



Geosites in Tourist Areas: the Best Method for the Promotion of Geotourism and Geoheritage (an Example from the Polish Flysch Carpathians)

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Abstract

Beskid Mały is a part of the Outer Western Carpathians of a geological structure and relief characteristic for this region. The rocks found here are mainly flysch sediments represented by complexes composed of conglomerates, sandstones and shales. Other types of rocks — limestones, marls and crystalline rocks — appear rarely and only as blocks within the flysch. Forty-nine geological sites of particular interest were specified in the analysed area. Some of them are protected by law or are located at the conservation areas. When geosites are located on tourist trails or near traffic routes, they can be used as geotourist attractions. In Beskid Mały, these attractions represent a wide range of the Earth sciences. They can be used to present elements of the geological structure of the region and processes of deposition of flysch deposits taking into account their lithological diversification. They also illustrate the effects of contemporary geological and geomorphological processes, such as weathering, mass movements and fluvial erosion. Scientific and educational values of geosites, diversification of subjects that can be presented, convenient location and good availability of geological sites contribute to a large geotourist potential of Beskid Mały.

Keywords Geological Sites · Geotourism · Nature Conservation · Beskid Mały Mountains · Carpathian Mountains · South Poland

Introduction

Geotourism concerns areas characterised by the significant landscape and natural values, frequently covered by various forms of legal protection. It focuses on scientific and educational aspects of geological conservation, geological history of the region and geointerpretation (Hose 2012). Therefore, the main areas of interest for geotourism are geological features and, in particular, geological and/or geomorphological sites. Its development offers opportunities for the promotion

of geological knowledge and supports conservation of geodiversity (Larwood and Prosser 1998; Alexandrowicz and Alexandrowicz 2002; Gordon 2018). There is no unambiguous definition of geotourism available, because various criteria are used to define it (e.g. Newsome and Dowling 2005; Migoń 2012). From a recipient's point of view, the most important features of geotourist attractions include their educational values, availability and safe sightseeing. Furthermore, information presented on maps, in guidebooks and Internet sources are also of importance. Unfortunately, descriptions of geotourist attractions located in the Polish part of the Carpathians are insufficient. Generally, available sources usually contain sparse information about the geological structure and relief of the region. The geological guidebooks are addressed to people having relevant specialist knowledge. However, catalogues of geosites play an important role here (Alexandrowicz et al. 1999; Alexandrowicz and Poprawa 2000; Słomka et al. 2006; Słomka (ed.) 2013).

The Beskid Mały range located in the western part of the Outer Carpathians is an area with perspectives for

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development of geotourism. It is located near to large urban agglomerations of Silesia (ca. 70 km) and Kraków (ca. 60 km) and close to attractions included in the UNESCO World Heritage List: Kraków (ca. 60 km), Wieliczka (70 km), the Sanctuary in Kalwaria Zebrzydowska (30 km), and the Auschwitz-Birkenau museum (20 km). Several tourist destinations are located in the Beskid Mały itself. Numerous hiking, cycling and skiing trails of a total length of ca. 500 km were marked within the range. A very well-developed tourist infrastructure and a dense network of roads facilitating travelling in that region should also be emphasised. Beskid Mały is visited by several tens of thousands of tourists every year. By expanding the available tourist range and expanding it with elements of geotourism, the attractiveness of the region will definitely increase. From this point of view, the presence of numerous easily available and well-marked geological sites, presenting an extensive range of issues of Earth science, is essential. The main aim of this study is to discuss a chain of geosites in the Beskid Mały region, together with their scientific and educational values and a possibility of using them as geotourist attractions.

Study Area

Beskid Mały is a small (stretching ca. 35 km W–E and up to 15 km N–S) mountain range located in the western part of the Polish Outer Carpathians. It includes four massifs, Magurka Wikowicka, Leskowiec-Łamana Skała, Żurawnica and Jaroszowicka Góra, separated by river valleys (Fig. 1) (Kondracki 2002). The peaks reach up to 1000 m a.s.l., and denivelations usually do not exceed 400 m. The Beskid Mały range is separated by two large valleys stretching north to south: Soła in the west and Skawa in the east (Fig. 1). Valleys of smaller streams are characterised by large gradients and steep slopes in their upper part. Their middle and lower parts are characterised by low gradient and are used for settlement or/and crop fields. The Beskid Mały range is mainly covered by transformed tree stands belonging to lower sub-alpine forests. In some parts, the Carpathian beech forest (*Dentario glandulosae-Fagetum*) communities are maintained. Its characteristic features are glades near the peaks, forming excellent viewpoints.

To protect natural values of the Beskid Mały range, a landscape park, three nature reserves (Zasolnica, Szeroka and Madohora) and the Natura 2000 area (Special Area of Habitat Conservation PLH 240,023) were created. When compared to many other flysch regions of the Polish Carpathians, geological values of Beskid Mały were relatively early covered by the legal protection. Some outcrops and sandstone tors were covered by the legal protection in the 1960s as geological nature monuments, mainly due to efforts of Professor M. Książkiewicz (Alexandrowicz 1963a, 1963b,

1963c, 1963d, 1964a, 1964b, 2011). During subsequent geological studies, a need to protect certain outcrops of importance for stratigraphy of flysch formations and their use for purposes of geotourism was emphasised. Currently, there are fourteen geological nature monuments and eight documentation sites in the Beskid Mały region. Additionally, three outcrops were specified to be entered in the European Geosites Network (Alexandrowicz et al. 1999; Alexandrowicz 2006).

Geological Structure Outline

The geological structure of the Beskid Mały, its diversity and representativeness in relation to the geological region, as well as a number, quality and accessibility of outcrops are of fundamental importance for possible opportunities for development of geotourism. We owe the first detailed determination of the geological structure of Beskid Mały to Professor M. Książkiewicz (Książkiewicz 1932, 1951; Alexandrowicz 2011). The Beskid Mały range is built of flysch deposits characterised by significant lithofacies diversification, belonging to the three large tectonic units of the Outer Carpathians: Magura, Silesian, and Sub-Silesian. Furthermore, it is a location of the unique rock outcrops representing a substrate of flysch sediments (the Andrychów Series), as well as interesting and impressive geomorphological structures, such as sandstone tors, crack caves and valleys with cascade waterfalls (Fig. 2).

Formations of the Magura Unit are found in the southern part of this region (Fig. 2). The most important role is played by sediments of the Łabowa Formation (Palaeocene–Middle Eocene) (Cieszkowski and Waškowska-Oliwa 2001; Cieszkowski et al. 2006). It is a sequence of variegated shale and thin-bed sandstones divided by two levels of thick-bed sandstones and conglomerates with pieces of crystalline rocks (Żurawnica Sandstone and Skawce Sandstone members) (Cieszkowski and Waškowska-Oliwa 2001; Cieszkowski et al. 2006). Thickness of the Magura Unit does not exceed 400 m. In the discussed zone, several steep folds and numerous faults can be distinguished (Cieszkowski et al. 2006; Ryłko and Paul 2013) (Fig. 2).

The majority of Beskid Mały is located in the area of the Silesian Unit (Fig. 2). Its profile includes the Cretaceous and the Palaeogene and reaches thickness of up to 4 km (Książkiewicz 1951). Formations representing the Early Cretaceous are found in the northern part of the range (Książkiewicz 1951; Ryłko and Paul 2013). They include black shale with siderites and inserts of thin-bed sandstones (Veřovice Formation–Late Aptian), dark laminated silica sandstones and silica shale (Lgota Formation–Albian and Early Cenomanian) and variegated shale and white silicified marls (Late Cenomanian). The rocks of the Late Cretaceous and Palaeocene play the most

