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Rocky Sandstone Landforms in Istebna, Silesian Beskid (Outer Carpathians, Poland)

Piaskowcowe formy skałkowe w Istebnej (Beskid Śląski, Karpaty Zewnętrzne)

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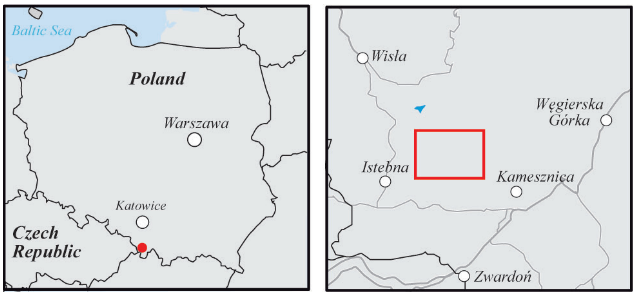

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Abstract: *The rocky sandstone landforms, which are interesting geotouristic objects, occur in the eastern part of Istebna village. The series of rock walls and pulpits is located on the southern slopes of the Karolówka Range. Fragments of the upper sandstones of Istebna Formation (Upper Cretaceous–Paleocene) crop out within these rocks. They represent the period of intensive supply of the clastic material into the Outer Carpathian Silesian Basin leading to the origin of thick-bedded, very coarse-grained sandstones and conglomerates. The occurrence of large, numerous crystalline rocks is a particular and unique feature of these outcrops. These magmatic and metamorphic rocks were derived from the basement of the Carpathian basins. This paper describes the detailed characteristics of these rocky landform objects.*

Keywords: *sandstone rocky landforms, Istebna Formation, Silesian Nappe, Silesian Beskid, thick-bedded gravity deposits, exotics*

Treść: *We wschodniej części wsi Istebna występują piaskowcowe formy skałkowe, które są interesującymi obiektami geoturystycznymi. Są to serie ambon i ścian skalnych znajdujące się w kilku miejscach na południowych zboczach grzbietu Karolówki. W ich obrębie odsłonięte są fragmenty profilu górnych piaskowców formacji istebniańskiej jednostki śląskiej (górna kreda-paleocen), które reprezentują okres intensywnej dostawy materiału okruchowego do karpackiego basenu śląskiego, w efekcie czego powstały serie gruboławicowych i bardzo gruboławicowych piaskowców i zlepieńców. Szczególną cechą związaną z tymi wychodniami jest obecność licznych i dużych bloków skał krystalicznych: magmowych i metamorficznych, pochodzących z erozji podłoża, na którym rozwinęły się baseny karpackie. W niniejszym artykule dokonano charakterystyki jednostkowej tych obiektów skałkowych.*

Słowa kluczowe: *formy skałkowe, formacja z Istebnej, płaszczowina śląska, Beskid Śląski, gruboławicowe osady spływów grawitacyjnych, egzotyki*

Introduction

The Outer Carpathians area is characterized by its high local and regional geotouristic potential related to morphological features (e.g. Alexandrowicz, 1978, 2008; Alexandrowicz & Poprawa, 2000; Radwanek-Bąk *et al*., 2009; Doktor *et al*., 2010; Słomka (ed.), 2013). The variety of the geomorphological forms depends on the geological structure of this area. The Outer Carpathians are built up mainly by turbiditic deposits represented by siltstones, mudstones, sandstones, conglomerates, and subordinately by marls, cherts, limestones and pyroclastic rocks. The turbidites were classically described as alternating beds of siltstones/mudstones and sandstones/conglomerates; however particular lithostratigraphic units display exclusive or dominant occurrence of one lithological member. In the case of coarse clastic deposits (sandstones-conglomerates), these form rocky landforms that are scattered about the Outer Carpathians area. The rocky landforms are represented by erosional monadnocks containing more weathering-resistant rocks. They belong to the specific Carpathian geomorphologic forms that have aroused touristic interest for many years. They are non-coincidentally located on touristic trails and marked on the touristic maps as characteristic landforms and interesting objects worth visiting, often having their own names. Several rocky landforms are protected by law, because they contain valuable and unique elements of the natural environment (e.g. Alexandrowicz, 1977, 1978, 2008; Alexandrowicz & Poprawa, 2000; Buła & Wieland, 2000; Radwanek-Bąk *et al*., 2009; Słomka (*ed.*), 2013; Tokarska-Guzik *et al*., 2015; Chybiorz & Kowalska, 2017). Most of these rocky landforms occur within the Silesian Nappe of the Outer Carpathians (Alexandrowicz, 1978). Beside the single tors, large gatherings of rocky landforms, named stone towns, are known from the Silesian Nappe within boundaries of Poland. The "Stone Town" in Ciężkowice, "The Spinners" near Krosno or "Devil's Rocks in Bukowiec" belong to this category. They developed in thick-bedded sandstones and conglomerates of the Upper Paleocene–Eocene Ciężkowice Formation (e.g. Leszczyński, 1981; Gruszka, 2009; Słomka (*ed.*), 2013; Stadnik & Waśkowska, 2015). On the other hand, in the western part of the Polish Carpathians, occurrences of rocky landforms are related to the Upper Cretaceous–Paleocene Istebna Formation. Usually, the single rocky landforms or small groups of them are scattered on the slopes or ridge parts of the Beskid Mountains (Alexandrowicz, 1978).

A dozen or so rocky sandstones built of coarse-clastic deposits of the Istebna Formation can be seen in the vicinity of Istebna village. Several fragments of this formation's profile belonging to different stratigraphic horizons are exposed there. The outcrops provide an opportunity to examine lithological variety and factors determining this diversity. The unique aspect of these rocks concerns the occurrence of large size exotic material constituting grains within conglomerates. This material, originating in the Protocarpathians, is considered as the basement on which Carpathian basins of the Tethys Ocean developed (Starzec *et al*., 2017, 2018). Turning our attention to these relatively unknown rocky objects and their geotouristic values constitutes the main goal of this work. These rocky landforms stand out as important elements of the region's morphology and are valuable for scenic, touristic, and scientific reasons.

Study area

The Istebna rocky landforms are located in the eastern part of the Istebna village in the vicinity of the Pietraszonka, Filipionka and Stoczek hamlets as well as in the western part of the Karolówka Range (Małopolska Province, Cieszyn County, Istebna Common). Geographically, this area is situated in the southern part of the Silesian Beskid mountain range, within the upper course of the river Olza (Fig. 1). The rocks

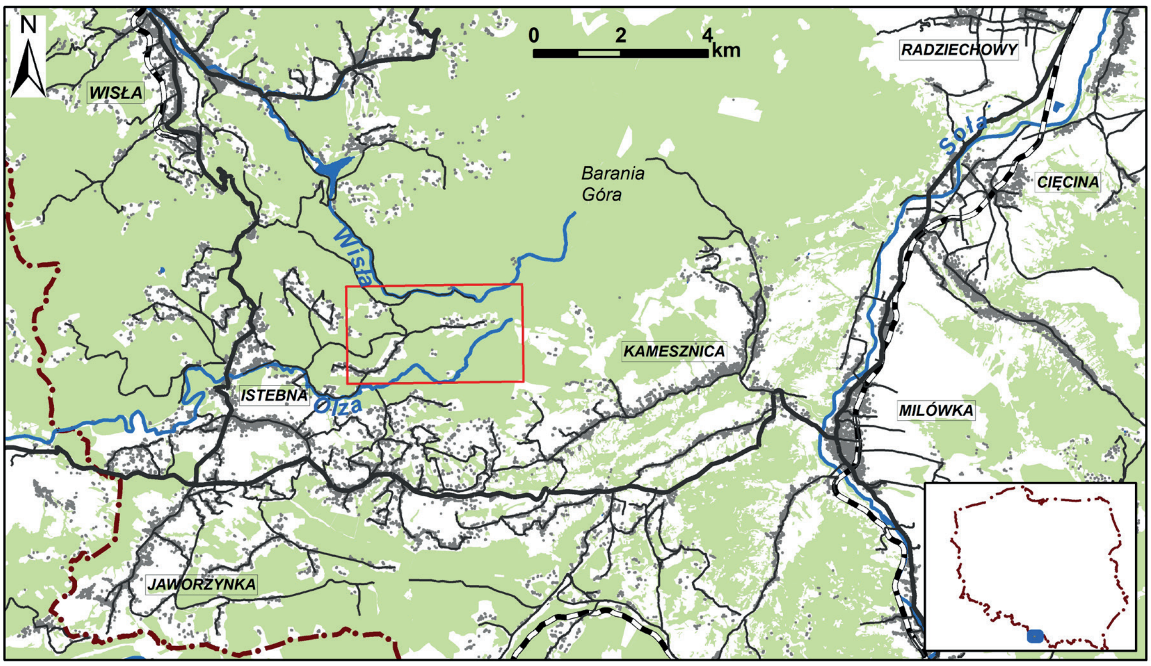

Fig. 1. Location of the studied area marked with a red rectangle on simplified topographical map, showing roads, main rivers, forested and urbanized areas

were eroded in the source fork of the Olza River and in their tributaries flowing from the Karolówka ridge slopes.

