacz and the southern slopes of the Gorce Mts. The profile of the formation is clearly observed in the deep indented valley of the Łopuszna stream, but the Poprad Sandstone Member is emphasized in the quarry in Klikuszowa (Cieszkowski et al., 1998; Fig. 6E). Because of the well – exposed outcrops of the Kowaniec Member in the valleys of Great Kowaniec and Small Kowaniec, the streams in the northern area of Nowy Targ town are called Kowaniec. Its *locus typicus* was located.

Bystrica Zone

The Jasień Formation (Fig. 7A) deposits of Albian-Cenomanian age starts the Bystrica Zone lithostratygraphic section**.** It was primarily distinguished in the Magura Nappe on the southern margin of the Mszana Dolna Tectonic Window, as the Lhoty Beds or the Hulina Formation. It is the oldest formation of the Magura series, known from the surface in the Polish sector of the Outer Carpathians. The deposits of the Jasień Formation outcropped in Koninki are developed as green spotted shales (the spots represent bioturbation) with occasional intercalations of silicified sandstones. There manganoferrous concretions with rhodochrosite occur, sometimes with well-preserved radiolarians inside (Burtan *et al.*, 1992b). In the deposits of the Jasień Formation, the traces of the copper mineralization were found (Burtan *et al.*, 1976, 1992b).

The Malinowa Shale Formation (Fig. 7B**)**, Turonian-Santonian in age, variegated shales are found, as well as cherry red, sometimes red and green noncalcareous with single thin-bedded greenish layers of fine-grained, often silicified mudstones. The shales are widespread along the northern slopes of the Gorce Mts., at least in two lines of the outcrops spread between Rabka and Olszówka on the west, and Zasadne, near Kamienica, on the east. In the higher parts of the Malinowa Shale Formation, there is the Wiatrówki Sandstone Member, Coniacian-Santonian in age (Cieszkowski *et al.*, 1998), which is represented by characteristic celadon-greenish colour. It is fractional graded, parallel laminated, and consists of quartz and fine clasts of greenish shales, occasionally feldspars and muscovite. These deposits were examined between the Zasadne and Lubomierz villages. The position of the stratotype is located on the left-bank tributary of the Kamienica stream, in Wiatrówki glade.

The Poręba Górna Formation (Santonian), described by Burtan (in: Burtan, Łydka, 1978; Burtan *et al.*, 1976, 1978, 1992a, c) as layers from Poręba Górna, is the olistostrome sequence. The submarine slump structures of the formation were described by Książkiewicz (1958) and Cieszkowski *et al.* (1987). In Poręba Górna, in the section of the Porębianka stream, in the higher parts of the submarine slump sequence, the degree of the flysch deposit disorder increases gradually in a way, that at the top they are completely disintegrated and disjunctive, creating isolated sandstone fragments. The deposits of the Poręba Górna Formation can be observed in the outcrops spread along the southern margin of the Mszana Dolna Tectonic Window and to the east of it, in Lubomierz and Szczawa.

The Białe Formation (Fig. 7C), of Santonian-Campian age, was described in the southern margin of the Mszana Dolna Tectonic Window as the Kanina Beds. The formation crops out from Kamienica on the east, to Olszówka on the west, and it is represented by grey medium- or thin-bedded, fine-grained, limy muscovitic sandstones and green or green-grey clayey shales and yellowish, soft marly shales as well. In the Białe Formation, there are intercalations of turbiditic limestones and hard marls (cf. Cieszkowski, Olszewska, 1986, 1989), which are the distinctive lithological features of the formation.


A
B
C
D
E
F
G
H
I
J
K
L

Fig. 7. Outcrops of deposits representing the Bystrica Subunit: A – green spotted shales with radiolarians – Jasień Fm. in Koninki; B – the Malinowa Shale Fm. developed mainly of red shales in Koninki; C – thin- and medium-bedded flysch of the Białe Fm. in Mszanka River valley in Lubomierz; D – thick-bedded sandstones of the Szczawina Fm. in Mszanka River valley in Lubomierz; E – the Ropianka Fm. croped out in the right bank of Kamienicki Creek in Rzeki; F – variegated shales of the Farony Mb. of the Ropianka Fm. in a gorge in Rabka (Zaryte); G – Głębieniec Mb. of the Ropianka Fm consists of marly mudstones – Głębieniec Stream in Szczawa; H – marly mudstones with Nereites trace fossil from Głębieniec Mb.; I – variegated shales of the Łabowa Shale Fm. in Zasadne Stream valley; J – Beloveža Fm. in Suchora Stream in Lubomierz; K – Bystrica Fm. consisting of the Łącko Marls lithotype in Suchora Stream in Lubomierz; L – Trusiówka Mb. of the Magura Fm. in the Kamienicki Creek Valley, A, B – photo R. Chodyń; C, E–H – photo M. Cieszkowski; D, I–L – photo M. Szczęch • Odsłonięcia utworów reprezentujących podjednostkę bystrzycką: A – zielone łupki plamiste z radiolariami – formacja z Jasienia w Koninkach; B – formacje łupków z Malinowej, reprezentowane głównie przez czerwone łupki, Koninki; C – cienko- i średniołаwicowy flisz formacji z Białego, dolina Mszanki – Lubomierz; D – gruboławicowe piaskowce formacji ze Szczawiny, dolina Mszanki – Lubomierz; E – odsłonięcie utworów formacji ropianieckiej w prawym brzegu Kamienickiego Potoku w Rzekach; F – łupki pstre ogniwa z Faronów formacji ropianieckiej w wąwozie w Rabce (Zarytem); G – ogniwo z Głębieńca formacji ropianieckiej zbudowanej z mułowców marglistych – potok Głębieniec w Szczawie; H – mułowce margliste z ichnoskamieniałością Nereites w ogniwie z Głębieńca; I – łupki pstre formacji łupków z Łabowej – potok Zasadne; J – formacja beloweska w dolinie potoku Suchora w Lubomierzu; K – formacja bystrzycka zbudowana z margli łąckich – potok Suchora – Lubomierz; L – ogniwo z Trusiówki formacji magurskiej – Kamienicki Potok; A, B – fot. R. Chodyń; C, E–H – fot. M. Cieszkowski; D, I–L – fot. M. Szczęch

In the shales, the occurrence of the very characteristic trace fossils, ichnogenus Nereites (Helminthoides), is observed. Their occurrence and the presence of ichnogenus *Helmithoides* converge the Białe Formation into some facies varieties of so-called Helminthoid Flysch, also called Zementmergelserie, from the Rheno-Danubian Flysch of the Eastern Alps (cf. i.a. Cieszkowski et al., 1999a). The stratotype section of the described formation is located in Białe – a hamlet of Szczawa village.

The Szczawina Sandstone Formation (Fig. 7D), Senonian-Maastrichtian in age, occurred in the south-east margin of Mszana Dolna Tectonic Window is spread to the east through Lubomierz and Szczawa to Zasadne and Kamienica. In this formation, there are thick-bedded sandstones often amalgamated, medium- and fine-grained, rarely coarse-grained and conglomeratic, sometimes with conglomerate intercalations. The sandstones are usually massive, and the uppermost parts of the layers bear parallel and cross lamination. In the thinner layers, clear sorting and gradation of the grains can be observed. In their composition, quartz dominates, less feldspars, muscovite, biotite and lithoclasts, in which the grains of metamorphic, siliceous and carbonate rocks can be noticed.