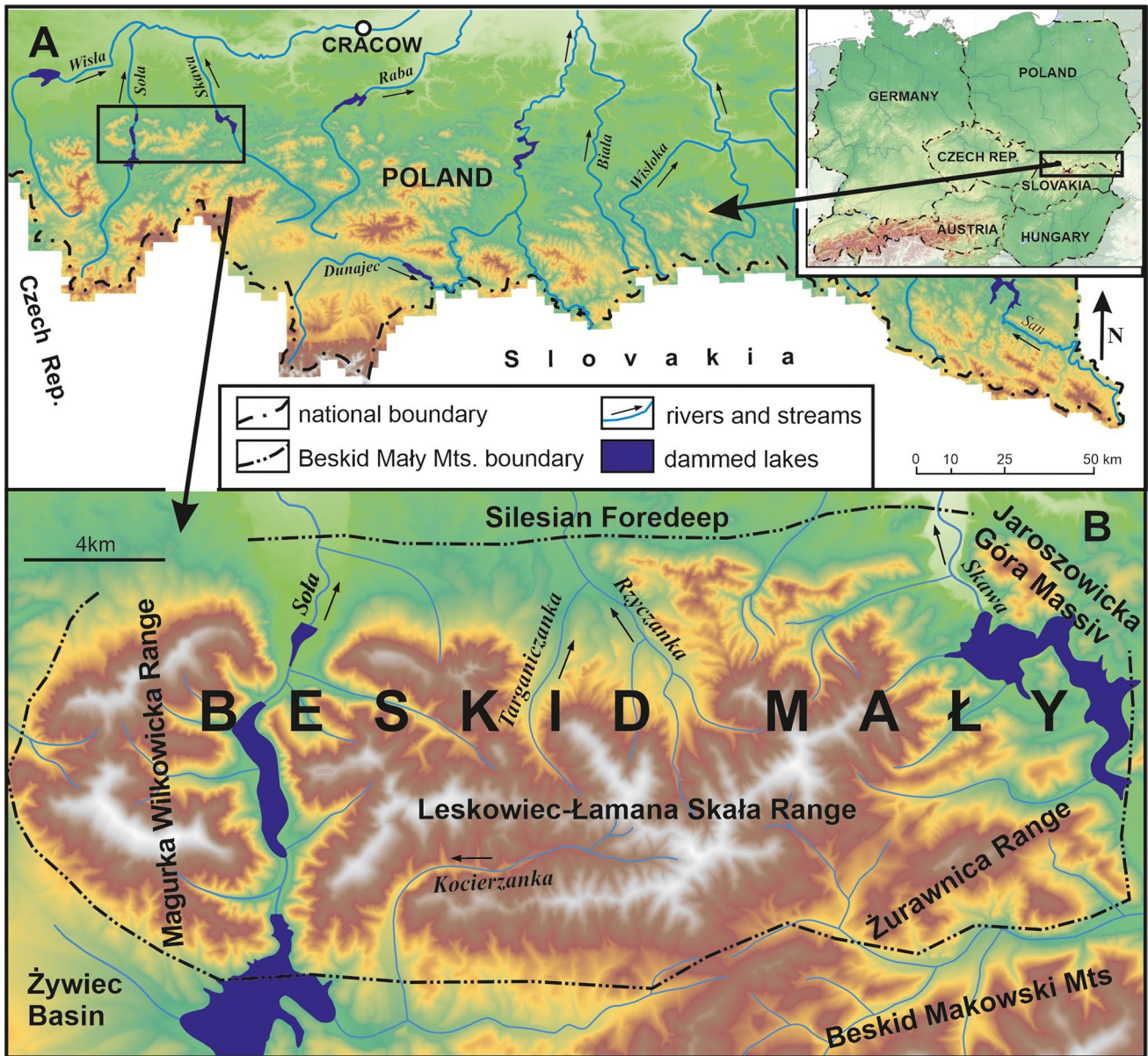


Fig. 1 Location of the research area (A) and geographic division of the Beskid Mały (B) (after: Kondracki 2000; map base: [www.https://polska.e-mapa.net](https://polska.e-mapa.net))

important role, forming the main ranges of Beskid Mały. This group includes the Godula Formation (Turonian–Santonian) and Istebna Formation (Campanian–Palaeocene) (Książkiewicz 1951; Słomka 1995; Golonka 1981; Ryłko and Paul 2013). Godula Formation forms a thick complex (up to 1500 m) of hard sandstones with glauconite. Istebna Formation is developed as thick and very thick sandstones with feldspars and exotic conglomerates. In Beskid Mały occurs mainly the lower part of the mentioned formation (Campanian–Maastrichtian) which reaches a thickness up to 1000 m (Książkiewicz 1951; Unrug 1963; Strzeboński 2015). The formations of the Silesian unit (mainly Late

Cretaceous) form a monoclinial, slightly uplifted block sinking to the south (Książkiewicz 1951; Golonka 1981; Ryłko and Paul 2013) (Fig. 2).

The Sub-Silesian Unit forms a narrow belt in the northern part of Beskid Mały. It mainly includes shale and marl members. Due to a low resistance of the rocks, this zone is characterised by a monotonous relief and a poor denudation of substrate rocks. Thin-bed glauconite sandstones (Gorzeń Beds–Early Palaeocene) are considered the most important division (Książkiewicz 1951; Waśkowska-Oliwa 2005; Golonka and Waśkowska-Oliwa 2007; Ryłko and Paul 2013) (Fig. 2).