The springs of the Olza River take their origin from the area where the lower member of the Istebna Formation occurs. It is on the southwestern part of the Barania Góra (1220 m a.s.l.) massif, the second highest peak of the Silesian Beskid. The Istebna rocky landforms occur in a mountainous area. The main range stretches latitudinally from the Stecówka area, where it reaches 758 m. a.s.l. to the culmination of Karolówka Mountain, 931m a.s.l. in altitude. The slopes are very steep on the northern side of the range, with well-marked steps related to the thick beds of Istebna sandstones (Fig. 2 and 3). The southern slopes are a little gentler tilting consequently with the dip of the upper part of the Istebna sandstone complex. The depression is marked below the Stoczek and Pietraszonka hamlets framed by a morphological step (Fig. 3). The depression is eroded in the less competent complexes of shales, while the step originated in the sandstones. Most of the rock formations are located in the upper part of this step (south of Pietraszonka and northwest of Filipionka, Fig. 3).

The rocky landforms were also sculptured in the fork of the Olza and its tributaries south of Stoczek. The tor cropping out in the axial zone of the Karolówka ridge is also described in this paper. The described rocky landforms are spread over an area of 1 km^2.

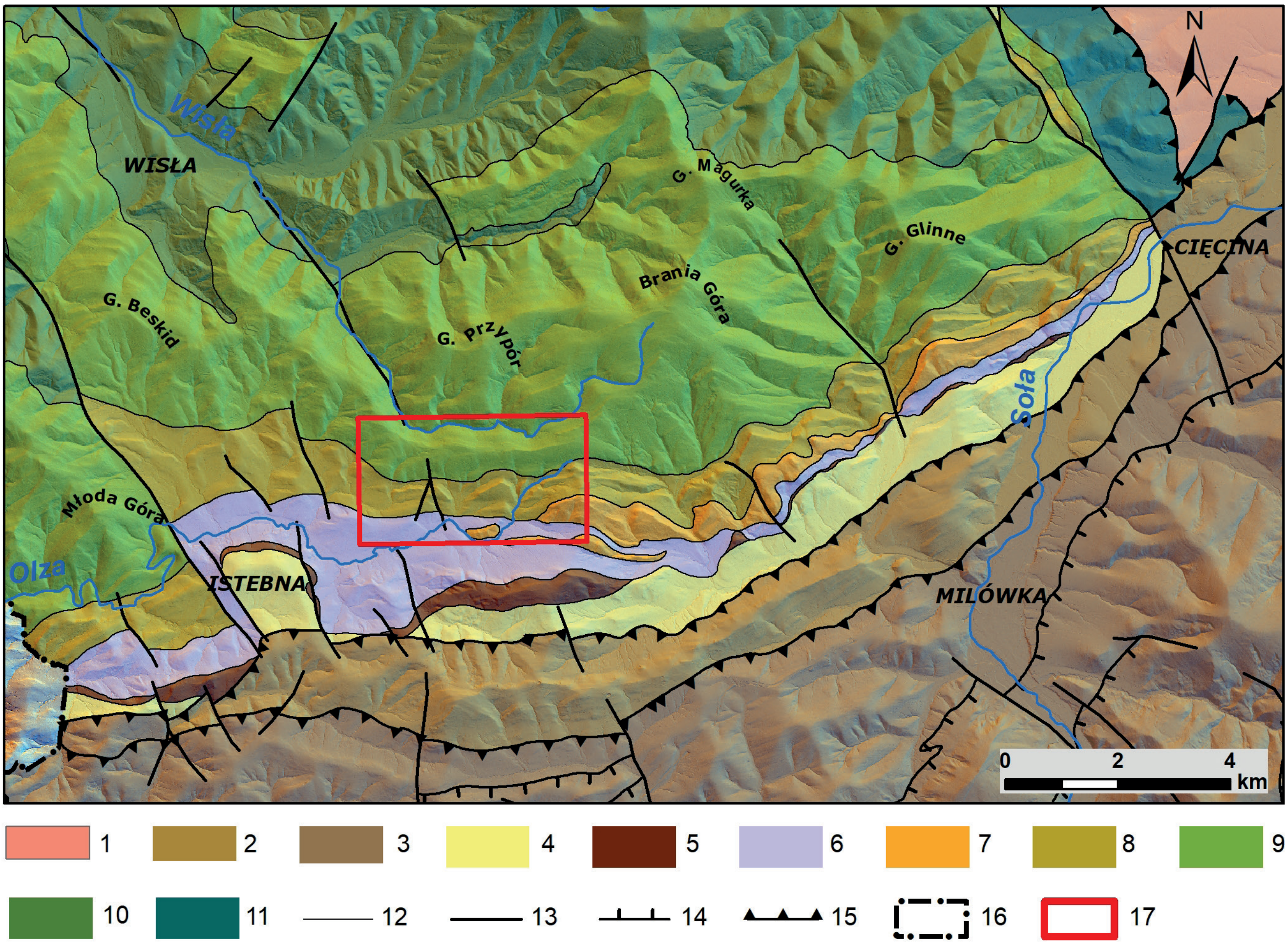

Fig. 2. Generalized geological map of the southern part of the Silesian Nappe at the border, with more southern units, location of the research area. Based on Burtanówna *et al*. (1936) and Starzec *et al*. (2014). Explanations: 1 – Subsilesian Unit – undivided, 2 – Foremagura Nappe – undivided, 3 – Magura Nappe – undivided, Silesian Nappe: 4 – Krosno Formation (Oligocene), 5 – Menilite Formation (Oligocene), 6 – Pogorzany Formation (Eocene), 7 – Ciężkowice Formation (Eocene), 8 – Janoska, Jasnowice and Kamesznica members undivided of Istebna Fm. (formerly Upper Istebna Beds) (Paleocene) – undivided, 9 – Czarna Wisełka Member of Istebna Fm. (formerly Lower Istebna Beds) (Upper Cretaceous), 10 – Godula Formation (Upper Cretaceous), 11 – Lower Cretaceous formations – undivided. Map symbols: 12 – stratigraphic contacts, 13 – faults, 14 – minor thrust faults, 15 –main thrust faults, 16 – Polish border, 17 – studied area. Shaded relief map as background