In Gryblówka – ahamlet of Szczawa – at the base of the formation specimens of ammonites, a species of *Saghalinites wrighti* Birkelund have been found (Haczewski, Szymakowska 1984), which date the sandstones age as Maastrichtian. Some crumbled shells of the Late Cretaceous mussels of the *Inoceramus* species, were found in places. The thick-bedded sandstones of the formation in the northern part of the Gorce Mts. and the adjacent part of Beskid Wyspowy play a ridge-forming role. Moreover, they build the rock steps and waterfalls on the rivers i.a. Mszanka, Kamienica, Koninki and Głębieniec.

The Ropianka Formation (Fig. 7E), Maastrichtian-Paleocene age, was described as Inoceramian Beds. It is represented by the medium- and thin-bedded sandstone-shale flysch. The sandstones are steel grey, grey-brown, after weathering, fine-grained, muscovitic, fractional, with parallel, cross and convolute lamination. In their composition the dominant ingredients are quartz and muscovite. There is also the plant detritus. On the basal surfaces of the layers, there are fine organic hieroglyphs. The sandstones are interlayered with thin-bedded clayey, grey and green shales with numerous ichnofossils. The most frequent are *Planolites* and *Chondrites*; less frequent *Nereites* (*Helminthoides*) and *Phycosipho*, rarely *Spiroraphe*. In the lower part of the Ropianka Formation, several meters thick, the Farony Shale Member (Fig. 7F) build of variegated shales can be observed (Uchman, Cieszkowski, 2008a, b). Its type section is located in Farony, a hamlet of Szczawa village. It is noticed that between Rabka and Kamienica, the shales have a local correlational factor. Nowadays, this takes shape of the picturesque gorge in Rabka Zaryte. In the higher parts of the Ropianka Formation, the amount of marly shales significantly increases. They are divided here as the Głębieniec Member (Uchman, Cieszkowski, 2008b; Fig. 7G), which *locus typicus* is located in Szczawa, in a valley of the Głębieniec Stream. In the marls and marly shales, there are a lot of trace fossils, ichnogenus *Planolites*, *Chondrites*, *Phycosiphon* and prevalent *Nereites* (*Helminthoides*) (Fig. 7H). The flysch sequence of the Głębieniec Mb. is similar to some facies varieties of Helminthoid Flysch from the Eastern Alps in its development.

The Łabowa Shale Formation (Fig. 7I), the Early Eocene, mainly consists of variegated, cherry-red claystones or mudstones, with occasional intercalations of green shales. In the shales, there are intercalations of green thin-bedded fine-grain sandstones. In some sections, there more thin-bedded shales and sandstones of Beloveža type occur so that the Łabowa Shale Formation passes gradually into the overlaid Beloveža Formation. In the Łabowa Shale Formation, there can be noticed in the Gorce Mts. the occurrence of bentonized tuffites and manganoferrous concretions, with birnesite (Cieszkowski, Wieser, 1979).

The Beloveža Formation (Fig. 7J) in the Gorce Mts. represents the Early Eocene. Primarily, they were called the Hieroglyphic or the Beloveža Beds. It consists of gray blue, fine-grained, fine-bedded, calcareous sandstones intercalated with gray, bluish and green shales. On the basal surfaces of the sandstones varied and distinctive trace fossils occur. Ichnofossils can be noted in the shales, as well. The characteristic feature of this formation is the diversity and great amount of ichnofossils.

The Bystrica Formation (Fig. 7K) of Middle Eocene age, also called the Łącko Beds, is one of the most distinctive deposit of the Bystrica Subunit. It is mainly composed of thick-bedded turbidites, at lower parts build of sandstones; in higher, of massive, marly mudstones and marls called the Łącko Marls. The sandstones in the lower part of the section of formation are glauconitic, similar to the Osielec Sandstones *sensu* Książkiewicz (1966), while the mudstones are dark grey, sometimes with dark cherts at the top of layers. In the higher part, the sandstones resemble the Magura Sandstones, and the marly mudstones and marls are grey. The thickness of the sandstones rarely goes beyond 1 m, but the marls are 1–5 m thick or even occasionally can reach up to 10 m (Oszczypko, 1991; Chodyń, Szczęch, 2014). In the higher part of the Bystrica Formation, on the west part of the Gorce Mts. some olistostrome deposits occur (Cieszkowski et al., 2009). The Bystrica Formation deposits gradually pass into thick-bedded sandstones of the Magura Formation.

The Magura Formation, Middle Eocene-Oligocene in age, begins from the Middle Eocene thick-bedded and medium- or coarse-grained sandstones, with a lithotype of the Magura Sandstones *sensu* Paul (1868), which belong to the Maszkowice Sandstone Member. Above, there is the Mniszek Shale Member, which is called in old literature as the Jazowsko Shale Member and what is more, it is represented by the thin-bedded flysch of Beloveža type, with level variegated shales. In the section, the youngest complex has 800-1000 m from the Late Eocene, and it comprises thick-bedded Magura sandstones equivalent to the Poprad Sandstones Member of the Krynica Subunit. In addition, it is similarly developed in terms of lithology. Between the thin-bedded flysch of the Mniszek Mb and thick-bedded sandstones of the Magura Fm, a passage sequence was noticed, which is called the Trusiówka Mb. (Fig. 7L). There, within thick-bedded sandstones, intercalation thin- and medium-bedded flysch and occasional tick layers of the Łącko Marls or dark grey shales occur.

Tectonics

The Magura Nappe is the greatest tectonic unit in the Polish Outer-Carpathians (Książkiewicz, 1972; Oszczypko, 1992; Oszczypko, Oszczypko-Clowes, 2006). Some mountain ranges are built of Magura Nappe deposits, that is: the highest range of the Beskidy Mts., which is Beskid Żywiecki, Beskid Makowski, Gorce, Beskid Wyspowy, Beskid Sądecki and Beskid Niski, as well. The Magura Nappe borders tectonically with the Pieniny Klippen Belt in the south. In the north, it is thrust over the Dukla Nappe and the units of the so-called Fore-Magura Zone (Oszczypko, 1992). Based on facies diversity of the Paleogene deposits and tectonic features, there were distinguished four subunits within the Magura Nappe (i.a. Koszarski et al., 1974). Usually, they contact each other along the overthrusts or the inverse faults of high amplitude.