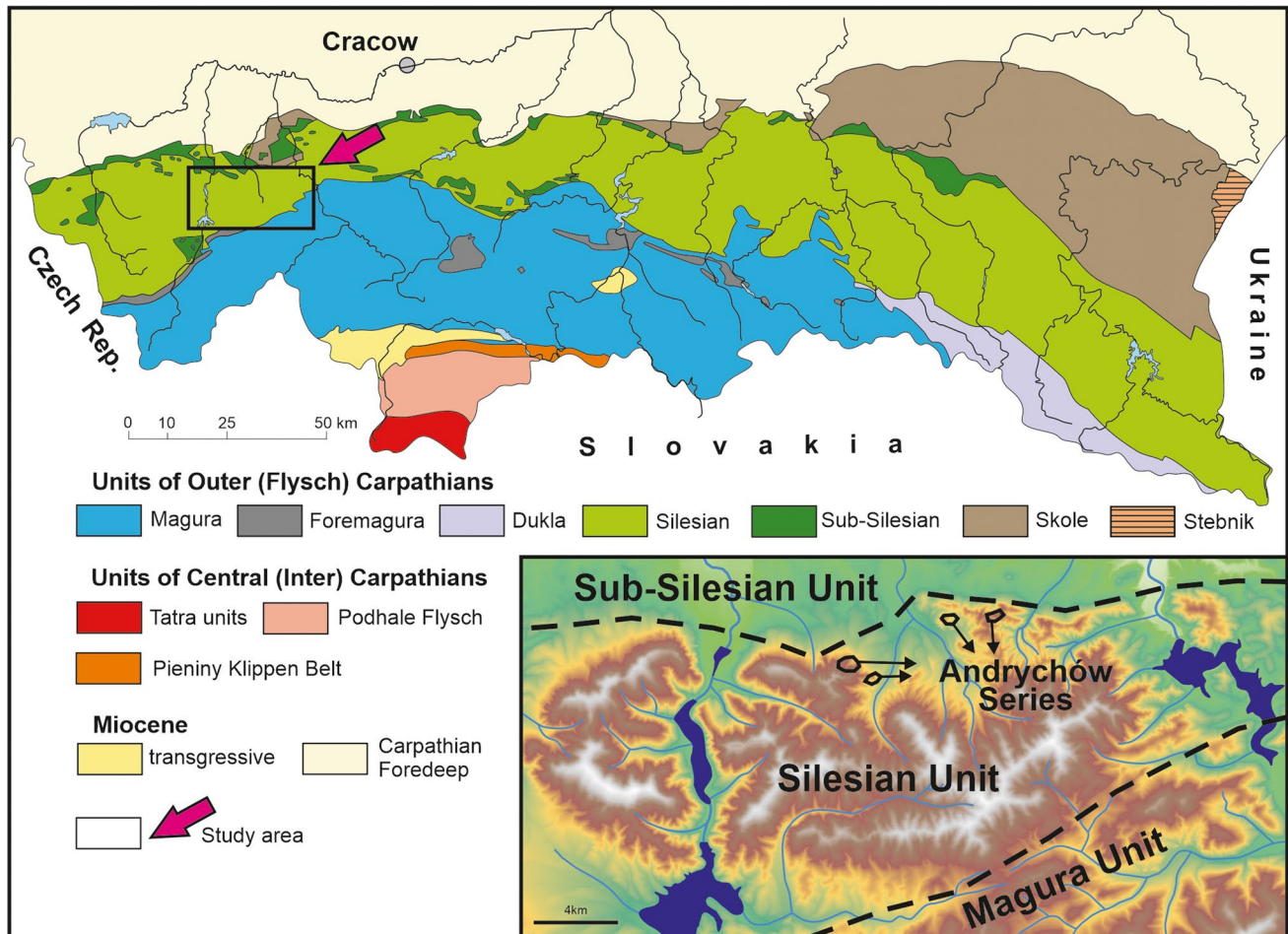


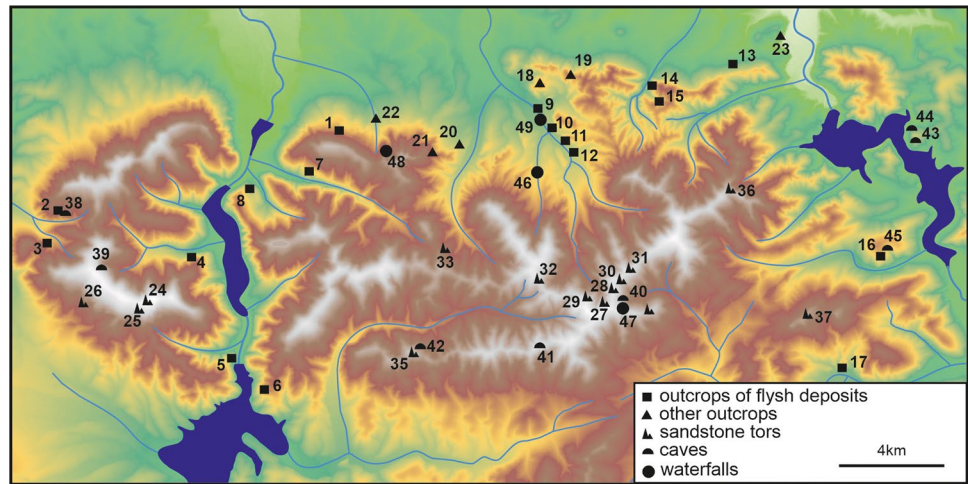
Fig. 2 The main tectonic units of the Beskid Mały against the background of the tectonic of the Polish Flysch Carpathians (after: Żytko et al. 1989; simplified; map base: [www.https://polska.e-mapa.net](https://polska.e-mapa.net))

The Andrychów Series is a geological phenomenon of Beskid Mały (Fig. 2). It includes carbonate rocks representing a substrate of flysch sequences (e.g. Książkiewicz 1932, 1935a, b, 1951; Książkiewicz and Liszkowa 1972; Olszewska and Wieczorek 2001; Waškowska-Oliwa et al. 2008; Cieszkowski et al. 2009). The Andrychów Series appears in as blocks interpreted as olistoliths and olistostromes (Waškowska-Oliwa et al. 2008; Cieszkowski et al. 2009). The oldest elements here are the Jurassic sediments: crinoidal limestones, limestones with cherts and reef limestones of the Štramberk facies. The Late Cretaceous and the Palaeogene sediments include white marls, lithothamnium limestone and limestones with cherts. The carbonate rocks are accompanied by blocks of granitic gneiss and mylonites from the Early Palaeozoic (Ryłko and Paul 2013) (Fig. 2).

Characteristics of Geosites

Beskid Mały is characterised by a large numbers of geological and geomorphological sites which are interesting as geotourist attractions. The majority of them are located in a direct vicinity of tourist trails or traffic routes. Some of the presented sites are legally protected. For purposes of this study, 49 sites were specified, illustrating various aspects of Earth science. They were divided into five groups (A–E) (Fig. 3; Tables 1 and 2). Brief characteristics of individual sites are presented in Table 1. Sites of special scientific and educational importance were selected from each group, and their more detailed descriptions are provided below.

Fig. 3 Location of described geosites in Beskid Mały (map base: [www.https://polska.e-mapa.net](https://polska.e-mapa.net))



Outcrops of Flysch Formations

Numerous outcrops of flysch rocks can be found in Beskid Mały. They include both non-operated quarries and natural outcrops, usually associated with stream valleys. The former ones can be easily accessed by roads used to transport spoils. The sites within valleys are less accessible and located at some distance from tourist trails and roads. Out of all flysch rock outcrops, a group of 17 sites was selected (sites 1–17; Fig. 3, Tables 1 and 2).

Kozy (Site 1) (Figs. 3 and 4, Tables 1 and 2) In the non-operated quarry, a complex of the middle part of the Lgota Formation (Silesian Unit) (Albian–Early Cenomanian) is visible, ca. 150 m thick. It is a stratotype site for this lithostratigraphic member. It contains silicified medium-bed sandstones and black shale. The sandstones are characterised by the presence of well-visible sedimentation structures (Unrug 1959, 1977). In many beds, elements of the Bouma sequence (Bouma 1962) can be noticed, especially laminations corresponding to intervals $T_{b,c,d}$. Normal graded bedding is visible in bottom parts of thicker beds (interval T_a). Numerous hieroglyphs of mechanical and biological origin are visible on thill surfaces of the beds. The rocks found in the quarry in Kozy represent typical sequences for flysch sediments deposited by low density gravity currents of the turbidite type on disposition lobes of a middle part of a submarine fan (e.g. Shanmugam and Moiola 1988; Reading and Richards 1994; Shanmugam 2016). Due to their scientific and educational values, the quarry was selected to be entered on the European Geosites Network (Alexandrowicz et al. 1988, 1999; Alexandrowicz 2006). There are plans to mark out an educational path within the quarry (Badera et al. 2011).

Rzyczanka Stream Valley (Sites 9, 10, 11, 12 and 49) (Figs. 3 and 4, Tables 1 and 2) It is a complex of outcrops stretching for ca. 3 km along the bed of the Rzyczanka Stream. The sediments found here represent the Cretaceous (Aptian to Turonian) of the Silesian Unit. The bottom part of the profile is formed by the Veřovice Formation (site 9, Figs. 3 and 4; Tables 1 and 2). It is formed as black silt shale with thin beds of fine-grained sandstone. They are dark grey and their laminations correspond to interval T_d of the Bouma sequence. Traces of activities of bottom-dwelling organisms are visible on surfaces of sandstone beds (Cieszkowski et al. 2001, 2003; Golonka et al. 2011; Głowacki 2019). The shale contains sphaerosiderites, frequently of up to 1 m. Predomination of the shale indicates that these sediments were deposited on the surface of the lower fan (e.g. Shanmugam and Moiola 1988; Reading and Richards 1994; Shanmugam 2016). In its discussed section, the Rzyczanka Stream forms a number of picturesque cascades and waterfalls of up to 1.5 m (site 49, Figs. 3 and 4, Tables 1 and 2) (Zieliński 2003). It is an example illustrating the fluvial erosion process occurring within the rocky obsequent valley. Further above denuded dark silicified sandstones and black shale, belonging to the Lgota Formation, are visible (site 10, Fig. 3, Tables 1 and 2). Their formation is similar to the one described in the non-operated quarry Kozy (site 1). Another division consists of white silicate marls and variegated shale (site 11, Figs. 3 and 4, Tables 1 and 2). Marls are dark grey, and their characteristic feature is numerous feeding channels. In the lower sequence, a several-metre-thick insert of silicified variegated shale is visible. The silicate marls and variegated shale were formed in the distal part of the lower fan (e.g. Shanmugam and Moiola, 1988; Reading and Richards 1994; Shanmugam 2016) in the Late Cenomanian. The youngest members denuded in the Rzyczanka