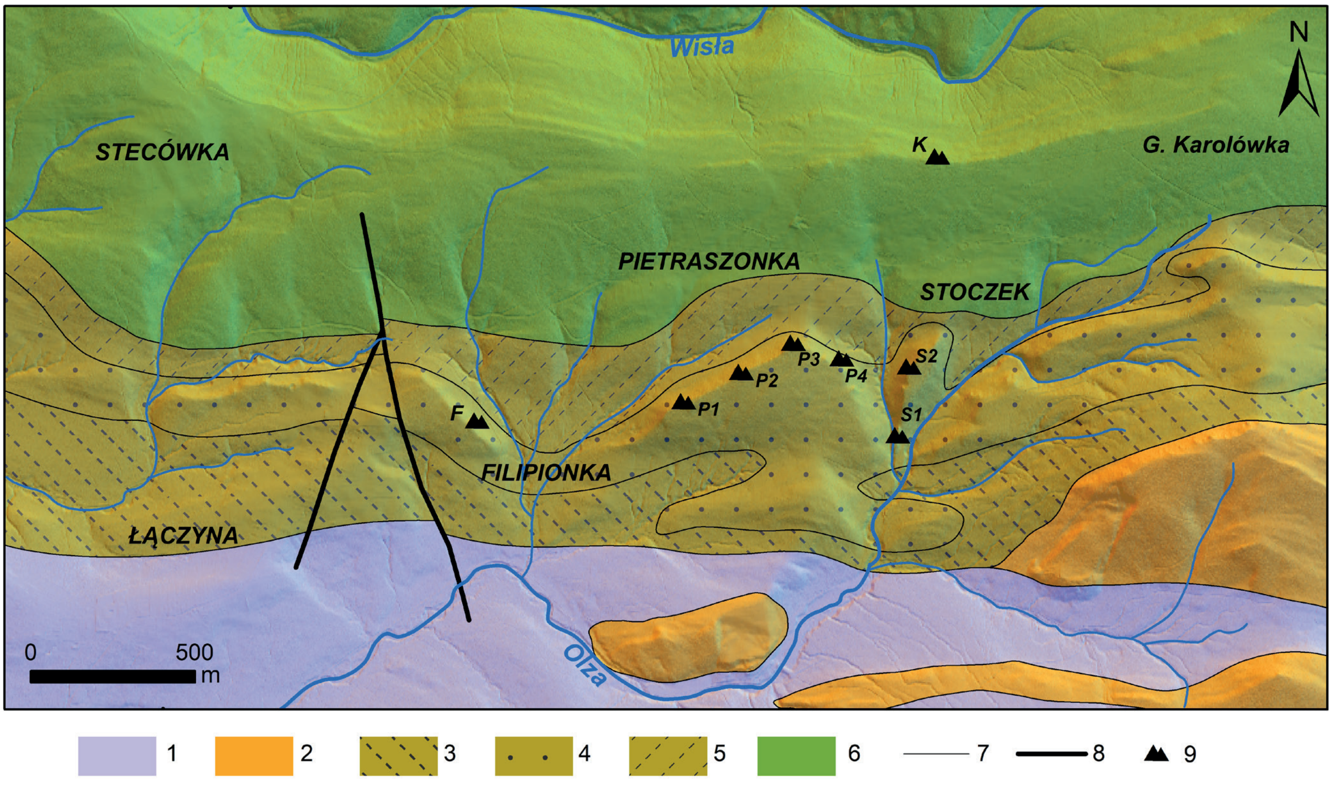

Fig. 3. Detailed geological map of the studied area. Explanations: 1 – Pogorzany Formation (formerly Hierogyphic Beds) (Eocene), 2 – Ciężkowice Formation (Eocene), Istebna Formation: 3 – Kamesznica Member (formerly Upper Istebna Shales (Paleocene), 4 – Jasnowice Member (formerly Upper Istebna Sandstones (Paleocene), 5 – Janoska Member (formerly Lower Istebna Shales) (Paleocene), 4 – Czarna Wisełka Member (formerly Lower Istebna Beds) (Upper Cretaceous), 7 – stratigraphic contacts, 8 – faults, 9 – location of the rocky landforms: *F* – Filipionka, *P1-P4* – Pietraszonka, *S1-S2* – Stoczek, *K* – Karolowka. Shaded relief map as background

The analyzed area is located in the Outer Carpathians, in the western part of the Silesian Nappe, in its southern zone, 2,5 km north of the Fore-Magura thrust front (Fig. 2). The sequence of Upper Cretaceous to Oligocene sedimentary rocks composes the stratigraphic profile of this area (e.g. Burtanówna *et al*., 1937, Burtan *et al*., 1956, Burtan, 1972, 1973) (Fig. 4). The rocky landforms are located within the Istebna Formation outcrops (e.g. Picha *et al*., 2006; Golonka & Waśkowska-Oliwa, 2007 and references therein) (Fig. 2). This formation was first described as the Istebna Beds by Burtan (1936) and Burtanówna *et al*. (1937). The Istebna Formation outcrops spread from the Morawski Beskid in the Czech Republic through the Silesian Beskid, Mały Beskid, up to the Bieszczady Mountains area in the eastern part of the Polish Carpathians (see Żytko *et al*., 1989). This formation is best developed in the Silesian Beskid, reaching around 2000 m in thickness (e.g. Burtanówna *et al*. 1937, Unrug 1963, 1968). According to Golonka *et al*. (2013) the lower 1500 m of this formation belongs to the Czarna Wisełka Member (Lower Istebna Beds according to traditional lithostratigraphic nomenclature), and over 400 m belong to the Janoska, Jasnowice and Kamesznica members (Lower Istebna shales, Upper Istebna sandstones, Upper Istebna shales part of Upper Istebna Beds according to traditional nomenclature of lithostratigraphic divisions) (Fig. 3).

The majority of the described rocky landforms in the Istebna hamlets area is developed within the sandstones of the Jasnowice Member. However, the tors on the Karolówka ridge represent sandstones of the Czarna Wisełka Member (Fig. 3). The rocky landforms formed in this member are known and were described also from a few other localities in the Silesian Beskid (Alexandrowicz, 2008; Słomka (ed.), 2013), while the tors from the Jasnowice Member or Karolówka tor have not yet been described.

The lower Czarna Wisełka Member of the Istebna Formation is composed mostly of very thick sandstones and conglomerate. They form the largest and highest part of the Silesian Beskid range. The Jasnowice Member occupies a much smaller area, since it forms an over three times thinner succession than the lower one. Its middle part is built of similar sandstones and conglomerates as in the lower member, whereas the Kamesznica and Janoska members are represented by dark grey to black, very thin bedded mudstones, abundant in sphaerosiderites. The middle sandstone complex reaches about 100 m in thickness, while the cumulative thickness of the mudstones complexes is about 300 m (Starzec *et al*., 2017), although their thickness, and as a consequence, the width of the rock outcrops, varies along the strike of this member. This particularly holds true for the sandstone complex. The layers of both the lower and upper member of the Istebna Formation lie concordantly, being tilted to the south at an angle of about 22°.

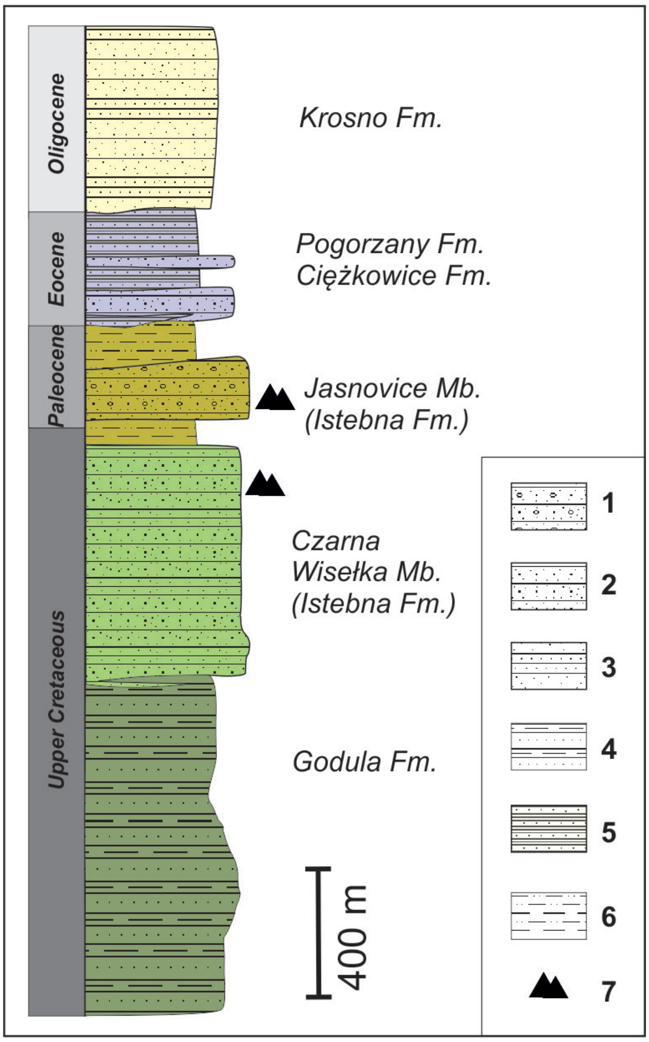

Fig. 4. Lithostratigraphic profile of the Silesian Unit in the Silesian Beskid Mts. (profile according to Burtan, 1972, Starzec *et al*., 2017, modified): 1 – thick-bedded, coarse grained sandstones and conglomerates, 2 – medium-thick bedded, medium and coarse grained sandstones, subordinately conglomerates, 3 – thin- to thick-bedded, medium and fine grained sandstones with thin shale intercalations, 4 – thin-medium bedded sandstones and shales, subordinately thick-bedded sandstones, 5 – sandstone-shale heterolithic deposits, 6 – shales, subordinately with thin bedded sandstones, 7 – fragments of the Istebna Formation's section visible in the described tors

The rocky forms

The series of four N-S striking outcrops represent the rocky landforms in the Stoczek area (Starzec *et al*., 2017). They extend out along the watershed range between the two uppermost branches of the Olza River and between the river's fork and the top of the range (Figs. 1 and 3). They belong to the table-like top or near table-like top outcrops. The most spectacular rocky landform is located in the fork zone of the river (Fig. 5A). It is a rock tower (classification of rocky landforms according to Alexandrowicz, 1978) 30 meters long and 8 meters high (Starzec *et al*. 2017). The near-surface 6 meter high rock pulpit with the horizontal cave is located higher up in the morphology. Respectively, a near-surface series of 5 meter high and several tens meters long rock walls can be seen.