In the Gorce Mts., there are two most southern subunits of the Magura Nappe: the Krynica and Bystrica Subunits (Fig. 4). The Krynica Subunit contacts directly with Pieniny Klippen Belt from the south, while in the north, it is overthrust on the Bystrica Subunit. The overthrust of the Krynica Subunits goes alongside the northern slopes of Obidowiec, Turbacz, Mostowinica, Kudłoń and towards Gorc. The flysch deposits of the Magura Nappe in both described subunits are folded to a series of synclines and anticlines. Some individual feature of the fold tectonic style occurs in Cretaceous and Paleocene deposits (Oszczypko et al., 1991; Cieszkowski et al., 1992). The fragment of the Krynica Subunit, building the northern part of the Gorce Mts. was distinguished by Watycha (1963) and called the Turbacz Skiba (skiba in Polish geological nomenclature is a large thrust sheet with inner complex structure). In both subunits, inner smaller thrust-sheets can be observed (Burtan et al., 1976, 1978, 1992b; Oszczypko et al., 1999). Moreover, they are cut by vertical and diagonal faults of varied extension and amplitude. In the southern part of the Gorce Mts., in the Krynica Subunit, the layers are back-turned to south. This refers to the flower-structure formed near the collision zone of the Inner Carpathians and the Outer Carpathians. At the northern margin of the Gorce Mts., units of the Fore-Magura Zone occur in the Maszana Dolna and Szczawa Tectonic Windows (Fig. 4). In the Maszana Dolna Tectonic Window, crops out the Dukla Nappe (the Mszana Dolna unit) and Grybów Nappe deposits (Książkiewicz, 1972; Burtan et al., 1976, 1978, 1992d; Mastella 1988). In the Szczawa Tectonic Window, the deposits of the Grybów Unit occur (Oszczypko-Clowes, Oszczypko, 2004; Uchman, Cieszkowski, 2008a). In the Miocene, the deposits filling the Magura Basin were folded, uprooted, removed from their primary base and overthrust northward on the outer units (Oszczypko, 1992; Oszczypko, Oszczypko-Clowes, 2006). What is more, the Gorce Mts. are still neo-tectonically active and constantly uplifted. This was documented in Zuchniewicz's research (1995, 2010). The deep structure of the Magura Nappe was investigated in deep boreholes of Obidowa IG-1 (4501 m deep) and Chabówka 1 (5001 m), located in the western parts of Gorce Mts. (Cieszkowski, Sikora, 1975; Cieszkowski 2006c).

Mineral and thermal water

The most precious inanimate natural resources in the Gorce Mts. are the mineral water springs. Rabka and Szczawa are the places which are well known for the occurrence of mineral water. In Rabka-Zdrój, salty chloridium-sodium mineral water can be found and also iodine water (Rajchel, 2009). They are used for medical purposes in local health resorts. In the health park resort, there is a graduation tower, which has been working for several years. What is more, in Szczawa (Fig. 8E) there can be found acidulous water which is carbonated-chloridium-sodium-calcium (Chrząstowski, 1971). Some springs of sulphurous water were investigated in Szczawa and on the southern slopes of the Gorce Mts. in Nowy Targ and in Waksmund. The sulphurous water springs are related with hydrogen sulphide exhalations. Thermal water was also found in wells on the Gorce Mts. area (Chowaniec *et al.*, 2001). Thermal water from the Poręba Wielka borehole reaches 42°C on the surface outflow. In Rabka-Zdrój, in the Rabka IG-2 borehole the water is 28°C on the surface outflow (Rajchel, 2009).

Geomorphological forms

The development of the Gorce Mts. relief began during the uplifting of the Carpathians in the Miocene, but the main shape emerged in the Pliocene (Paul, Ryłko, 1987; Cieszkowski et al., 2015a). Two facts, that is: the absence of the slopes below solifluction deposits mantled and the occurrence of structural landslide suggest that the discussed terrain is young (Starkel, 1972). One of the most characteristic features in the Gorce Mts. is the para-radial arraignment mountain ranges with dome rounded shaped mountain peaks with highs of 1100–1300 m a.s.l. (Starkel, 1972). This system is also reflected in a radial arrangement network of watercourses, with a springs of streams at the center of the massif and flowing to massif borders and inflowing to major rivers: from the south and east, to the Dunajec River, from the west and north-west, to Raba and Mszanka Rivers and from north-east, to Kamienica River. The ridges are wide and wavy undulated. Undulations have developed as a result of deep valley heads situated on both ridges sides (Baumgart-Kotarba, 1974). One of most spectacular is the Borek Pass (1009 m a.s.l.) between Mt. Mostownica (1251 m a.s.l.) and Mt. Kudłoń (1276 m a.s.l.), (cf. Barmuta, 2011). It is interesting that the difference in height between the bottom of nearby flowing Kamienicki Creek and the passes is only several meters (Fig. 8J). In the morphology of the Gorce Mts., the asymmetry of slopes can be noticed. Northern slopes are steeper than the southern ones. Baumgart-Kotarba (1974) points that the difference lies in the varied heights of the erosive base at the both sides of the Gorce Mts. The watercourse valleys are deep-indented, with a clearly observed V-shaped section. It is common, in the Flysch Carpathians area, to observe geomorphological inversions. However, in the Gorce Mts. on some distances, watercourse orientations are related to the extension of fold axes. The Gorce Mts. stream valleys in the upper parts have unleveled longitudinal sections and present significant declines. Within the segments, with occurrence of thick-bedded sandstones are waterfalls (Fig. 8A, B, C, D, H, I), rocky steps and plunge pools (Fig. 8A, B). These are clearly visible in the spring sections which drain the Gorce Mts. slopes in the range from Lepietnica Stream, through the upper parts of Łopuszna (Fig. 8B) up to the Ochotnica Streams. There, on the outcrop thick-bedded sandstones, picturesque waterfalls occur and form the rapids, reaching up to 9 meters. One of the most wonderful and highest waterfalls is thein the Urwisków Stream, whose springs are located on the eastern slopes of the Mt. Gorc Troszacki (Fig. 8H). Big waterfalls can be found in Szczawa, on the Kamienica River. These are waterfall named Spad (Fig. 8D), in hamlet Bukówka (nature monument) and the waterfall in the center of the Szczawa village (Fig. 8A). What is more, the waterfall in Nowy Targ – Kowaniec is close to Długa Polana. The landslides are the common character features in the Gorce Mountains. In this area, there are rocky, rocky-waste and waste landslides. Waste landslides form in the shales deposits and thin-bedded sandstone-shale flysch. However, the two mentioned landslides occur in the higher parts of the slopes, which consist of thick-bedded, strongly fractured sandstone underlaid by thin- and medium-bedded sandstone-shaly flysch or shales. One of the most interesting features of its kind, is the rocky landslide located on the western slope of Mt. Kiczora (1282 m a.s.l.; Fig. 9B), where the thick-bedded Piwniczna Sandstone Memeber is underlaid with sandstone-shaly flysch. In the landslide niches, peat bogs (Fig. 8F), marshes and small ponds are found (Fig. 8G), as a result of the breaks in the groundwater level. Landslide genesis has created the biggest and the most famous lake called Pucółowski Stawek in the Gorce Mts., and it is located on the southern slopes of Mt. Wysznia in Łopuszna village. Recently some "ponds" have been formed as the result of the activity of beavers, which build dams on streams (Fig. 8C). Some of the most interesting relief forms in the Gorce National Park and its surroundings are the outcrops, which create often picturesque tors (Fig. 9A-H) and other rocky forms of varied shapes and sizes. Alexandrowicz (1978, 1982) researched some of these structures in her work concerning the Polish Outer Carpathians. They are also found in Nyka's (1974) and Baumgart-Kotarba's (1974) work. The author's research based on detailed analysis and high resolution digital elevation models showed that there are much more rocky formations in the GPN than has been described. The genesis of the rocks is connected with the denudation, landslide and fluvial processes. Most of the rocks are located in the upper part of the ridge slopes. Mostly, the rocks of denudation origin belong to this group. The rocky forms occur also in the lower parts of the slopes. Their origin is connected with mass movements. Fluvial processes have a great influence on the rocks forming in the beds of the rivers and streams or in the channel zone. The rocks in the Bystrica Subunit and in the Krynica Subunit constitute thick-bedded sandstones of Magura Formation, Szczawina Formation (Bystrica Subunit) and Szczawnica Formation (Krynica Subunit). They occur individually or in groups. The rocky forms in the Gorce Mts. are varied in shapes. Generally, they form rock towers and cliffs (Fig. 2, 9C, D). It is also possible to notice rock walls (Fig. 6K). During the fieldwork, it was observed that two objects in rock spire shapes were located on Kudłoń slopes (Fig. 10, 9G). The biggest amount of rock forms is investigated in the Kudłoń northern slopes in GPN. They are built of deposits of Magura Formation, mainly Piwniczna Sandstone Member, of Krynica Subunit. They are located on the slope curve zone, where the inclinations increase up to 30–45 degrees. In this place, there are the most magnificent Gorce Mts. rock objects: Białe Skały rock group (Fig. 9A, D, G) beneath the Mt. Gorc Troszacki, and the most popular rock, which is the spire called Kudłoński Baca (Fig. 10). Bigger groups of rock forms are located in the Obidowiec massif, and they are built of the Szczawnica Formation (Fig. 6B). Moreover, they occur in the catchment of the Łopuszna Stream, in which the outcrops are made of the Magura Formation. In this picturesque valley, numerous varied rock forms can be observed (Fig. 6K, 9C). There are also interesting outcrops on the southern slopes of the Gorce Mts., in the surroundings of Ochotnica village. Single objects can be noticed in the area of Mt. Gorc and Mt. Mostownica, on the northern slopes of Mt. Jaworzyna Kamienicka, and on the southern slopes of the Mt. Kudłoń, where the majority is of landslide origin.