Table 1 Description of the selected geosites in Beskid Mały

No	Name	Geological description
1	Kozy	Description in text
2	Straconka	Thick-bed, glauconite sandstones and conglomerates. Normal graded bedding, laminations (cross and parallel) and hieroglyphs are visible in sandstones. Deposition, low density currents (turbidites); distribution channels; middle part of the submarine fan (Godula Formation (lower part); Silesian Unit) (Słomka 1995)
3	Mała Straconka	Medium- and thin-bed, glauconite sandstones and dark shale. Parallel, cross and wavy laminations are found in sandstones and hieroglyphs on thill surfaces of the beds. Deposition: low density currents (turbidites); depositing lobes; middle part of the submarine fan (Godula Formation (lower part); Silesian Unit) (Słomka 1995)
4	Międybrodzie Bialskie	Medium- and thick-bed, glauconite sandstones and dark shale. Thill surfaces of the beds are erosive, with large load casts. Normal graded bedding, cross and parallel laminations are present. Deposition: low density currents (turbidites); distribution channels; middle part of the submarine fan (Godula Formation (lower part); Silesian Unit) (Słomka 1995)
5	Tresna	Medium-bed, glauconite sandstones with dark shale. Parallel and cross laminations are found in the sandstones. Deposition: low density currents (turbidites); depositing lobes; middle part of the submarine fan (Godula Formation (middle part); Silesian Unit) (Słomka 1995)
6	Oczków	Thick-bed sandstones with feldspars and exotic conglomerates with pebbles of crystalline and sedimentary rocks. Thill surfaces of the beds are erosive with large casts. Deposition: high density currents (fluxoturbidites); distribution channels; upper part of the submarine fan (Istebna Formation (lower part); Silesian Unit) (Unrug 1953; Strzeboński 2005)
7	Porąbka	In the lower part of the outcrop, thick-bed, glauconite sandstones predominate. Thill surfaces of the beds are erosive, with parallel laminations found in roof parts. The upper part of the outcrop is formed by thin-bed sandstones with parallel and cross laminations and dark shale. Deposition: low density currents (turbidites); middle part of the submarine fan, distribution channels (bottom part), depositing lobes (upper part) (Godula Formation (lower part); Silesian Unit) (Słomka 1995)
8	Porąbka-Wielka Puszcza	Thick-bed, glauconite sandstones with dark shale. Normal graded bedding occurs; there also parallel and cross laminations present. Deposition: low density currents (turbidites); distribution channels; middle part of the submarine fan (Godula Formation (lower part); Silesian Unit) (Słomka 1995)
9	Rzyczanka Stream	Description in text
10	Rzyczanka Stream	Description in text
11	Rzyczanka Stream	Description in text
12	Rzyczanka Stream	Description in text
13	Gorzeń Górny	Thin-bed sandstones with glauconite hieroglyphs are found on thill surfaces, and laminations (cross, parallel, and lens) are visible in the beds. Deposition: low density currents (turbidites); depositing lobes; middle part of the submarine fan (Gorzeń Beds; Sub-Silesian Unit) (Książkiewicz 1951; Waškowska-Oliwa 2005; Golonka and Waškowska-Oliwa 2007)
14	Kaczyna	Dark medium-bed silicate limestones and dark shale. Various types of laminations, representing all segments of the Bouma sequence, can be found in the sandstones. Hieroglyphs are visible on thill surfaces. Small folds and faults can be found in many places. Deposition: low density currents (turbidites); depositing lobes; middle part of the submarine fan (Lgota Formation; Silesian Unit) (Alexandrowicz and Lalik 1999; Alexandrowicz 2001)
15	Głębień Stream	Description in text
16	Tarnawa	Thick-bed sandstones with inserts of variegated silt shale. Erosion channel can be noted on cross-sections of the beds, and hieroglyphs are visible on their thill surfaces. Small folds and faults are also visible. Deposition: low density currents (turbidites); distribution channels; middle part of the submarine fan (Skawce Sandstones; Łabowa Formation; Magura Unit) (Cieszkowski and Waškowska-Oliwa 2001; Cieszkowski et al. 2006)
17	Stryszawa Stream	Variegated silt shale and scarce thin beds of laminated sandstones, marls and limestones. Layers of siderites, black manganese-rich shale and grey bentonite are also present. Deposition: very low density currents (turbidites); distal part of a lower submarine fan transforming into abyssal plain (Łabowa Formation; Magura Unit) (Cieszkowski et al. 2006)
18	Inwałd	Description in text
19	Pańska Góra	Late Cretaceous limestones with cherts and white lithothamnium limestones (Palaeogene) A block of granitic gneiss can be found on the northern slope of the hill (Andrychów Series) (e.g. Książkiewicz 1935b, 1951; Waškowska-Oliwa et al. 2008)
20	Targanice	Description in text
21	Roczyny	Description in text
22	Domaczka Stream	Description in text
23	Gorzeń Dolny	A spring fan with current precipitation of calcium carbonate. The calcareous tufa found here consists of hard porous travertines and loose tufas. A rich malacofauna is present in these last formations (Alexandrowicz 2009)

Table 1 (continued)

No	Name	Geological description
24	Diabelski Kamień I <i>Devil's Stone I</i>	Description in text
25	Diabelski Kamień II <i>Devil's Stone II</i>	A rock pulpit (15 m long, 7 m wide and 7 m high) consisting of thick-bed sandstones and conglomerates (upper fan; channel sediments of the fluxoturbidite type). Its bottom part separated along joints and slid along a very steep slope (Istebna Formation (lower part); Silesian Unit), (Alexandrowicz 1964a, 1978)
26	Skałka Czarownic <i>Witches Tor</i>	A rock pulpit (12 m long, 8 m wide, and 8 m high) consisting of thick-bed sandstones and conglomerates (upper fan; channel sediments of the fluxoturbidite type) (Istebna Formation (lower part); Silesian Unit) (Alexandrowicz 1978)
27	Madohora	Description in text
28	Wędrujące Kamienie <i>Wandering Stones</i>	A group of rock walls and rock pulpits up to 10 m high, consisting of thick-bed sandstones and conglomerates (upper fan; channel sediments of the fluxoturbidite type). The individual elements are separated by cracks and shifted gravitationally (Istebna Formation (lower part); Silesian Unit) (Alexandrowicz 1978)
29	Skałki na Przykrej <i>Tors on Przykra</i>	A system of thresholds, walls and rock pulpits of the total length of ca. 50 m and the height of up to 3 m consisting of thick-bed sandstones and conglomerates (upper fan; channel sediments of the fluxoturbidite type) (Istebna Formation (lower part); Silesian unit) (Alexandrowicz 1978)
30	Skałki na Smrekownicy <i>Tors on Smrekownica</i>	A system of walls, rock thresholds and rock pulpits of the height of up to 12 m consisting of thick-bed sandstones and conglomerates (upper fan; channel sediments of the fluxoturbidite type) (Istebna Formation (lower part); Silesian unit) (Alexandrowicz 1978)
31	Skałki na Beskidzie <i>Tors on Beskid</i>	A system of walls, rock thresholds and rock pulpits of the height of up to 10 m consisting of thick-bed sandstones and conglomerates (upper fan; channel sediments of the fluxoturbidite type). The individual forms indicate a gravitational shift (Istebna Formation (lower part); Silesian Unit) (Alexandrowicz 1978)
32	Zbójnickie Okno <i>The Robbers' Window</i>	Description in text
33	Warownia na Trakcie <i>Stronghold on the Road</i>	A ridge stretching along the range (the length of ca. 150 m and the height of up to 10 m) consisting of thick-bed sandstones and conglomerates (upper fan; channel sediments of the fluxoturbidite type) (Istebna Formation (lower part); Silesian Unit) (Alexandrowicz 1978)
34	Skałki na Czarnej Górze <i>Tors on Czarna Góra</i>	A group of rock pulpits, walls and thresholds separated by cracks that slid down the slope. They stretch in rows along the ridge at the length of 350 m and the height of up to 7 m. The rocks consist of thick-bed sandstones and conglomerates (upper fan; channel sediments of the fluxoturbidite type) (Istebna Formation (lower part); Silesian Unit) (Alexandrowicz 1978)
35	Zamczysko <i>The Castle</i>	Description in text
36	Skałki na Górze Żar <i>Tors on Żar</i>	Description in text
37	Kozie Skały <i>Goat Rocks</i>	Description in text
38	Jaskinia Straconka <i>Straconka Cave</i>	A crack cave, the length of corridors of 135 m and the depth of 16.5 m in the Straconka quarry (site 2). The cave is formed within the Godula Formation (lower part); Silesian Unit (Słomka 1995; Klassek 1997)
39	Wietrzna Dziura <i>Windy Hole</i>	A crack cave in thick-bed sandstones (Godula Formation (middle part); Silesian Unit), the length of corridors of 33 m and the depth of 6 m (Klassek 1997)
40	Grota Komonieckiego <i>Komoniecki Cavern</i>	Description in text
41	Czarne Działy <i>Czarne Działy Caves</i>	Description in text
42	Jaskinia Lodowa <i>Ice Cave</i>	Description in text
43	Mysiorowa Jama <i>Mysiorowa Pit</i>	Description in text
44	Jaskinia Lisia <i>Fox Cave</i>	Description in text
45	Jaskinia Dziurawa <i>Leaky Cave</i>	A crack cave in Skawce Sandstone (Łabowa Formation; Magura Unit), the length of corridors of 160 m and the depth of 8.5 m in the Tarnawa quarry (site 22) (Cieszkowski and Waškowska-Oliwa 2001; Cieszkowski et al. 2006)
46	Pracica	Description in text
47	Dusiółek	Description in text

Table 1 (continued)

No	Name	Geological description
48	Złota Górk <i>Golden Hill</i>	A system of rock thresholds of the height of up to 2.5 m within a obsequent valley. The threshold formed on outcrops of thin and medium-bed sandstones (Godula Formation (middle part); Silesian Unit)
49	Rzyczanka Stream	Description in text