The rocky landforms in the Pietraszonka area constitute the 70 meters long series of the table-like top or near table-like rock pulpit and walls (Fig. 5B-D), stretching along the western bank of the Olza river branch that divides the slope between Stoczek and Pietraszonka (Fig. 3). The rock pulpits reach 10 meters in height and are 725 to 750 m a.s.l. in altitude (Barański, 2007). The slope tilting northward from the tors base is very steep, covered by young beech trees on the western side and by old firs on the eastern side. A forest road runs at the foot of the slope.

The rocky landforms in the Filipionka area constitute the westernmost occurrence of the Istebna sandstones in the tors' form within the investigated area. A single, significant in size, rock pulpit is found here (Fig. 5C). It reaches almost 15 m in width and 680 m a.s.l. in altitude. The pulpit's upper part constitutes the table-like top of the ridge. The top and base of the tor offers a scenic view northward on the valley between Filipionka and Pietraszonka (Fig. 6). The slope dips gently southward. Dense young birch woods cover the slope below the tor base and the forest road at the hill base is abandoned and partially covered by vegetation.

The rocky landforms on the Karolówka ridge – two neighboring tors are located in the top zone of the Karolówka ridge. They form rock pulpits (Fig. 5E). Their height, up to 4 m between the base and top, is much smaller compared with the previously described tors. The tors located at the black trail running along Karolówka ridge reach 860 m a.s.l. The high-power electric line runs a dozen or so meters from the western tor, perpendicularly to the Karolówka ridge strike. The landslide forms originated after clear cutting of the woods along this line. The landslide bowl and tongue are well marked; the crown reaches the tor base.

Fig. 5. Rocky forms in the studied area: A – spectacular rock tower in the Stoczek area, 8 m high (*S1* in Fig. 3), B – 5 m high table-like rock pulpit in the Pietraszonka area (*P3* and *P4* in Fig. 3, respectively), C – almost 15 m high rock pulpit in the Filipionka area (*F* in Fig. 3), D – 10 m high table-like rock wall, E – rock pulpit at the top of the Karolówka Ridge, 4 m high (*K* in Fig. 3); photo K. Starzec

Fig. 6. View northward from the top of the rock tor pictured in Fig. 5C. The valley between Filipionka and Pietraszonka, with slightly uneven surface, is occupied by the Janoska Member shales. Dotted yellow line marks the boundary between shales and sandstones. Orange arrow indicates steep slope with rock walls on its top in the Pietraszonka area (see Fig. 5B, Fig. 5D). Dotted white line marks the border between two sheet-like packages of thick bedded sandstone layers that gently dip to the south; photo K. Starzec

The lithology of the rocky landforms

The Istebna Formation is a sand-dominated lithostratigraphic unit. It consists mostly of thick-bedded (mainly 1–4 m), coarse-grained sandstones and granule/fine-pebble conglomerates with rare interbeds of shales or thin-bedded fine-grained sandstone-shale packets. As was mentioned above, there are also two thicker shale complexes, belonging to the Kamesznica and Janoska Members that consist almost exclusively of black shales. They represent only about 15% of the Istebna Formation succession. Locally gravelly or pebbly mudstones are an important component of this formation (Unrug, 1963; Strzeboński, 2005). These rocks are built with a muddy matrix in which granules, pebbles and boulders are randomly distributed. In the area of Istebna, which is the *locus typicus* (type locality) for this unit, conglomerates with large sized clasts represent a significant, locally prevailing part of the formation. Each of described rock tors is composed of conglomerate and sandstones with a different ratio of these two lithologies. Within the Filipionka and Stoczek localities conglomerates predominate, whereas the tors on Pietraszonka and Karolówka ridge are mainly built of coarse-grained sandstones that in some parts are conglomeratic.

Within the tors south of the Stoczek hamlet the thickest part of the Jasnowice Member (Upper Istebna Sandstone) profile is exposed in the most southern one (Fig. 5A). It begins with a thick conglomerate layer that reveals normal grading. Quartz and different crystalline lithoclasts form the biggest components within the conglomerate, with maximum size reaching about 4 – 6 cm. In the middle part of the layer shale clasts and more often caverns after these clasts occur (Fig. 7A). The caverns are elongated, usually disc-shaped, and sometimes contain only remnants of the material that once filled them. Shale clasts are interpreted to have formed when already lithified shaly deposits were torn from the underlying beds by gravity currents and carried away in fragments and, subsequently, deposited with coarse-grained material (Stadnik & Waśkowska, 2015). The conglomerate layer reveals a sharp top surface, and it has a distinctive border with another conglomerate. Within the lower part of the latter one, a thirty-cm thick interval with reverse grading occurs, passing to the top into normal grading. The normal graded interval starts with granules, reaching about 1 to 6 cm in diameter, and changes to the top of the layer into medium to fine gravel. At about 1.3 m above the bottom of the layer, the largest crystalline boulders are enclosed. The biggest boulder reaches 70 cm (Fig. 7B). They have different shapes. Some of them are angular, but there are also very well rounded ones (Fig. 7C).