Fig. 8. Geomorphological features of: A – waterfall and plunge pool on Kamienica River formed of the Oligocene sandstones of the Grybów Unit in Szczawa Tectonic Window – center of Szczawa village; B – waterfall and plunge pool on Łopuszna Stream formed of the sandstones of the Magura Fm.; C – beaver lodges on the Kamienicki Creek close of the Borek Pass; D – waterfall named Spad (nature monument) formed on thick-bedded sandstones of the Szczawina Fm. on Kamienica river in Bukówka, hamlet of Szczawa; E – mineral water spring in Szczawa; F – marsh in a niche of the landslide on the eastern slope of Kudłoń Mt.; G – lake formed in a niche of the landslide in Białe, hamlet of Szczawa; H – a part of the highest Gorce Mts. waterfall formed on thick-bedded sandstones of the Magura Fm. on Urwisków Stream, tributary of Kamienica River; I – picturesque waterfall in Łopuszna Stream valley, formed on thick-bedded sandstones of the Magura Fm.; J – Borek Pass (1009 m a.s.l.) between Mostownica Mt. (1251 m a.s.l.) and Kudłoń Mt. (1276 m a.s.l.). It is interesting, that the difference in height between the bottom of nearby flowing Kamienicki Creek and the passes are only several meters; D, F – photo M. Cieszkowski; A-C, E, G-J – photo M. Szczęch • Formy geomorfologiczne: A – wodospad i kocioł eworsyjny w dolinie potoku Kamienica zbudowany z oligoceńskich piaskowców jednostki grybowskiej w oknie tektonicznym szczawy – centrum wsi Szczawa; B – wodospad i kocioł eworsyjny w dolinie potoku Łopuszna zbudowany z piaskowców formacji magurskiej; C – bobrza tama na Kamienickim Potoku w pobliżu przełęczy Borek; D – wodospad Spad uformowany na gruboławicowych piaskowcach formacji ze Szczawiny na Kamienicy w Bukówce – przysiółek Szczawy; E – źródło mineralne w Szczawie; F – zatorfienie w niszy osuwiskowej na wschodnich stokach Kudłonia; G – jezioro uformowane w niszy osuwiskowej w Białem – przysiółek Szczawy; H – część najwyższego gorczańskiego wodospadu uformowanego w gruboławicowych piaskowcach formacji magurskiej w potoku Urwisków, dopływie Kamienicy; I – malowniczy wodospad w dolinie potoku Łopuszna, założonego na gruboławicowych piaskowcach formacji magurskiej; J – Przełęcz Borek (1009 m n.p.m.) pomiędzy Mostownicą (1251 m n.p.m.) a Kudłoniem (1276 m n.p.m.) (jest to ciekawe miejsce, ponieważ różnica pomiędzy dnem doliny Kamienickiego Potoku a przełęczą wynosi zaledwie kilka metrów); D, F – fot. M. Cieszkowski; A–C, E, G–J – fot. M. Szczęch

Fig. 9. The Gorce rock tors and caves: A – cliffs rock – Białe Skały rock group, B – "Turnice" – large block of sandstones in the main scarp of the landslide, C – tower rock tor in Łopuszna stream valley, D – cliffs rock – Białe Skały rock group, E – rocky wall on the northern slop of the Kudłoń Mt., F – rocks of landslide genesis with cave on the lower part of the southern slope of the Kudłoń Mt., G – needle rock tor – Białe Skały rock group, H – rocks of landslide genesis on the lower part of the southern slope of the Kudłoń Mt., I – tower rock tor on the northern slope of Kudłoń, photo M. Szczęch • Gorczańskie skałki i jaskinie: A – baszta skalna – Białe Skały; B – Turnice – duże piaskowcowe blokowisko znajdujące się w skarpie głównej osuwiska; C – baszta skalna w dolinie potoku Łopuszna; D – baszta skalna – Białe Skały; E – ściana skalna na północnych stokach Kudłonia; F – skałki o genezie osuwiskowej z jaskinią w dolnej części południowych stoków Kudłonia; G – iglica skalne – Białe Skały; H – skałki o genezie osuwiskowej w dolnej części południowych stoków Kudłonia; I – baszta skalna na północnych stokach Kudłonia, fot. M. Szczęch

What is even more noteworthy, is the group of rocks with a splendid rock tower 12 meters long and 6 meters high (Fig. 9H), which is located below the blue touristic route from Trusiówka meadow to Borek Pass, to the west from the Stawieniec Stream. They belong to the groups that are, according to Alexandrowicz (1970, 1978), detached from the basement and developed in the processes of shifting the rock masses, as a result of landslide processes. Also worthy of note is the Skalny Gronik (Fig. 6D). It is a group of landslide origin creating the amphitheatre form in the main scarp, closed by a "rock wall". Below, there are huge rock blocks and a group of rocks called Trunice (Fig. 9B), located in the main scarp of the mentioned landslide on the Kiczora Mt. western slopes. Beside the rock forms, ruble and running hills in landslides, talus caves can be observed (Fig. 6D, 9F, H). In the Gorce National Park there are about 50 caves of this type. They are small and closed for tourists. The biggest cave in Gorce is Zbójnicka Jama. It is 50 meters long and about 10 meters deep (Szczęch, Czarnota, 2015), and located in the area of the peak of Jaworzyna Kamienicka (Margielewski, Urban, 2000, 2002). The caves are precious objects and are protected by the Natura 2000 program. In the caves, there is the occurrence of many bat species, but they do not hibernate there because of the bad conditions in winter (Szczęch, Czarnota, 2015).