Table 2 Types, location and nature conservation of geosites in Beskid Mały

No	Site	Localisation GPS	Type of outcrop	Nature conservation					
				L	R	M	D	E	
1	Kozy	49°49'46"N; 19°09'03"E	non-operated quarry						
2	Straconka	49°47'47"N; 19°06'27"E	non-operated quarry						
3	Mała Straconka	49°47'26"N; 19°06'28"E	non-operated quarry						
4	Międzybrodzie Bialskie	49°47'01"N; 19°11'02"E	non-operated quarry						
5	Tresna	49°44'53"N; 19°12'19"E	non-operated quarry						
6	Oczków	49°44'10"N; 19°13'05"E	non-operated quarry						
7	Porąbka	49°48'35"N; 19°12'03"E	non-operated quarry						
8	Porąbka-Wielka Puszcza	49°48'36"N; 19°14'43"E	non-operated quarry						
9	Rzyczanka Stream	49°49'57"N; 19°22'21"E	natural outcrop						
10	Rzyczanka Stream	49°49'36"N; 19°22'24"E	natural outcrop						
11	Rzyczanka Stream	49°49'14"N; 19°22'54"E	natural outcrop						
12	Rzyczanka Stream	49°48'58"N; 19°23'06"E	natural outcrop						
13	Gorzeń Górny	49°51'19"N; 19°29'51"E	natural outcrop						
14	Kaczyna	49°50'35"N; 19°25'47"E	non-operated quarry						
15	Głębień Stream	49°50'11"N; 19°26'10"E	natural outcrop						
16	Tarnawa Dolna	49°46'40"N; 19°33'15"E	non-operated quarry						
17	Stryżawa Stream	49°44'27"N; 19°32'02"E	natural outcrop						
18	Inwałd	49°51'01"N; 19°23'14"E	non-operated quarry						
19	Pańska Góra	49°50'53"N; 19°21'11"E	non-operated quarry						
20	Targanice	49°50'05"N; 19°20'02"E	non-operated quarry						
21	Roczyń	49°49'25"N; 19°17'59"E	non-operated quarry						
22	Domaczka Stream	49°49'08"N; 19°17'15"E	natural outcrop						
23	Gorzeń Dolny	49°51'39"N; 19°30'18"E	natural outcrop						
24	Diabelski Kamień I	49°45'13"N; 19°09'42"E	single tor						
25	Diabelski Kamień II	49°45'00"N; 19°09'41"E	single tor						
26	Skalka Czarownic	49°45'22"N; 19°07'35"E	single tor						
27	Madohora	49°45'44"N; 19°23'45"E	group of tors						
28	Wędrujące Kamienie	49°45'45"N; 19°24'27"E	group of tors						
29	Skalki na Przykrej	49°45'50"N; 19°23'44"E	group of tors						
30	Skalki na Smrekownicy	49°45'48"N; 19°24'17"E	group of tors						
31	Skalki na Beskidzie	49°46'21"N; 19°24'37"E	group of tors						
32	Zbójnickie Okno	49°46'11"N; 19°22'23"E	single tor						
33	Warownia na Trakcie	49°46'50"N; 19°19'46"E	single tor						
34	Skalki na Czarnej Górze	49°45'46"N; 19°25'45"E	group of tors						
35	Zamczysko	49°44'52"N; 19°18'17"E	single tor						
36	Skalki na Górze Żar	49°49'01"N; 19°28'43"E	group of tors						
37	Kozie Skalki	49°45'35"N; 19°30'45"E	group of tors						
38	Jaskinia Straconka	49°47'48"N; 19°06'27"E	cave						
39	Wietrzna Dziura	49°46'12"N; 19°08'22"E	cave						
40	Grota Komonickiego	49°45'30"N; 19°21'40"E	cave						
41	Czarne Działy	49°44'22"N; 19°24'36"E	cave						
42	Jaskinia Lodowa	49°44'54"N; 19°18'19"E	cave						
43	Mysiorowa Jama	49°49'26"N; 19°23'14"E	cave						
44	Jaskinia Lisia	49°49'33"N; 19°34'24"E	cave						
45	Jaskinia Dziurawa	49°46'40"N; 19°33'15"E	cave						
46	Pracica	49°47'30"N; 19°34'24"E	group of waterfalls						
47	Dusiołek	49°45'28"N; 19°17'26"E	single waterfall						
48	Złota Górk	49°49'15"N; 19°34'24"E	group of waterfalls						
49	Rzyczanka Stream	49°49'59"N; 19°22'22"E	group of waterfalls						

L. Beskid Mały Landscape Park, R. Nature reserve, M. geological monument, D. documentation geological site, E. European Geosites Network

Fig. 4 Examples of geosites: natural outcrops, non-operated quarries



Stream are medium- and thin-bed sandstones containing glauconite, with beds of dark shale. The sandstones contain structures characteristic for the Bouma sequence indicating that these deposits were formed by deposition from low density currents (turbidites) on deposition lobes of a middle fan (e.g. Shanmugam and Moiola, 1988; Reading and Richards 1994; Słomka 1995; Shanmugam 2016). The discussed sediments are classified as the lower part of the Godula Formation (Turonian) (site 12, Fig. 3, Tables 1 and 2). The sequence of sediments in the Rzyczanka Stream has significant scientific values, confirmed in numerous publications (e.g. Książkiewicz 1951; Cieszkowski et al. 2001, 2003; Zieliński 2003; Golonka et al. 2011; Głowacki 2019), as well as indisputable educational and aesthetic values.

Individual sections of the profile are easily accessible, and an educational path runs along the valley (Zieliński 2003). The Rzyczanka Stream valley is protected as a geological documentation site.

Głębień Stream Valley (Site 11, Fig. 3, Tables 1 and 2) It is a profile representing a border between the Lgota Formation and the Godula Formation (Silesian Unit). At the same time, the discussed rock series separates two development stages of the Carpathian Basin: Early Cretaceous, with predominating dark sediments accumulating in a reducing environment, and Late Cretaceous, with predominating sandstones accumulated in oxidative conditions (Golonka et al. 2011). Several elements can be distinguished within

the border sequence. They include dark silicified marls forming three levels, variegated silicified shale and two levels of thick-bed silicate sandstones with glauconite classified as the Godula Formation (Książkiewicz 1932, 1951). The entire border sequence in the Głębień Stream is about 200 m thick (Alexandrowicz and Lalik 1999; Alexandrowicz 2001). The outcrops are located in a narrow valley, at a significant distance from tourist trails and traffic routes. Therefore, they are difficult to access. The profile in the Głębień Stream valley is a geological documentation site.

Other Outcrops

Beskid Mały is made almost entirely of flysch sediments. However, in its northern part, outcrops of carbonate rocks, limestone and marls, appear, in some places accompanied by crystalline rocks. It is the so-called Andrychów Series, denuded as large blocks in flysch sediments in the region where the Silesian Unit thrusts over the Sub-Silesian Unit (e.g. Książkiewicz 1932, 1935a, b, 1951; Książkiewicz and Liszkowa 1972; Olszewska and Wieczorek 2001; Waškowska-Oliwa et al. 2008; Cieszkowski et al. 2009) (Fig. 2). They are shallow-water sediments deposited on an elevation called Inwałd Cordillera (Waškowska-Oliwa et al. 2008) interpreted as olistoliths and olistostromes moved to deep-sea flysch basins in a consequence of submarine mass movements (Waškowska-Oliwa et al. 2008). The group of “other outcrops” also includes a site of Holocene calcareous tufa (site 23, Fig. 3; Tables 1 and 2).

Inwałd (Site 18, Figs. 3 and 4, Tables 1 and 2) Outcrops of limestones belonging to the Štramberg facies (Late Tithonian), common in the Carpathians, can be found in a non-operated quarry (Książkiewicz 1932, 1935a, 1951; Waškowska-Oliwa et al. 2008). The fauna found here indicates the shallow-water sedimentation in a reef environment (Waškowska-Oliwa et al. 2008). Furthermore, in this quarry a contact between limestones and mylonite is also visible. The mylonite represents the Early Palaeozoic and was formed from eroded waste of igneous rocks subjected to tectonic pressures. Marls containing fauna of the Late Cretaceous can also be found here (Książkiewicz 1951; Książkiewicz and Liszkowa 1972; Waškowska-Oliwa et al. 2008). Carbonate rocks reach to flysch rocks of the Sub-Silesian (in the north) and Silesian (in the south) Units (Książkiewicz 1951; Książkiewicz and Liszkowa 1971; Waškowska-Oliwa et al. 2008). The site is a geological monument.

Targanice (Site 20, Figs. 3 and 4; Tables 1 and 2) A contact between the Andrychów Series and flysch sediments is visible along banks of the Targaniczanka Stream (Książkiewicz 1935b, 1951; Książkiewicz and Liszkowa

1972; Waškowska-Oliwa et al. 2008). Here, the Andrychów Series is represented by the Late Jurassic limestones with chert lenses. Their development, together with palaeontological contents, indicates that they were formed in a slightly deeper sea than Štramberg limestones disclosed in Inwałd (site 19) (Książkiewicz 1951; Olszewska and Wieczorek 2001). Further along the stream, Late Cretaceous limestones with cherts and marls containing Foraminifera microfauna can be found. The youngest elements of the profile are marls and shale with inserts of limestone of organic origin, with remains of Bryozoa representing the Palaeocene (Olszewska and Wieczorek 2001). The entire profile was selected to be included to the European Geosites Network (Alexandrowicz et al. 1988, 1999; Alexandrowicz 2006). The site is a geological monument.