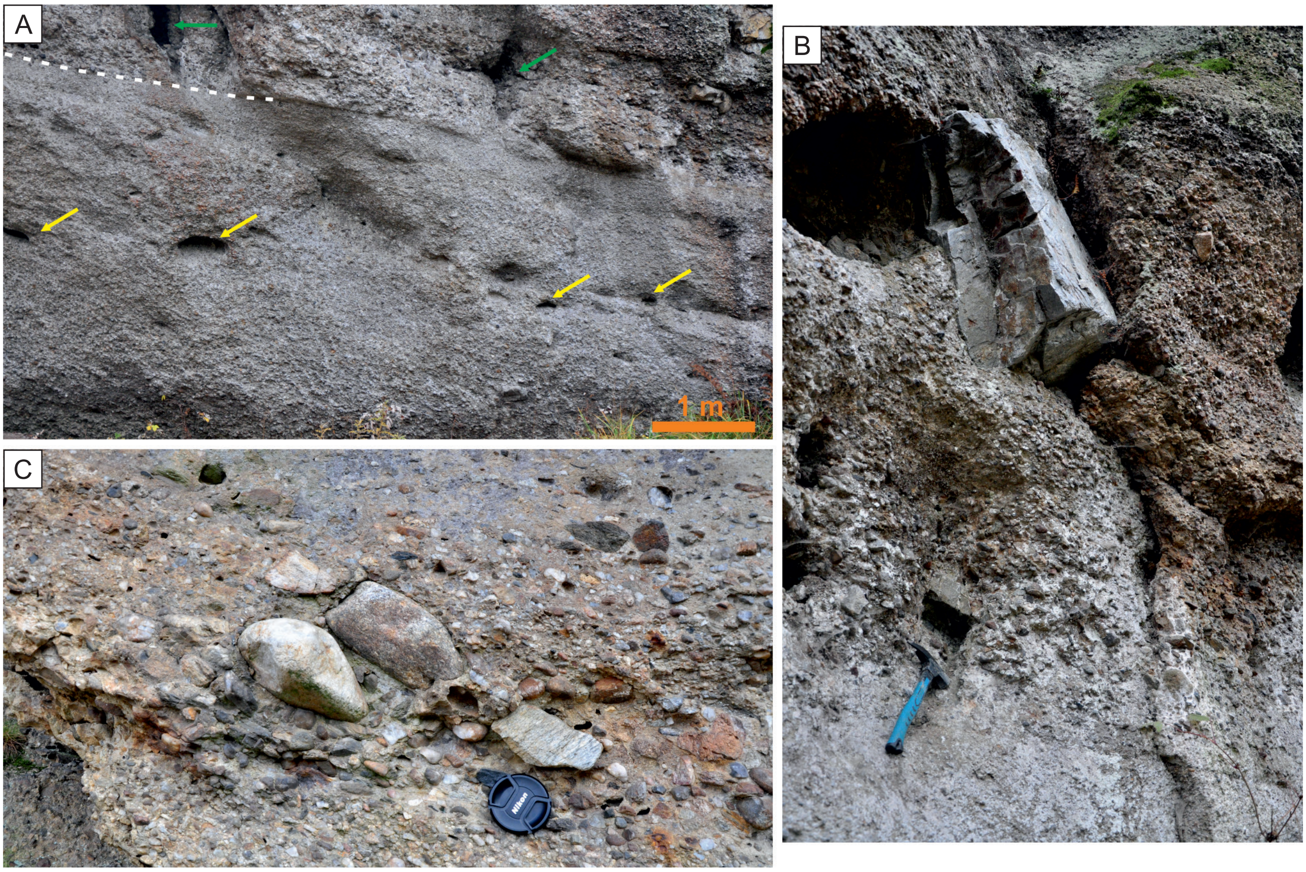

Fig. 7. Lithological characteristics of the tor in Stoczek area (see Fig. 5A): A – lower part of the tor, in which normally graded conglomerate layer and basal part of another layer are visible (the boundary between them is marked with white line); the caverns left after separation of the elongated shale clasts marked by yellow arrows; the cavern left after separation of gneiss blocks marked by green arrows, B – sharp-edge block of gneiss vertically set against bedding; its longer axis reaches 0,7 m; the cavern left after separation of another block next to the gneiss block, C – blocks of gneisses and large pebbles with the various roundness constituting the basic components of conglomerate; photo K. Starzec

The conglomerate is followed by a sandstone layer whose thickness is about 1.7 m. This sandstone reveals rather poorly defined normal grading with dispersed fine gravel-sized grains. Within some parts of the layer a through cross-stratification can be recognized (Fig. 8A), the origin of which is unclear. This kind of structure has been interpreted as a sedimentary structure (Ślączka & Thompson, 1981; Dziadzio *et al*., 2006), but recently Leszczyński *et al*. (2015) have described it as a tensile fracture. Moreover, the sandstone contains isolated, lenticular gravel pockets (Fig. 8A), up to 80 cm in length and 20 cm in thickness that are irregularly distributed within the layer. The top contact of the sandstone with the overlaying conglomerate is sharp, but highly uneven. It is a result of the loaded erosional base of the conglomerate with large load-flame structures (Fig. 8B).

The other rock tors in the Stoczek area, located more to the north, represent a continuation of the facies types described above, although only part of the second conglomerate and sandstone layers crops out within the tors. The lithology and sedimentary features of deposits correspond to the sequence described by Lowe (1982). Within individual layers, the R2-R3-S1 or R3-S1 divisions can be recognized, i.e., very coarse and coarse-grained conglomerate with reverse grading (R2), upwards with normal grading (R3), turning into to coarse-grained sandstone with lenses of pebbles (S1) (Fig. 9).

Fresh, unweathered surfaces on tors in the Pietraszonka area occur rather seldomly. They are mostly covered by lichens and mosses in the upper surfaces. Thus, grading, sorting and sometimes even grain size are poorly recognized, although some other structures, e.g. parallel stratification, are emphasized by the weathering process. Most of the tors consist of a very coarse-grained sandy material, usually with dispersed gravel. Intervals with much coarser, gravel fraction can be also noticed. They are poorly sorted and consist of gravels and cobbles up to 15 cm in diameter (Fig. 10). Some of the beds are massive; others show parallel stratification (Fig. 5B, Fig. 5D).

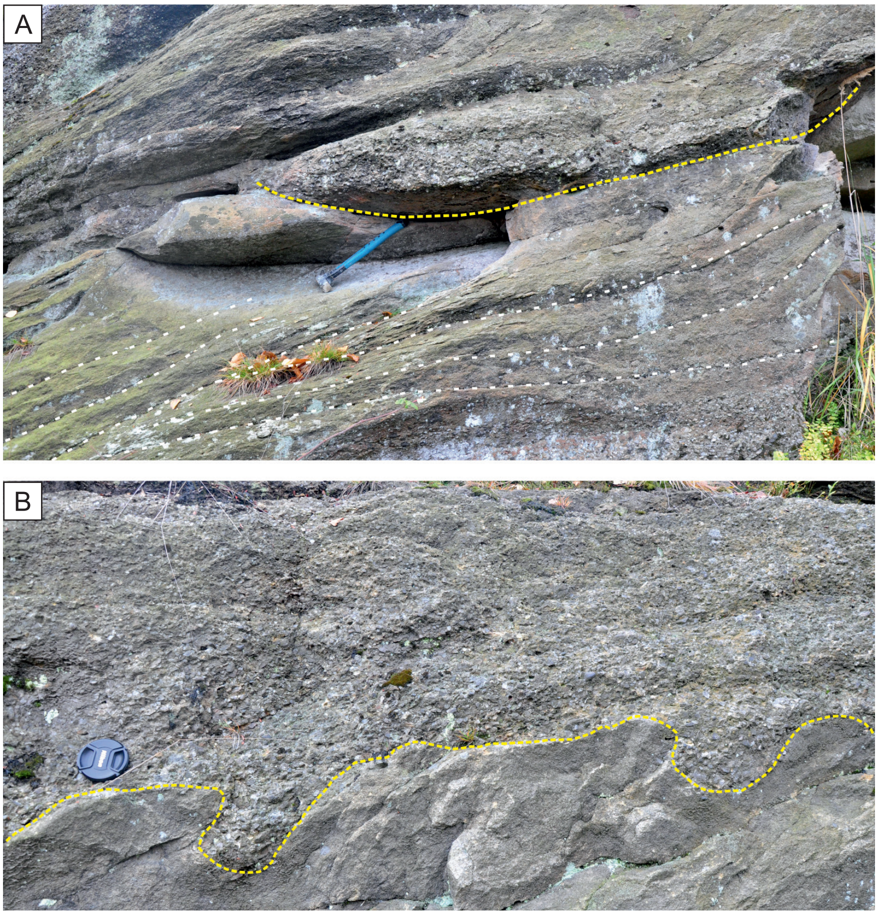

Fig. 8. Sedimentological features of the tor in Stoczek area: A – fragment of sandstone bed with cross-bedded laminae marked by white lines and with lense-shaped conglomerates marked by yellow line laminae, B – loading deformations at the boundary of conglomerate and sandstone layers marked by yellow line; photo K. Starzec

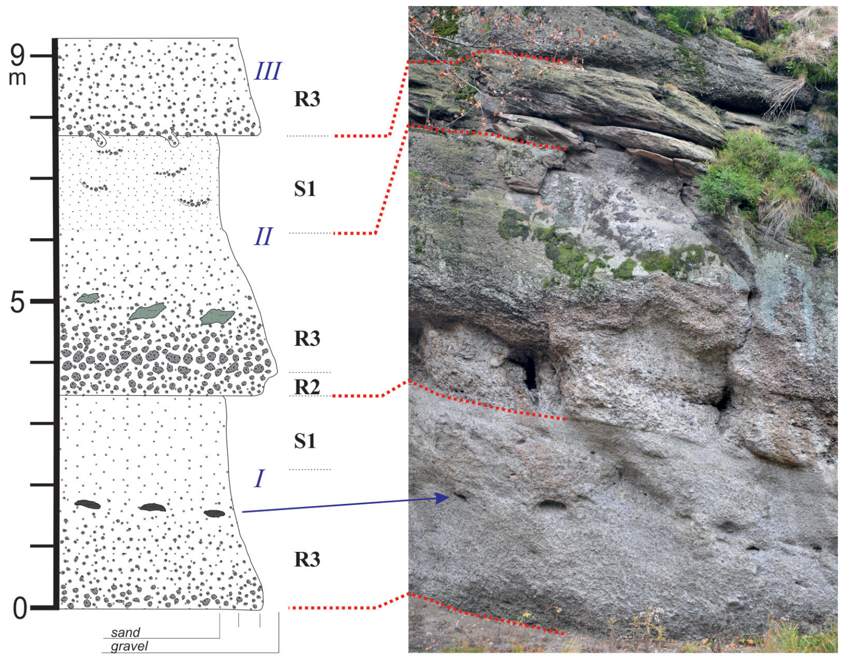

Fig. 9. Lithofacies profile of deposits in the Stoczek area with the facies succession corresponding to Lowe's succession intervals; Bed I – very coarse and coarse-grained conglomerate displaying normal grading (R3) transiting to medium and fine-grained conglomerate (S1); Bed II – very coarse- and coarse-grained conglomerate with reverse grading (R2), upwards with normal grading (R3) and large gneiss blocks, transiting to coarse-grained sandstone with lenses of pebble; Bed III – coarse-grained conglomerate displaying normal grading (after Starzec et al., 2017); photo K. Starzec