Fig. 10. The most famous tor in the Gorces, needle Kudłoński Baca, built of Magura Sandstones (north slopes of Kudłoń Mt.), photo M. Szczęch • Najbardziej znana skałka gorczańska, iglica skalna Kudłoński Baca, zbudowana z piaskowców magurskich (północne stoki Kudłonia), fot. M. Szczęch

Summary

The big amount and good condition of the outcrops exposures of rocky basement and their great size make the Gorces an extremely precious massif in a scientific way, which has been demonstrated in numerous research in this area confirmed by many publications. Some parts of these sites are unique in the Carpathians. For instance, the outcrops of the upper Cretaceous period in the Jasień Formation, which are exposed in only one place in Beskid Wyspowy in the Półrzeczki hamlet (Burtan et al. 1976, 1978, Bąk, Oszczypko 2000). Because of their good condition and the representative feature, some of the outcrops were qualified as stratotype places for lithostratygraphic divisions: in Szczawa, the Białe Formation, the Głębieniec and Farony Member in the Ropianka Formation, in Lubomierz, the Wiatrówki Sandstone Member, the Malinowa Formation and the Trusiówka Member (Rzeki), in the Magura Formation. It is also an ideal region to study the geological structure of the Magura Nappe and the processes of forming the middle-height mountains morphology. It is valuable for science, academic studies and in schools. The geological variety is reflected in the interesting morphology, which is rich in many valuable and magnificent regional forms: deep cut to rock basement valleys, which form in some place small canyons, a lot of landslides, ponds, peat bogs and marshes, charming and picturesque rock formations and waterfalls, stream rocky bed and plunge pools. In addition, some of the objects, for instance, rock exposures, rock walls, spire rock, rock towers, cliffs, or the caves are the habitats for unique plant groups, and they are a shelter for many animal species (Szczęch, Czarnota, 2015). The bats and cave spiders take shelter in the Gorce Mts. caves. The rock tors and some caves are used as shelter by lynxes (Fig. 11A). In addition to some mentioned interesting mineralogical facts in the Gorce Mts. in the Magura Nappe deposits, there are also traces of gold, (Cieszkowski et al., 1999b), and in Fore Magura Zone deposits, Marmarosh "diamonds" occur – quartz crystals refracting beautifully light (Cieszkowski, 2006b; Cieszkowski et al., 2015a). Connecting the rich morphology with the geological structure allows one to develop a branch of tourism, namely geotourism (Cieszkowski, 2005; Cieszkowski, 2006b; Barmuta, 2011; Cieszkowski et al., 2015b). Many features such as the geological and natural richness full of marvelous views (Fig. 12; e.g. a beautiful Tatra Mts. panorama from the southern slopes of Gorce Mts.; Fig. 1), also the massif morphology and the accessible valued geosites, provide the opportunity to study the geology (Unrug, 1969; Ślączka, Kamiński, 1998) and the processes which have formed the current picturesque terrain of the Gorce Mts. The Gorce Mts. and their surroundings are also a huge cultural wealth associated with folklore of the Podhale and Zagórzanie highlanders. The folklore manifests itself in the highlanders' originally ornamented costumes (Fig. 13), folk music and wooden constructions. Traveling around the Gorce Mts. Villages, we can find wooden houses built of spruce or fir logs, occasionally with rich decorations, of which many elements, shapes and forms derive from the surrounding nature's patterns.