Roczynny (Site 21, Fig. 3; Tables 1 and 2) Here, the oldest elements of the Andrychów Series can be found, crinoidal limestones representing the Callovian (Książkiewicz 1935a; Olszewska and Wieczorek 2001; Waškowska-Oliwa et al. 2008). Limestones with cherts, similar to those found in Targanice (site 20) and limestones of the Štramberg facies similar to those described for the Inwałd site (site 18), are slightly younger. Late Jurassic rocks are covered by limestones and marls containing microfauna of the Late Cretaceous (Książkiewicz 1951; Olszewska and Wieczorek 2001). The site is a geological monument.

Domaczka Stream (Site 22, Fig. 3; Tables 1 and 2) In the stream bed and on its banks, shale, mudstones, sandstones and marls are denuded, belonging to the Cretaceous, the Palaeocene and the Eocene of the Sub-Silesian Unit. They contain a rich microfauna (the plankton Foraminifera, the Radiolaria and calcareous nannoplankton). Blocks of limestone and crystalline rocks can also be found. It is an example of an olistostrome created as a result of a submarine landslide active in the Early Miocene (Wójcik et al. 1999). This outcrop was selected to be included to the European Geosites Network (Alexandrowicz et al. 1988, 1999; Alexandrowicz 2006).

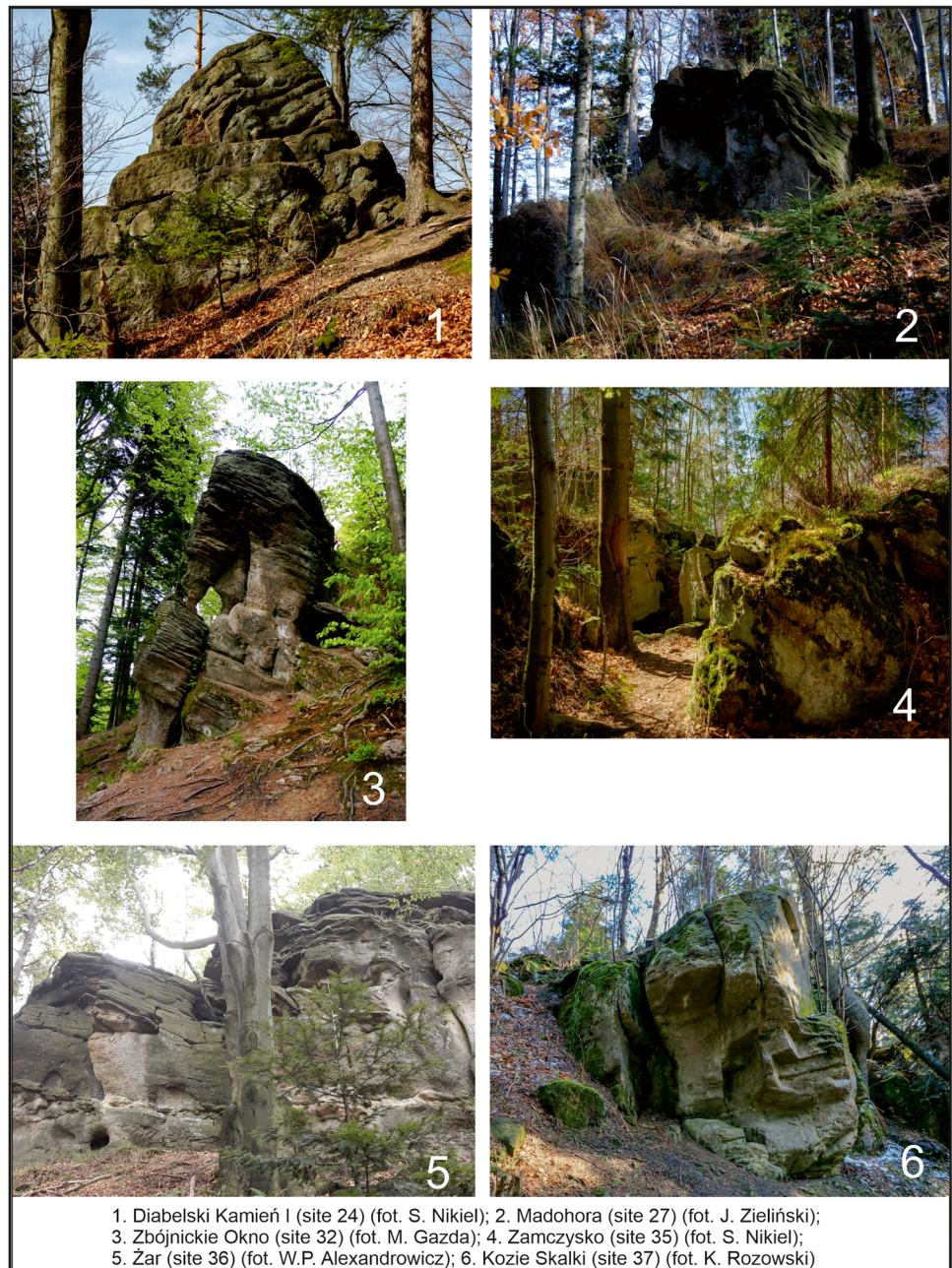
The outcrops of the Andrychów Series are of great importance for understanding palaeogeography of the flysch basin of the Outer Carpathian. The sites in Inwałd, Targanice and Roczynny, together with the quarry on Pańska Góra (site 19), are easily accessible and offer good conditions for observations. Due to a complex nature of issues related to sediments, facies and tectonic, all sites with Andrychów Series require visitors to have an extensive knowledge in Earth science. Educational paths are planned in the quarry in Inwałd and on Pańska Góra (Zieliński et al. 2007, 2011).

Sandstone Landforms (Tors)

Most of the sandstone tors in the Beskid Mały are located in the outcrop zone of the lower part of the Istebna Formation (Campanian–Maastrichtian; Silesia Unit). They are a thick-bed sandstones with feldspars and exotic conglomerates, with pieces of crystalline and sediment rocks. The individual beds show traces of amalgamation, and their thickness frequently exceeds 4 m. The tors in the Żurawnica range are formed from thick-bed sandstones included in the Żurawnica Sandstones member and belonging to the Magura Unit. Both divisions mentioned above are sediments of high density

gravitational currents of the fluxoturbidite type deposited in distribution channels of an upper fan (e.g. Shanmugam and Moidola 1988; Reading and Richards 1994; Leszczyński 1989; Shanmugam 1996, 2016). In the case of sandstone tors, their geomorphological values are of importance. These forms are frequently noticeable in the landscape as towers, slope pulpits and thresholds. Original shapes of these rocks mainly depend on a lithological composition of sandstones, their beds, sedimentation structures and processes of selective weathering. Several dozen sandstone tors were registered in the Beskid Mały region (Alexandrowicz 1978). Due to their educational, visual and aesthetic properties, they are

Fig. 5 Examples of geosites: sandstone tors



particularly valuable as geotourist attractions (Alexandrowicz 1978, 2008; Strzeboński 2009). For the purpose of this study, 14 sites (sites: 24–37) with attractions representing single or (more frequently) groups of rocks were selected.

Diabelski Kamień I (Devil's Stone I) (Site 24, Figs. 3 and 5, Tables 1 and 2) It is an isolated rocky tower that is 10 m long, 4.5 m wide and 5 to 7 m high, consisting of thick-bed sandstones and conglomerates (upper fan; channel sediments of the fluxoturbidite type) (Istebna Formation (lower part), Silesian Unit) (Alexandrowicz 1964a, 1978). The tor is a geological monument.

Madohora (Site 27, Figs. 3 and 5, Tables 1 and 2) It is a complex of tors consisting of thick-bed sandstones and conglomerates (upper fan; channel sediments of the fluxoturbidite type) (Istebna Formation (lower part), Silesian Unit) (Książkiewicz 1951; Alexandrowicz 1963a, 1964b, 1978). The steep slopes of the hill are characterised by numerous tors of various size and shape, limited by joint cracks. The external parts of these forms frequently became separated and slid down the slope, forming accumulations of blocks and slabs of various sizes (Alexandrowicz 1963a, 1978). At some places, the hill slopes are framed by high rock walls disclosing sedimentation structures clearly exposed by selective weathering. The area of so-called Zwalisko, representing a labyrinth of rock slide forms, including fissures, walls, thresholds and sandstone slabs, can be considered particularly interesting (Fig. 5) (Alexandrowicz 1964b). With a large number of tors, Madohora has a unique ruin relief (Migoń et al. 2017). The rocks are located in the nature reserve “Madohora”.