Fig. 10. Characteristics of the tors in the Pietraszonka area: A – conglomeratic interval, about 1 m in thickness, within sandstone dominated sequence, B, C, D – rocky walls divided by almost vertical joint fractures, triangle-shaped caverns (A and D) or even small caves (C) are developed at the base of the walls. Rocks in the Figures B and C reach almost 10 m high; photo K. Starzec

If a conglomerate interval is present, bed boundaries are easily noticeable. In case there are only sandstones the boundaries are hardly recognizable, which may be connected with original thickness of layers or amalgamation of two or more layers. Such a characteristic feature results from collateral overlapping of subsequent currents carrying clastic material. A very distinctive feature of rocks in this area, rather not visible in other localities, is their fracturing. Joint fractures cut the rocks in perpendicular direction to the bedding surface (Fig. 10B-D). Only a one-direction joint system is developed, striking approximately along N–S. Very often, fractures are widened at the base of the rock tor, forming a small, triangle-shaped cavern (Fig. 10B-D).

The rock tor in the Filipionka area displays a very interesting example of facies succession, different than the other tors described. It still consists of conglomerates and sandstones, with prevailing of the first lithology, however their relations are specific. These two lithologies are interbedded and their boundaries are usually very sharp (Fig. 11A). Besides thick layers of normal graded conglomerates, occurring also in other rock tors, this one is characterized by intervals with thin to medium alternating beds of sandstone and conglomerate (Fig. 11A-B). Some of the thin beds are discontinuous and pinch out. Sandstones show a flat base surface, whereas the top one can be either flat or uneven. This is a result of erosional (Fig. 11B) or deformation structures (Fig. 11D). The last ones are called load casts and have the form of drops or plumes of conglomerate descending into sandstone. These features develop when a denser layer of sediment is deposited on top of less-dense sediment.

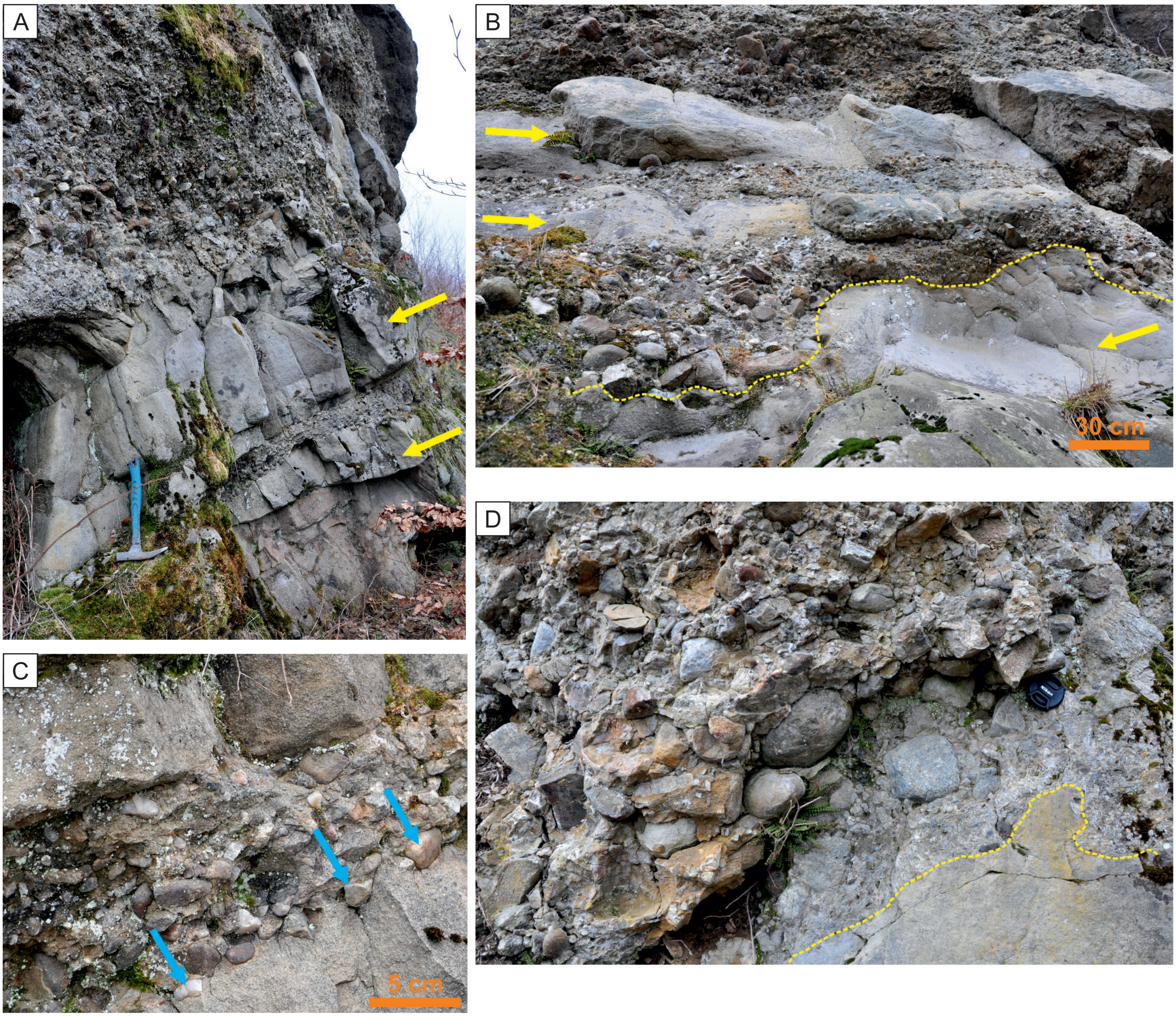

Fig. 11. Sandstone-conglomerate alterations within the rock tor in Filipionka area: A – fragment of the base part of the tor consisting of two sandstone layers (yellow arrows), about 0,5 m thick, interbedded with thin conglomerate layer and overlain by very thick conglomerate, in each case layer contacts are very sharp, B – erosional base of conglomerate layer (dotted line) causing very uneven surface between sandstone and conglomerate (sandstone layers are marked with yellow arrows), C – angular granules of conglomerate pressed into underlying sandstone (blue arrows), D – load casts at the sandstone-conglomerate boundary; photo K. Starzec

Such an arrangement is gravitationally unstable, causing penetration of the upper layer into the lower one. This process occurs shortly after sediment deposition and can be classified as a kind of soft-sediment deformation. Moreover, in some cases the uneven surface is a result of dipping of coarse and angular granules of the overlying conglomerate into sandy deposits (Fig. 11C) that can be interpreted rather as an effect of erosion of the bottom during deposition of coarser material than soft sediment deformations.

The rock tors in the Karolówka ridge represent a similar character in terms of lithology and sedimentary structures, although they belong to the Czarna Wisełka Member (the lower part of the Istebna Formation). They are composed of coarse-grained sandstones and conglomeratic sandstones. Bedding surfaces are rather indistinct and reveal the only form of a change in grain size. Coarser conglomeratic material of the overlaying bed is diffused into the sandy material of the lower bed (Fig. 12A). On weathered surfaces, sandstones display slightly undulating lines, more-or-less regularly spaced, often with upward-curving margins (Fig. 12B). They represent fluid escape structures, whose formation is related to soft-sediment deformation, as in the case of load casts. They are generated during the sediment consolidation process, that involves pore-fluid escape and sediment compaction resulting largely from gravitational loading (Lowe, 1975).