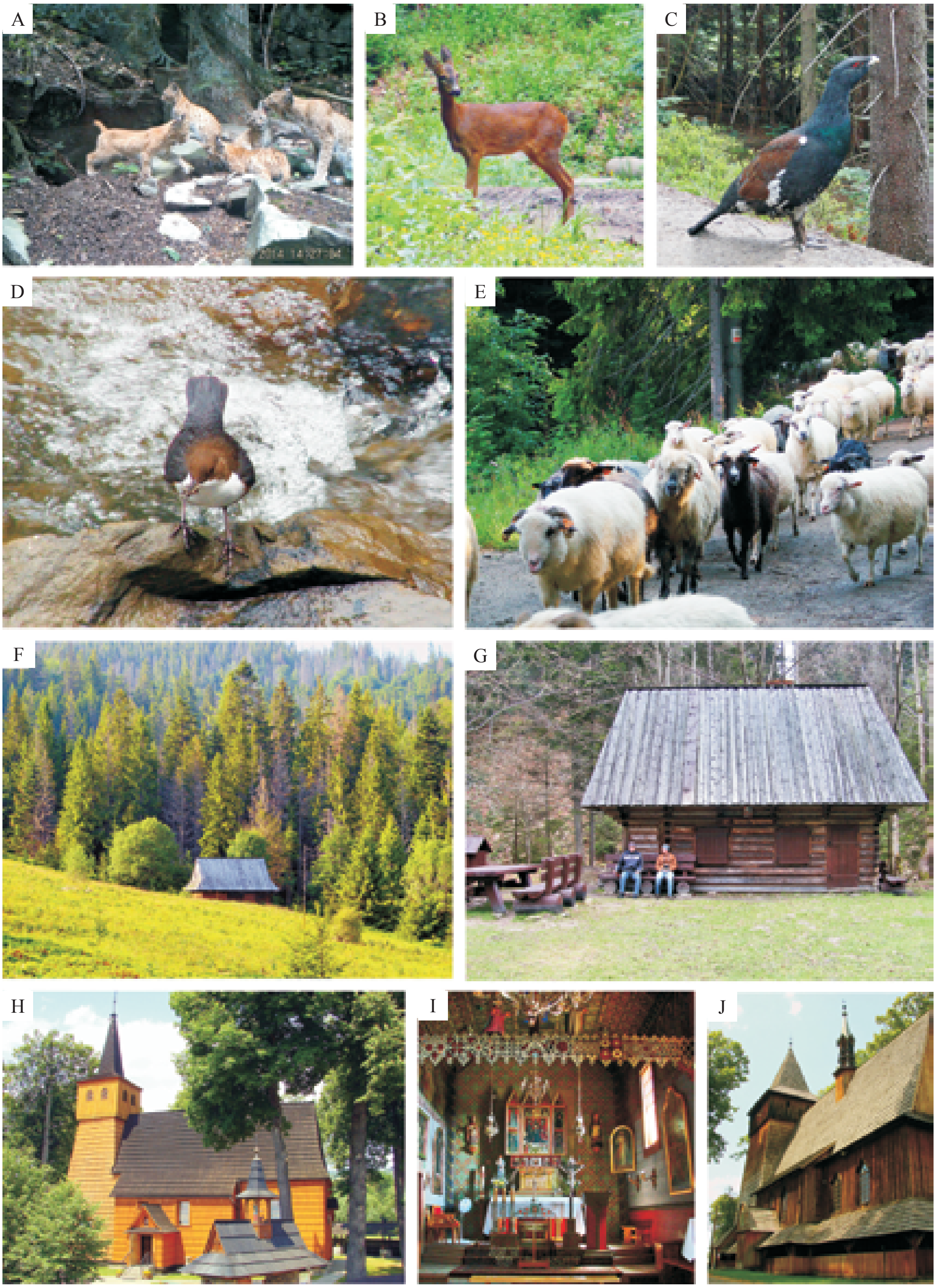

Fig. 11. Lively nature and wooden monuments in the Gorce Mts.: A – very rare case of a lynx family – mother with four kittens in 2014 in a cave formed in sandstones of the Piwniczna Mb. in Białe Skały rock group; B – roe on the mountain path; C – capercaille; D – dipper dive in the water stream; E – cultural sheep grazing; F – shepherds' shelter on the meadow; G – "Papieżówka" (the Pope's hut) in Kamienicki Creek valley – here cardinal Karol Wojtyła, later Pope John Paul II, spent several days in the summer of 1976; H – XV century wooden church in Łopuszna; I – presbytery of the church in Łopuszna; J – XV century wooden church in Harklowa, A – phot. J. Loch; B, G – photo M. Cieszkowski; C–F, H–J – photo M. Szczęch • Gorczańska przyroda oraz drewniana architektura: A – rodzina rysi – matka z czterema młodymi, które w 2014 roku miały legowisko w jaskini uformowanej w piaskowcach ogniwa z Piwnicznej w grupie Białych Skał; B – sarna na górskiej drodze; C – głuszec; D – pluszcz; E – kulturowy wypas owiec; F – szałas pasterski na polanie Stawieniec; G – "Papieżówka" w dolinie Kamienickiego Potoku, 1976 r. (Karol Wojtyła spędził tutaj kilka dni); H – XV-wieczny drewniany kościół w Łopusznej; I – prezbiterium i ołtarz główny w kościele w Łopusznej; J – XV-wieczny kościół w Harklowej, A – fot. J. Loch; B, G – fot. M. Cieszkowski; C–F, H–J – fot. M. Szczęch

The most valuable objects are wooden Gothic churches from the XV-XVI century in Łopuszna (Fig. 11 H, I), Harklowa (Fig. 11 J), Grywałd and Nowy Targ. On the mountain meadows in the Gorce National Park, one can find shepherds' shelters (Fig. 11 F, G). Today, within the GPN cultural sheep grazing is organised, in order to preserve the tradition and valuable habitats of nature (Fig. 11 E). It is a great chance to explore for the unqualified tourists resting in the area and also for the qualified geotourists searching for some unique elements of the inanimate and animate nature (Fig. 11A-D). The important factor in the studies and analysis of the scientific and educational features of Gorce Mts. is the Gorce National Park, which protects the valuable geosites. In fact, according to Cieszkowski (2006b), considering the protection of the geosites, the park borders are rather randomly located. The most valuable geosites outside the Park should be legally protected. Considering the specificity of the sites, in most cases, this should be active protection to take care of the scientific, esthetic and habitat features.

This study was financially supported by UJ ING grants no. K/ZDS/001463 and DS/MND/WBiNoZ/ING/12/2015.

Fig. 12. Autumn landscape on a creek valley, with a rock wall built of thick-bedded sandstones of the Piwniczna Sandstone Mb.; right bank of Łopuszna Stream tributary, photo M. Szczęch • Jesienny pejzaż doliny górskiego potoku ze ścianą skalną zbudowaną z gruboławicowych piaskowców ogniwa z Piwnicznej w brzegu jednego z dopływów potoku Łopuszna, fot. M. Szczęch

Fig. 13. Wooden house in Szczawa village with traditional Zagórzanie highlanders ornaments, photo M. Szczęch • Tradycyjny drewniany dom zagórzański z lokalnymi ornamentami, znajdujący się w Szczawie, fot. M. Szczęch

References (Literatura)

Alexandrowicz Z., 1970. Skałki piaskowcowe w okolicy Ciężkowic nad Białą. *Ochrona Przyrody*, 35: 281–335.

Alexandrowicz Z., 1978. Skałki piaskowcowe zachodnich Karpat fliszowych. *Prace Geologiczne PAN*, 113: 7−87.

Alexandrowicz Z., 1982. Skałki piaskowcowe Gorczańskiego Parku Narodowego i jego otoczenia. *Ochrona Przyrody*, 44: 293−316.

Balon J., German K., Kozak J., Malara H., Widacki W., Ziaja W., 1995. Regiony fizycznogeograficzne. In: Warszyńska J. (ed.), *Karpaty Polskie: przyroda, człowiek i jego działalność*. Kraków, 117−130.

Barmuta M., 2011. Geoturism during excursion to the northeasern part of the Gorce National Park. *Geoturism/Geoturystyka*, 26–27: 51−64.

Baumgart-Kotarba M., 1974. Rozwój grzbietów górskich w Karpatach fliszowych. *Prace Geograficzne Instytutu Geografii PAN,* 106: 1−133.

Bąk K., Oszczypko N., 2000. Late Albian and Cenomanian redeposited foraminifera from Late Cretaceous-Paleocene deposits of the Rača Subunit (Magura Nappe, Polish Western Carpathians) and their paleogeographical significance. *Geologica Carpathica,* 51: 371−382.

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

Burtan J., Łydka K., 1978. On metamorphic tectonites of the Magura nappe in the Polish Flysch Carpathians. *Bulletin de L'Academie Polonaise des Sciences Série des Sciences de la Terre*, 26: 95−101.

Burtan J., Paul Z., Watycha L., 1976. Szczegółowa Mapa Geologiczna Polski 1 : 50000. Arkusz Mszana Górna (1033). Wydawnictwa Geologiczne, Warszawa.

Burtan J., Paul Z., Watycha L., 1978. Objaśnienia do Szczegółowej Mapy Geologicznej Polski 1 : 5000, Arkusz Mszana Górna (1033). Wydawnictwa Geologiczne, Warszawa: 1–68.

Burtan J., Cieszkowski M., Paul Z., 1992a. Płaszczowina magurska na obrzeżeniu okna tektonicznego Mszany Dolnej. In: Zuchiewicz W., Oszczypko N. (eds), *Przewodnik LXIII Zjazdu Polskiego Towarzystwa Geologicznego, Koninki*, 17–19 września 1992. ING PAN, Kraków: 65−68.

Burtan J., Cieszkowski M., Paul Z., Wieser T., 1992b. A.2.1. Koninki. Stratygrafia utworów kredy płaszczowiny magurskiej na południowym obrzeżeniu okna tektonicznego Mszany Dolnej. Przejawy mineralizacji miedziowej. In: Zuchiewicz W., Oszczypko N. (eds), *Przewodnik LXIII Zjazdu Polskiego Towarzystwa Geologicznego*, Koninki, 17–19 września 1992. ING PAN, Kraków: 68−74.

Burtan J., Cieszkowski M., Paul Z., 1992c. Litologia, stratygrafia i deformacje synsedymentacyjne warstw z Poręby Wielkiej. In: Zuchiewicz W., Oszczypko N. (eds), *Przewodnik LXIII Zjazdu Polskiego Towarzystwa Geologicznego*, Koninki, 17–19 września 1992. ING PAN, Kraków: 74−76.

Burtan J., Cieszkowski M., Mastella L., Paul Z. 1992d. A.2.3. Niedźwiedź – Konina. Okno tektoniczne Mszany Dolnej. In: Zuchiewicz W., Oszczypko N. (eds), *Przewodnik LXIII Zjazdu Polskiego Towarzystwa Geologicznego*, Koninki, 17–19 września 1992. ING PAN Kraków: 76−88.