Okno Zbójcekie (The Robbers' Window) (Site 32, Figs. 3 and 5, Tables 1 and 2) The tor can be found at the western end of a belt of outcrops of the thick-bed sandstones and conglomerates belonging to Istebna Formation (lower part; Silesian Unit). It has a form of an elongated tower of 30 × 13 m at its base and 9 m high (Alexandrowicz 1963b, 1978). On its walls, sedimentation cycles associated with phases of fluxoturbidite deposition are visible. A window of 1.2 × 1 m is a characteristic element of this rock (Fig. 5). The tor is a geological monument.

Zamczysko (The Castle) (Site 35, Figs. 3 and 5, Tables 1 and 2) It is a labyrinth developed along a system of gravitationally open joint cracks in the Istebna Formation (lower part; Silesian Unit) (Alexandrowicz and Alexandrowicz 1988). The lateral vertical walls of the labyrinth corridors are up to 12 m high. This site also includes several crack caves. The largest of them is Jaskinia Lodowa (Ice Cave), 59 m long and 10 m deep (site 42, Fig. 3, Tables 1 and 2). It is the only cave in the Polish Carpathian (outside the Tatra Mountains)

in which a permanent ice cover can be found (Klasek 1997). The outcrop is protected as a geological documentation site.

Skałki na Górze Żar (Tors on Żar) (Site 36, Figs. 3 and 5, Tables 1 and 2) They include three sites of tors formed of sandstones and conglomerates of the Istebna Formation (lower part; Silesian Unit). The largest form is shaped as a 9-m-high and 50-m-long slope pulpit (Alexandrowicz 1963c). Thick beds deposited by high density currents (fluxoturbidites) are visible on the walls. Numerous exotics, mainly gneiss, can be found in the conglomerates (Alexandrowicz 1963d). In the sandstones, horizontal and cross lamination, normal, locally inverted graded bedding and hollows left by clayey pebbles are visible. The sedimentation structures are exposed by a process of selective weathering determined, on one hand, by lithological parameters of the rocks, and on the other, by exposure of the rocks and different thermal and humidity conditions (Alexandrowicz and Brzeźniak 1989). The tor is a geological monument.

Kozie Skały (Goat Rocks) (Site 37, Figs. 3 and 4, Tables 1 and 2) This is a belt of tors stretching along the range over ca. 750 m. The height of individual forms exceeds 10 m. In some places, gravitational shifts of blocks separated along the joint cracks are visible, indicating the initial phase of the landslide development (Alexandrowicz 1978; Margielewski and Urban 2003; Margielewski 2004; Alexandrowicz and Alexandrowicz 2006). The rocks are formed of thick-bed sandstones classified as the Żurawnica sandstone member, Łabowa Formation (Magura Unit).

All presented tors are located near tourist trails. Some of them are described in guidebooks and marked on maps. Therefore, these sites are important from the point of view of geotourism development and have large scientific, educational and aesthetic value. On the other hand, the rocks are exposed to damage due to the man activities, especially, because they are used for climbing and in particular for bouldering (Alexandrowicz 2017).

Caves

Caves formed in thick-bed sandstone complexes, with corridors 30 to 50 m long, on average, and maximum length of nearly 300 m and the depth of up to 10 m. Development of these forms is associated with mass movements, relaxation and gravitation processes, resulting in opening of the cracks. They are typical crack caves (Margielewski and Urban 2003), characterised by narrow corridors of parallel walls, sometimes crossing and forming larger chambers. Several dozen caves can be found in Beskid Mały (Klasek 1997).

Grota Komonieckiego (Komoniecki Cavern) (Site 40, Figs. 3 and 4, Tables 1 and 2) It is a cavern with a wide entrance (16×2 m), containing a large chamber of over 100 m² and several narrow and short crack corridors. The cave is covered by a thick bed of sandstones belonging to the Istebna Formation (lower part; Silesian Unit). In the vicinity of the cave, there is also the Dusiołek waterfall, 2.5 m high (site 47; Figs. 3, Tables 1 and 2). The cave was first mentioned at the beginning of the seventeenth century (Grodziski and Dwornicka 1987). The conducted archaeological studies indicate that it was periodically inhabited already in the Neolithic (Foltyn 1990; Waga 1993). The cave is a geological monument.

Czarne Działy (Czarne Działy Caves) (Site 41, Fig. 3, Tables 1 and 2) It is a complex of several adjacent crack caves that formed within thick-bed sandstones of the Istebna Formation (lower part; Silesian Unit). Three larger forms of corridors of up to 55 m long (Klassek 1997) and several smaller cracks were described here. The two largest caves are protected as geological monuments.

Mysiorowa Jama (Mysiorowa Pit) and Jaskinia Lisia (Fox Cave) (Sites 43 and 44, Fig. 3, Tables 1 and 2) Mysiorowa Jama is the longest cave in Beskid Mały, with determined corridor length of 282 m (Klassek 1997). It was formed by gravitational expansion of joint cracks within thick-bed sandstones of the Istebna Formation (lower part; Silesian Unit) (Alexandrowicz and Lizak 1997). The cave is characterised by a complicated layout of its corridors and several large chambers. Jaskinia Lisia is about 20 m long and 3 m deep. It is possible that both caves are connected by a system of cracks. They are protected as geological monuments.

The crack caves in Beskid Mały are forms of a large scientific importance both from the geological and from the wild life (habitats of bats) points of view. Some of them are located near tourist trails, or access routes to them are marked. On the other hand, these sites are dangerous for possible tourists, and in many cases, they can be accessed only with a special equipment.

Waterfalls and Fragments of Brook Valleys

In certain stream valleys crossing the Beskid Mały range, cascade waterfalls typical for flysch areas can be found, characterised by systems of low rapids (Alexandrowicz 1994). These rapids develop on thicker and more resistant sandstone beds. The erosive evolution of cascades depends mainly on the thickness of sandstone beds, a sequence of formations and their position (layer course and dip) in relation to a stream course. Typical examples of such cascade waterfalls can be observed in the Rzyczanka Stream valley

(site 49; Figs. 3 and 4, Tables 1 and 2) and in the fragment of the Pracica Stream valley protected as a geological monument (site 46; Fig. 3, Tables 1 and 2). Both these sites are located near traffic routes.

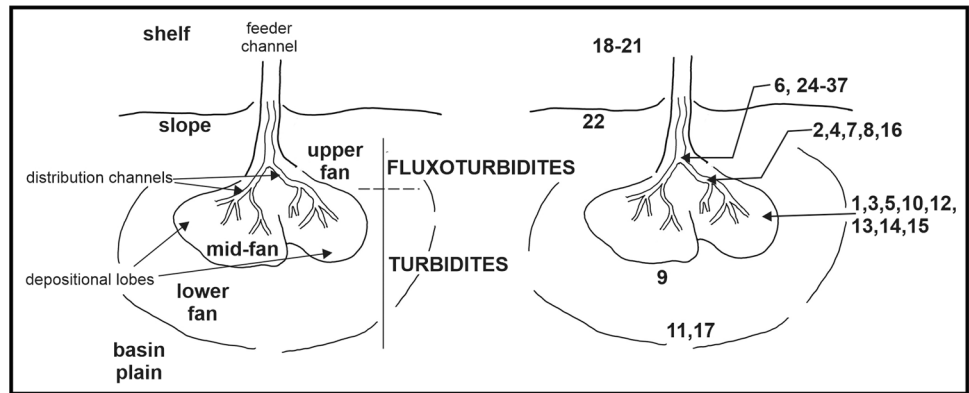
Geotourist and Educational Values of Geosites in Beskid Mały

The geological sites in the Beskid Mały range, presented above, have a large geotourist potential. The majority of these sites are characterised by a good condition of the outcrops and are easily available and located near tourist trails and communication routes. The sites can be used to present a wide range of Earth science issues, and in particular:

Elements of the Regional Structure and a Morphology of a Sedimentation Basin Beskid Mały is built by flysch sediments typical for the Outer Carpathians. The rocks found in the discussed area are included into three tectonic units: Magura (sites 16, 17, 37), Silesian (sites 1–12, 14, 15, 24–44, 46–49) and Sub-Silesian (site 13) (Fig. 3, Tables 1 and 2) representing the Cretaceous and the Palaeogene. During uplifting (the Early Neogene), they formed separate nappes shifted to the north, overlapping and uplifted. Sites present main lithostratigraphic divisions and their role in the geological structure of this region. Apart from a typically developed deep-sea flysch, limestones and marls are denuded in the northern part of the range, in some cases accompanied by blocks of crystalline rocks. These elements are of olistostrome or olistolith character and got into the flysch formations in consequence of submarine landslides from an elevated zone separating the Silesian and the Sub-Silesian Basins, the so-called Inwałd Cordillera (Waśkowska-Oliwa et al. 2008). The outcrops of the above-mentioned sediments enable the characterisation of the primary morphology of the flysch basin (sites 18–22) (Fig. 3, Tables 1 and 2).