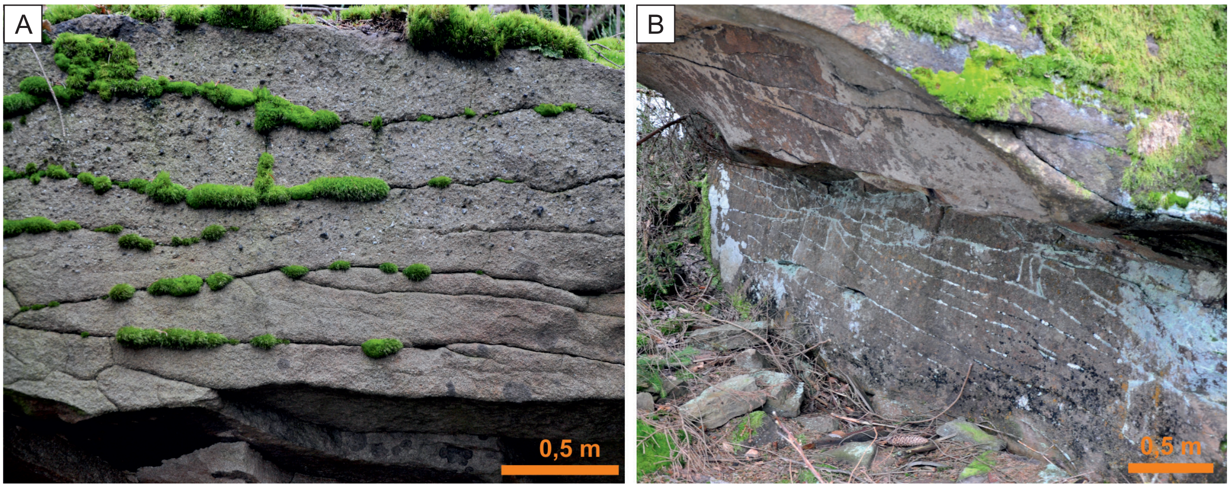

Fig. 12. Sedimentological features of the tor in Karolówka area: A – gradual transition between sandstone and conglomerate layer, with no sharp boundary, B – fluid escape structures in sandstone that are underlined on the rock wall by bluish-white lichens; photo K. Starzec

The Protocarpathians elements

The Istebna Formation containing the exotic bearing deposits stretches along the entire Silesian Nappe of the Polish Outer Carpathians, but conglomerates with the largest exotic blocks are found in its westernmost part, cropping out in the Istebna area.

The rock fragments differ in size and roundness. Some clasts are small, a few centimeters in size and well-rounded, while some poorly rounded or sharp-edged blocks reach 70–80 centimeters in size (Fig. 7B). The larger blocks occur sporadically. The largest one reaches 160 centimeters in size. It was eroded from the Istebna sandstone tor and now is located *ex situ*, on the bottom of a temporary stream. The crystalline blocks represent magmatic, metamorphic, and rarely sedimentary rocks. Various white-grey gneisses dominate. They display oriented, pencil-like, or layered structures. Schists, phyllites, pegmatites, milky or dark quartzites, pinkish granites, and sporadically dark limestones also occur here. Locally the number of magmatic and metamorphic rocks is exceptionally high. The largest concentrations of the large size crystalline clasts occur in the Karolówka and Filipionka tors. These crystalline rocks represent fragments of the basement upon which the Carpathian basins, belonging to the Alpine Tethys, developed during Mesozoic and Cenozoic times. This so far poorly known basement is customarily called the "Protocarpathians" (Gawęda & Golonka, 2011; Starzec *et al*., 2017, 2018). In fact, this basement was destroyed in the Polish Carpathians and is not available for direct observation.

The occurrence of the Protocarpathian fragments is linked to advanced erosional processes on the surface of the Tethyan basement, followed by transportation and deposition in the sedimentary rocks. Taking into account the paleotransport direction marked in the upper Istebna sandstones that indicate an N direction of the material's supply, the hypothetical Silesian Ridge (cordillera) was the source area for the Protocarpathian clasts. This represented an elevation of the sea floor, as a fragment of the North European Platform. Initially, during Jurassic and Cretaceous times, the Silesian Ridge separated the Magura and Severinic-Moldavidic (Protosilesian) basins. It formed a barrier between the Silesian and Fore-Magura basins after the Late Cretaceous geotectonic reorganization (e.g. Golonka *et al*., 2005, 2006a, b, 2013 and references therein). It was later destroyed in the process of expansion of the Carpathian accretionary prism and now is known only from fragments emplaced in the prism deposits and known as exotics in the Polish and Czech parts of the Outer Carpathians.

Large fragments of this ridge are available for observation within outcrops in the Marmarosh Massif in the Ukrainian and Romanian Carpathians. The Protocarpathian exotic material plays a key role in paleotectonic reconstructions. Accumulations of large, lithologically various exotic clasts are rare in the Polish Outer Carpathians. Therefore, the outcrops of the upper Istebna sandstones in Istebna Village, characterized by the abundance of large-size crystalline exotics, constitute a unique geological phenomenon providing important scientific material for reconstructing the Precambrian – Paleozoic history of this region. They represent fragments of the ancient Cadomian, more than 600 million year old continents and oceans (Starzec *et al*., 2018).

The abundance of clastic exotic material in the Istebna landforms is caused by a specific process within the Outer Carpathians, whereby the valleys formed at the foot of the tors were filled by crystalline rock fragments. The material from the tors was gravitationally transported downhill into the stream valleys and washed by running water. The fluvial transport removed the sand and small conglomeratic grains, leaving only the large crystalline clasts, and thereby, forming a specific concentration of magmatic and metamorphic rocks that is unique for this area.

Discussion

Sandstone rocky landforms are an outstanding feature of the western part of the Silesian Nappe in the Outer Carpathians (e.g. Alexandrowicz, 1978; Strzeboński, 2009). They are characterized by their uniqueness and morphological diversity, caused by weathering and erosional processes in terrestrial conditions. This feature determines the geotouristic attractiveness of these objects. These rocky sandstone landforms are not only geomorphological, but also geological unique objects. The Istebna region provides the best large and well visible outcrops of the Istebna sandstones. Rocky landforms are especially important among these outcrops. Their good exposure allows lithological analysis of the clastic structure in several sections perpendicular to the beds' strike. The occurrence of erosional features highlights the rock structure (Stadnik & Waśkowska, 2015). The rocky landforms outcrops allow one to recognize the lithological characteristics of the Istebna sandstones in their type locality. The exposed fragments of the profiles are representative of the Istebna sandstone development and present a variety of its architecture that is an important scientific attribute, showing typical features of Upper Cretaceous – Paleocene fluxoturbidites. The occurrence of large-size crystalline exotics, representing remnants of the Carpathian basement, is a unique feature, rarely available for direct observation of this scale in the Outer Carpathians.

These rocky landforms are located in the area protected within the Natura 2000 network, no. PLH240005, that includes a huge part of the Beskid Śląski Mts. This is the territory of the State Forests that is under the administration of the Wisła State Forest District. Felling trees, followed by reforestation and rehabilitation, is currently conducted at least on this part of the area. One of the described rocky landform in the Filipionka site is within a young birch forest. The old pathway, running at the foot of this rock is completely overgrown. As such it is not easy to reach. The others are much more easily accessible, from which the two in the Pietraszonka and Stoczek sites are close to the unpaved roads, whereas the one on the Karolówka ridge is situated on the black touristic trail leading to the highest peak of the Beskid Śląski, i.e. Barania Góra. The concentration of the rocky landform objects within a small, 1 km^2 area allow s observation during a one-day field trip and is a winner. These features all speak well for the inclusion of the described rocky sandstone landforms as objects of high geotouristic value.

Conclusions

The not very well known group of sandstone rocks in the form of rock pulpits and walls occur in the western part of Istebna village, on the southern slope of the Karolówka Range. They are built of thick-bedded and very thick-bedded sandstones of the Istebna Formation (Upper Cretaceous–Paleocene) of the Silesian Nappe of the Polish Outer Carpathians. They represent a prime geotouristic site, displaying great potential, because of their good exposure and large size of rock outcrops, lithological structure typical for the Istebna Formation, variety of lithologies and sedimentological structures, variety of morphological shapes, and uniqueness manifested by an abundance of large-size exotic material. Their concentration within a small, 1 km^2 in size area allows one to observe their features during a short fieldtrip.