Chodyń R., Szczęch M., 2014. Plan ochrony Gorczańskiego Parku Narodowego i plan zadań ochronnych dla obszaru Natura 2000 PLH 120018 Ostoja Gorczańska. Operat ochrony zasobów i walorów przyrody nieożywionej i gleb (dokończenie) – manuskrypt. Gorczański Park Narodowy. Poręba Wielka 2013/2014.

Chowaniec J., Poprawa D., Witek K., 2001. Występowanie wód termalnych w polskiej części Karpat. *Przegląd Geologiczny*, 49: 728−742.

Chrząstowski J., 1971. Wody mineralne Szczawy na tle budowy geologicznej. *Problemy Zagospodarowania Ziem Górskich*, 9: 99−136.

Cieszkowski M., 2003. The Outer Carpathians Thrustbelt. Part 3. In: Golonka J., Lewandowski M. (eds), *Geology, Geophysics, Geothermics and Deep Structure of the West Carpathians and their Basement. International Workshop, Zakopane, Poland, August 31–September 5*. Publications of the Institute of Geophysics, Polish Academy of Sciences. Monographic volume M-28 (363), Warszawa, 107−110.

Cieszkowski M., 2004. Budowa geologiczna Gorców. In: Luboński P. (ed.), Gorce. *Przewodnik dla prawdziwego turysty*. Oficyna Wydawnicza Rewasz, Pruszków: 141−147.

Cieszkowski M., 2005. Geotouristic atractions of the Gorce Mts., Outer Carpathians. Poland. In: Doktor M., Waśkowska A. (eds), *„Geoturism – new dimensions in XXI Century tourism and chances for future developemenrt", 2nd International Conference GEOTUR 2005, 22–24 September 2005, Kraków, Poland*: 19−20.

Cieszkowski M., 2006a. Budowa geologiczna i rzeźba terenu. In: Różański W. (ed.), Gorczański Park Narodowy – 25 lat ochrony dziedzictwa przyrodniczego i kulturowego Gorców. Gorczański Park Narodowy, Poręba Wielka: 38−49.

Cieszkowski M., 2006b. Geologiczne walory naukowe Gorczańskiego Parku Narodowego i jego otoczenia. (English summary: Scientific geological atractions of the Gorce National Park and its surroundings). Ochrona Beskidów Zachodnich, GPN Poręba Wielka, 1: 45−57.

Cieszkowski M., 2006c. Stop 2. Chabówka: Structures of the Flysch Carpathians between Nowy Targ and Rabka. *Proceedings of the 4th Meeting of the Cental European Tectonic Studies Group / 11th Meeting of the Czech Tectonic Studies Group / 7th Carpathian tectonic Workshop*, Zakopane, Poland, April 19–22, 2006. *Geolines*, 20: 173−176.

Cieszkowki M., Olszewska B., 1986. Malcov beds in Magura nappe near Nowy Targ, Outer Carpathians, Poland. *Annales Societatis Geologorum Poloniae*, 56: 53−71.

Cieszkowski M., Sikora W., 1975. Geologiczne wyniki otworu Obidowa IG1. *Kwartalnik Geologiczny*, 19: 441−442.

Cieszkowski M., Wieser T., 1979. Konkrecje rodochrozytowe z birnesytem w eoceńskich łupkach pstrych z Chabówki. Sprawozdania z posiedzeń naukowych Instytutu Geologicznego. *Kwartalnik Geologiczny*, 23: 497−498.

Cieszkowski M., Ślączka A., Wdowiarz S., 1985. New data on structure of the Flysch Carpathians. *Przegląd Geologiczny*, 6, 313–333.

Cieszkowski M., Oszczypko N., Zuchiewicz W., 1987. Late Cretaceous submarine slump in the Inoceramian beds of the Magura Nappe at Szczawa, Polish West Carpathians. *Annales Societatis Geologorum Poloniae*, 57: 189−201.

Cieszkowski M., Oszczypko N., Zuchiewicz W., 1989. Upper Cretaceous siliciclastic-carbonate turbidites at Szczawa, Magura Nappe, West Carpathians, Poland. *Bulletin of Polish Academy of Sciences, Earth Sciences*, 37: 231−245.

Cieszkowski M., Oszczypko N., Zuchiewicz W., Uchman A., 1992. Stratygrafia, sedymentologia i tektonika warstw z Kaniny. In: Zuchiewicz W., Oszczypko N. (eds), *Przewodnik LXIII Zjazdu Polskiego Towarzystwa Geologicznego*, Koninki, 17–19 września 1992. ING PAN, Kraków: 89−94.

Cieszkowski M., Zuchiewicz W., Schnabel W., 1998. Sedimentological and Tectonic Features of the Poprad Sandstone Member, Eocene, Magura Nappe: Case Study of the Klikuszowa Qarry, West Carpathians. *Bulletin of Polish Academy of Sciences, Earth Sciences*, 46: 55−74.

Cieszkowski M., Egger H., Oszczypko N., Schnabel W., 1999a. The Zasadne section of the Magura Nappe (Western Outer Carpathians, Poland) and its relation to the Rhenodanubian Flysch (Eastern Alps, Austria). *Abhandlungen der Geologischen Bundesanstalt*, 56: 333−336.

Cieszkowski M., Kusiak M., Michalik M., Paszkowski M., 1999b. Origin of gold placers in the Polish Carpathian thrust belt (Podhale Region). *Geologica Carpathica*, 50: 186−186.

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

Cieszkowski M., Chodyń R., Szczęch M., 2015a. Gorce – góry fliszowe. In: Czarnota P., Stefanik M. (eds), *Gorczański Park Narodowy. Przyroda i krajobraz pod ochroną*. Gorczański Park Narodowy, Poręba Wielka: 39–51.

Cieszkowski M., Chodyń R., Loch J., Szczęch M., 2015b. Geoturystyczne walory Gorczańskiego Parku Narodowego i jego otoczenia (Karpaty Zewnętrzne, Polska). *I Międzynarodowa Konferencja Naukowo--Branżowa „Geoturystyka i turystyka uzdrowiskowa w regionie. Geologia – zdrowie – ekologia*". Podhalańska Państwowa Wyższa Szkoła Zawodowa w Nowym Targu, Akademia Górniczo-Hutnicza im. Stanisława Staszica w Krakowie. Nowy Targ, 17–18 kwiecień 2015 r. http://www.ppwsz.edu.pl/edc_media/Structure/Item-2114/TinyFiles/Cieszkowski-2.pdf (accessed: 20.05.2015).

Haczewski G., Szymakowska F., 1984. Znalezisko amonita *Saghalinites wrighti* Birkelund w kredzie jednostki magurskiej. *Kwartalnik Geologiczny,* 28: 649−654.

Koszarski L., Sikora W., Wdowiarz S., 1974. The Flysch Carpathians. Polish Carpathians. In: Mahel M. (ed.), *Tectonics of the Carpathian-Balkan Regions*. Geologický Ústav Dionýza Štúra, Bratislava: 180−197.

Książkiewicz M., 1958. Osuwiska podmorskie we fliszu karpackim. *Rocznik Polskiego Towarzystwa Geologicznego*, 28: 123−158.

Książkiewicz M., 1972. *Budowa geologiczna Polski*, T. IV *Tektonika*, Cz. 3 *Karpaty.* Wydawnictwa Geologiczne, Warszawa.