Deposition of Flysch Deposits The flysch formations can be observed at the majority of the presented sites. Flysch is deposited within deep-sea fans (e.g. Shanmugam and Moiola, 1988; Reading and Richards 1994; Shanmugam 2016) (Fig. 6). In Beskid Mały, sediments of different types of gravitational currents deposited at various parts of a submarine fan can be found. The first group includes thick-bed sandstones and conglomerates with exotics, without shale insertions. The sedimentation structures are usually poorly visible. Graded bedding and in some cases also water escape structures and parallel lamination can be recognised. Sediments of such character were deposited by high density currents (fluxoturbidites) or by sandy flows within distribution channels of an upper fan (e.g. Shanmugam and Moiola 1988; Reading and Richards 1994; Leszczynski

Fig. 6 Lithofacial differentiation of geosites in Beskid Mały against the model of flysch deposition (after: Shanmugam 2016; simplified)



1989; Shanmugam 1996, 2006, 2016) (Fig. 6). Such lithofacies can be observed at sites 6, 24–37, 40–44 and 47 (Figs. 3 and 6, Tables 1 and 2). Sediments deposited in the middle part of the fan developed in a different way. They are characterised by the presence of sandstone and shale sequences. A similar ratio of sandstones and shale is typical for zones of deposition lobes. A predomination of sandstones indicates the sedimentation process within the distribution channels (e.g. Shanmugam and Moiola 1988; Reading and Richards 1994; Shanmugam 2016). The described formations develop through sedimentation of low density currents (turbidites). The sandstones are usually characterised by a well-visible specific succession of sedimentation structures (the Bouma sequence (Bouma 1962)), covering five intervals (T_a – T_e). In thicker sandstone beds, normal graded bedding is usually visible (interval T_a). However, various types of laminations corresponding to intervals T_b , T_c and T_d can be observed. Numerous hieroglyphs (mechanical and biological) are visible on thill surfaces of the beds. Sediments of the turbidite type are denuded at sites 1–5, 7, 8, 10, 12–16, 38, 39, 45, 46, 48 and 49 (Figs. 3 and 6, Tables 1 and 2). Sequences with predominating shale represent a lower fan and are formed through deposition of diluted turbidity currents. Here, the predominating shale is accompanied by thin beds of laminated sandstones representing roof segments of the Bouma sequence (usually, interval T_d). Their thill surfaces are characterised by the presence of hieroglyphs. Sediments of that character can be observed at sites 9, 11 and 17 (Figs. 3 and 6, Tables 1 and 2).

Formation of Sandstone Tors Numerous sandstone landforms can be found in Beskid Mały, usually rocky pulpits, towers, ridges and thresholds, in some cases of a significant size. These forms were created through joint action of various denudation processes, especially weathering and mass movements occurring in conditions of a periglacial climate during the Pleistocene. At this time, thick-bed complexes of sandstones and conglomerates were exposed (e.g. Alexandrowicz 1978; Strzeboński 2009). The forms created this way on one hand

represent outcrops of flysch sediments, especially those formed by high density currents (fluxoturbidites), while on the other they are impressive geomorphological structures (sites 24–37) (Fig. 3, Tables 1 and 2).

Present Geomorphological Processes

- Weathering. Sandstone tors are particularly convenient sites for observation of weathering phenomena (sites 24–37) (Fig. 3, Tables 1 and 2). Here, manifestations of both physical and chemical processes are visible. This first group includes effects of frost causing separation of rock blocks or granular disintegration occurring very clearly especially in conglomerate beds. Furthermore, exfoliation processes can also be observed on the rock surface. A characteristic manifestation of chemical processes is the development of the weathering crust. It mainly develops due to the movement of secondary minerals towards the surface and their influence on rock walls (Alexandrowicz and Pawlikowski 1982; Alexandrowicz et al. 2014; Alexandrowicz and Marszałek 2019).
- Mass Movements. They occur within slopes and cause movements of rock masses. Then a system of open underground cracks and formation of crack caves develops within zones of thick-bed sandstone outcrops, examples of which can be found at sites 38–45 (Fig. 3, Tables 1 and 2). Similar processes also occur on the surface, resulting in opening of cracks in sandstone tors. In consequence, diverse forms of separated blocks are created, resulting in a specific ruin relief of the area (Alexandrowicz and Alexandrowicz 1988; Margielewski 2004; Migoń et al. 2017).
- Erosion in Stream Valleys. This process leads to the creation of waterfalls. Cascade waterfalls developing in obsequent valleys in sandstone and shale complexes are particularly impressive. In this case, waterfalls form on thicker, more resistant sandstone beds (Alexandrowicz 1994) (sites 46–49) (Fig. 3, Tables 1 and 2).

- d. 4d. Precipitation of Calcareous Tufa. In the area of the Flysch Carpathian, these processes occur near springs. Calcium carbonate precipitates in consequence of changes pressure and temperatures and CO₂ absorption by plants (Alexandrowicz 2009) (site 23) (Fig. 3, Tables 1 and 2).

Conclusions

1. One of the main assumptions of geotourism is a support for geoprotection by creating a chain of site promoting and spreading knowledge about a geological structure and a relief of a selected area. Educational geotourism is therefore an element supporting conservation of the geological heritage.
2. To this date, Beskid Mały is one of several planned geotouristic areas in the Polish Carpathians. The presented geosites are easily accessible through tourist trails and traffic routes. They represent both sites of significant educational values, and attractions distinguished by their landscape and aesthetic characteristics.
3. The Beskid Mały area covers fragments of three lithostratigraphic flysch units tectonically overlapping each other and shifted to the north. They include the most northerly located Sub-Silesian Unit, the most extensively present Silesian Unit and the northern part of the Magura Unit. The Silesian Unit plays the most important role in the geological structure of the region, and its sediments can be observed at many outcrops. They are characterised by high lithofacies diversity and present issues associated with sedimentation mechanisms of flysch sediments.
4. The sandstone and conglomerate complexes included in the Silesian Unit (Istebna Formation, especially its lower part) and Magura Unit (the Żurawnica sandstone) create impressive tors. Apart from their aesthetic values, they represent good outcrops of sediments of high density currents (fluxoturbidites).
5. In the northern marginal zone of Beskid Mały, the Andrychów Series is denuded in form of olistoliths and olistostromes. They mainly include limestones and marks and block of crystalline rocks. They belong to the oldest formations found in the Outer Carpathians region. The Andrychów Series represents a substrate of flysch sediments and illustrates the palaeogeographical variability of the flysch basin.
6. Sites with sandstone rocks, caves and rock fragments of river valleys can be used to present issues associated with currently occurring geological processes: weathering, mass movements and fluvial erosion.
7. A number of described geosites are legally protected (geological monuments and geological documentation sites) or are located at protected areas (landscape park, nature reserves, the Natura 2000 area), which emphasises their importance for the nature, science and education.
8. Historical records of Komoniecki from the seventeenth century (Grodziski and Dwornicka 1987) prove the knowledge and respect for specific rock formations.
9. To adapt the geological sites to their role of geotourist attractions, it is necessary to widely promote their values in publicly available sources (tourist guidebooks, maps and Internet sources). Also, this purpose is supported by the creation of nature or geological educational paths. There are several such trails established in Beskid Mały, and more are planned. Another good way for the promotion of geological issues can be the development of special applications that can be downloaded to mobile phones for free. It is also important to ensure that these attractions are well-marked, and potentially dangerous places are secured.
10. To maintain the value of tourist attractions, they must be protected against destruction. Many sandstone tors are used as climbing areas. This leads to their destruction, especially, through the establishment of permanent anchor points and the use of climbing chalk. In the case of quarries, they must be protected against being used as illegal landfills.
11. When the range of tourist services of Beskid Mały is expanded by geotourist sites, the attractiveness of this region will increase. At the same time, educational values of the sites presented above will contribute to the promotion of the knowledge of Earth science and, eventually, to the intensification of activities aiming at conservation of the geological heritage.

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Declarations

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