Książkiewicz M., 1977. The Tectonics of the Carpathians. In: Pożaryski W. (ed.), *Geology of Poland*, vol. 4. *Tectonics. The Alpine Tectonic Epoch.* Geological Institute, Warsaw: 476−608.

Kucharska M., Krawczyk M., Kamiński M., Chowaniec J., 2013. *Gorczański Park Narodowy, Mapa geologiczno-turystyczna, skala 1 : 25000.* Państwowy Instytut Geologiczny – Państwowy Instytut Badawczy, Warszawa.

Margielewski W., Urban J., 2000. Charakterystyka inicjacji ruchów masowych w Karpatach fliszowych na podstawie analiz strukturalnych uwarunkowań rozwoju wybranych jaskiń szczelinowych. *Przegląd Geologiczny*, 48: 268−275.

Margielewski W., Urban J., 2002. Crevice-type caves as initial forms of rock landslide development in the Flysch Carpathians. *Geomorphology*, 54: 325−338.

Mastella L., 1988. Budowa i ewolucja strukturalna okna Tektonicznego Mszany Dolnej, polskie Karpaty Zewnętrzne. *Annales Societatis Geologorum Poloniae*, 58: 53−173.

Nyka J., 1974. Gorce. Sport i Turystyka, Warszawa.

Oszczypko N., 1991. Stratigraphy of the Palaeogene deposits of the Bystrica subunit (Magura Nappe, Polish Outer Carpathians). *Bulletin of Polish Academy of Sciences, Earth Sciences*, 39: 415−431.

Oszczypko N., 1992. Late Cretacous though Paleogene evolution of Magura Besin. *Geologica Carpathica*, 43: 333−338.

Oszczypko N., 2004. Structural position and tectonosedimentary evolution of the Polish Outern Carpatians. *Przegląd Geologiczny*, 52: 780−791.

Oszczypko N., Cieszkowski M., Zuchiewicz W., 1991. Variable Orientation of Folds within Upper Cretaceous-Palaeogene Rocks near Szczawa, Bystrica Subunit, Magura Nappe, West Carpathians. *Bulletin of Polish Academy of Sciences, Earth Sciences*, 39: 67−84.

Oszczypko N., Malata E., Oszczypko-Clowes M., 1999. Revised position and age of deposits on the northern slope of the Gorce Range (Bystrica Subunit, Magura Nappe, Polish Western Carpathians). *Slovak Geological Magazine*, 5: 235−254.

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 (Beskid Wyspowy and Gorce Ranges; Poland). *Annales Societatis Geologorum Poloniae*, 75: 27−69.

Oszczypko N., Oszczypko-Clowes M., 2006. Rozwój basenu magurskiego. In: Oszczypko N., Uchman A., Malata E. (eds), *Rozwój paleotektoniczny basenów Karpat Zewnętrznych i pienińskiego pasa skałkowego*, Instytut Nauk Geologicznych UJ, Kraków: 134−164.

Oszczypko-Clowes M., Oszczypko N., 2004. The position and age of the youngest deposits in the Mszana Dolna and Szczawa tectonic windows (Magura Nappe, Western Carpathians, Poland). *Acta Geologica Polonica*, 54: 339−367.

Paul C.M., 1868. Die nördliche Arva. *Jahrbuch Geologische Reichsanstalt*, 18, Wien.

Paul Z., 1978. Objaśnienia do Szczegółowej Mapy Geologicznej Polski 1 : 50.000. Arkusz Łącko (1034). Wydawnictwa Geologiczne, Warszawa.

Paul Z., 1980. Objaśnienia do Szczegółowej Mapy Geologicznej Polski 1 : 50.000. Arkusz Łącko (1034). Wydawnictwa Geologiczne, Warszawa: 1−44.

Paul Z., Ryłko W., 1987. Objaśnienia do Szczegółowej Mapy Geologicznej Polski 1 : 50.000. Arkusz Rabka (1032). Wydawnictwa Geologiczne, Warszawa, 1−59.

Rajchel L., 2009. Występowanie i wykorzystanie wód chlorkowych Rabki--Zdrój, *Geologia*, 35: 271−278.

Sikora W., Żytko K., 1968. Warunki geologiczne dolin Jaszcze i Jamne w Gorcach. In: Medwecka-Kornaś A. (ed.), Doliny potoków Jaszcze i Jamne w Gorcach. *Studia Naturae. Seria A*, 2: 23–38.

Starkel L., 1972. Karpaty Zewnętrzne. In: Klimaszewski M. (ed.), *Geomorfologia Polski*, T. 1. PWN, Warszawa, 52−115.

Szczęch M., Czarnota P., 2015. W uroczyskach pośród tajemniczych skał. In: Czarnota P., Loch J., Matysek M., Pierścińska A., Przybyłowicz Ł., Stańko R., Strauchmann E., Szczęch M., Tomasiewicz J., *Gorce – europejskie dziedzictwo przyrody*. Gorczański Park Narodowy, Poręba Wielka: 72–83.

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

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

Uchman A., Cieszkowski M., 2008a. Stop – Szczawa-Centrum – Grybów Beds (Early Oligocene) and Sub-Cergowa Beds (Early Oligocene): Diplocraterion deep-sea sediments. 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*. Polish Geological Institute: 110−115.

Uchman A., Cieszkowski M., 2008b. Stop 5 Szczawa-Głębieniec – upper part of the Roppianka Formation (Palaeocene): Nereites ichnosubfacies of the Nereites ichnofacies and ichnological evidence of turbiditic sedimentation in shales. 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*. Polish Geological Institute: 115−118.

Unrug R., (ed.), 1969. Przewodnik geologiczny po zachodnich Karpatach fliszowych. Wydawnictwa. Geologiczne, Warszawa.

Watycha L., 1963. Flisz magurski południowej części Gorców. *Przegląd Geologiczny*, 6: 371−378.

Watycha L., 1966. Szczegółowa Mapa Geologiczna Polski 1 : 50 000 (bez utworów czwartorzędowych). Arkusz Mszana Górna (M-34-89A), wydanie tymczasowe. Instytut Geologiczny, Warszawa.

Watycha L., 1975. Szczegółowa Mapa Geologiczna Polski 1 : 50 000. Arkusz Nowy Targ (1049). Wydawnictwa Geologiczne, Warszawa.

Watycha L., 1976. Objaśnienia do Szczegółowej Mapy Geologicznej Polski 1 : 50 000. Arkusza Nowy Targ (1049). Wydawnictwa Geologiczne, Warszawa: 1–101.

Zuchiewicz W., 1978. Czwartorzędowe ruchy tektoniczne a rzeźba przełomu Dunajca przez Beskid Sądecki. *Rocznik Polskiego Towarzystwa Geologicznego*, 48: 517−531.

Zuchiewicz W., 1995. Selected aspects of neotectonics of the Polish Carpathians. *Folia Quaternaria*, 66: 145−204.

Zuchiewicz W., 2010. Neotektonika Karpat polskich i zapadliska przedkarpackiego. Wydawnictwa AGH, Kraków.

Zuchiewicz W., Oszczypko N. (eds), 1992. *Przewodnik LXIII Zjazdu Polskiego Towarzystwa Geologicznego, Koninki, 17–19 września 1992*. ING PAN, Kraków.