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References

Alexandrowicz Z., 1977. The origin of sandstone tors in the Polish Western Carpathians. *Bulletin de L'Académie Polonaise des Sciences, Série des Sciences de la Terre*, 25: 83–90.

Alexandrowicz Z., 1978. Skałki piaskowcowe Zachodnich Karpat fliszowych. *Prace Geologiczne*, 113, *Polska Akademia Nauk – Odział w Krakowie, Komisja Nauk Geologicznych*.

Alexandrowicz Z., 2008. Sandstone rocky forms in Polish Carpathians attractive for education and tourism. *Przegląd Geologiczny*, 56: 680–687.

Alexandrowicz Z. & Poprawa D. (eds.), 2000. *Ochrona georóżnorodności w polskich Karpatach*. Państwowy Instytut Geologiczny, Warszawa.

Barański M.J., 2007. *Beskid Śląski. Przewodnik*. Oficyna Wydawnicza "Rewasz", Piastów.

Buła R. & Wieland Z., 2000. Pomniki przyrody nieożywionej w woj. śląskim. *Przyroda Górnego Śląska*, 22: 1–4 (appendix).

Burtan J., 1936. Stratigraphie der Schlesischen Beskiden. *Bulletin international de l'Académie polonaise dessciences et des lettres.* Série *A,* 41: 195–209.

Burtan J., 1972. *Szczegółowa mapa geologiczna Polski, 1:50 000, arkusz Wisła (1028)*. Wydawnictwa Geologiczne, Warszawa.

Burtan J. 1973. *Objaśnienia do Szczegółowej mapy geologicznej Polski, 1:50 000, arkusz Wisła (1028)*. Wydawnictwa Geologiczne, Warszawa.

Burtan J., Sokołowski S., Sikora W. & Żytko K., 1956. *Szczegółowa Mapa Geologiczna Polski. 1:50 000, arkusz Milówka (1029)*. Instytut Geologiczny, Warszawa.

Burtanówna J., Konior K. & Książkiewicz M., 1937. *Mapa geologiczna Karpat Śląskich w skali 1:50 000 (z objaśnieniami)*. Wydawnictwo Śląskie, Polska Akademia Umiejętności, Kraków.

Chybiorz R. & Kowalska M., 2017. Inwentaryzacja i ocena atrakcyjności geostanowisk województwa śląskiego. *Przegląd Geologiczny*, *65*: 365–374.

Doktor M., Golonka J., Waśkowska A., Słomka T., 2010. The best geotouristic objects of the Silesian Unit, Outer Flysch Carpathians in the vicinity of Kraków, Poland. In: Christofides G., Kantiranis N., Kostopoulos D.S., Chatzipetros A.A., *Proceedings of the XIX Congress of the Carpathian Balkan Geological Association, September 23–26 2010, Thessaloniki, Greece, Scientific Annals of the School of Geology*, Aristole University of Thessaloniki, spec. vol. 100: 459–466.

Dziadzio P.S., Borys Z., Kuk S., Masłowski, E., Probulski J., Pietrusiak M., Górka A., Moryc J., Baszkiewicz A., Karnkowski P., Karnkowski P.H. & Pietrusiak M., 2006. Hydrocarbon resources of the Polish Outer Carpathians – Reservoir parameters, trap types, and selected hydrocarbon fields: A stratigraphic review. In: Golonka J. & Picha F.J. (eds), *The Carpathians and Their Foreland: Geology and Hydrocarbon Resources. American Association of Petroleum Geologists, Memoirs*, 84: 259–291.

Gawęda A. & Golonka J., 2011. Variscan plate dynamics in the Circum-Carpathian area. *Geodinamica Acta*, 24/3–4: 141–155.

Golonka J. & Waśkowska-Oliwa A., 2007. Stratygrafia polskich Karpat fliszowych pomiędzy Bielskiem-Białą a Nowym Targiem. *Geologia*, 33: 5–27.

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

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

Golonka J., Krobicki M., Oszczypko N. & Ślączka A., 2006b. Modelowanie palinspastyczne i mapy paleogeograficzne Karpat w fanerozoiku. In: Oszczypko N., Uchman A., Malata E. (eds.), *Rozwój paleotektoniczny basenów Karpat zewnętrznych i pienińskiego pasa skałkowego*, Instytut Nauk Geologicznych Uniwersytetu Jagiellońskiego, Kraków: 19–43.

Golonka J., Ślączka A., Waśkowska A., Krobicki M. & Cieszkowski M. 2013. Budowa geologiczna zachodniej części polskich Karpat zewnętrznych. In: Krobicki M. & Feldman-Olszewska A. (eds.), *Głębokomorska sedymentacja fliszowa. Sedymentologiczne aspekty historii basenów karpackich*. V Polska Konferencja Sedymentologiczna. Państwowy Instytut Geologiczny − Państwowy Instytut Badawczy, Warszawa: 11–62.

Gruszka I., 2009. Walory i formy ochrony przyrody na Pogórzu Ciężkowickim. *Geologia*, 35(2/1): 77–78

Leszczyński S., 1981. Piaskowce ciężkowickie jednostki śląskiej w Polskich Karpatach: studium sedymentacji głębokowodnej osadów gruboklastycznych. *Annales Societatis Geologorum Poloniae*, 51: 435–502.

Leszczyński S., Dziadzio P. & Nemec W., 2015. Some current sedimentological controversies in the Polish Carpathian flysch. *31st IAS Meeting of Sedimentology.* Kraków, Poland, June 2015, *Guide to field trip B*, 247–287.

Lowe D.R., 1975. Water escape structures in coarse-grained sediments. Sedimentology, 22: 157–204.

Lowe D.R., 1982. Sediment gravity flows: II. Depositional models with special reference to the deposits of high-density turbidity currents. *Journal of Sedimentary Petrology*, 52: 279–297.

Picha F.J., Stránik Z. & Krejči O., 2006. Geology and Hydrocarbon Resources of the Outer Western Carpatians and Their Foreland, Czech Republic. In: Golonka J. & Picha F.J., *The Carpathians and Their Foreland: Geology and hydrocarbon resources*, AAPG Memoir, 84: 49–175.

Radwanek-Bąk B., Bąk B., Kopciowski R., Laskowicz I., Szeląg A. & Wójcik A., 2009. *Georóżnorodność i atrakcje geoturystyczne województwa małopolskiego*. Wydawnictwo Kartograficzne „Compass", Kraków.

Słomka T. (ed.), 2013. *Katalog obiektów geoturystycznych w obrębie pomników i rezerwatów przyrody nieożywionej*. AGH Akademia Górniczo-Hutnicza. Wydział Geologii Geofizyki i Ochrony Środowiska. Katedra Geologii Ogólnej i Geoturystyki, Kraków.

Stadnik R. & Waśkowska A., 2015. Sedimentary indicators of a deep sea environment, in the sandstones of rocky forms, from the Ciężkowice-Rożnów Landscape Park (Outer Carpathians, Poland). *Geotourism*, 40–41: 37–48.

Starzec K., Schnabel W., Szotek A. & Pastuch M., 2014. *Aktualizacja powierzchniowej mapy geologicznej dla projektu „polowe prace sejsmiczne 2D Sól"*, Archiwum Geokrak, unpublished.

Starzec K., Golonka J. & Waśkowska A., 2017. Zespół form skałkowych na Karolówce w Istebnej (Beskid Śląski, zachodnie Karpaty zewnętrzne) – godne ochrony stanowisko z unikatowym materiałem egzotycznym. *Chrońmy Przyrodę Ojczystą*, 73: 271–283.

Starzec K., Golonka J., Waśkowska A., Gawęda A., Szopa K., 2018. Exotics of the Protocarpathians in the western area of the Silesian Nappe. In: Neubauer F., Brendel U. & Friedl G. (eds.), CBGA 2018 – Austria: *Advances of geology in southeast European mountain belts.* XXI International Congress of the Carpathian Balkan Geological Association (CBGA), Salzburg (Austria), September 10–13, 2018. *Geologica Balcanica*: 110.

Strzeboński P. 2005. Debryty kohezyjne warstw istebniańskich (senon górny – paleocen) na zachód od Skawy. *Geologia*, 31: 201–224.

Strzeboński P., 2009. Sandstone-conglomerate rocky forms – more than a tourist attraction. *Geoturystyka*: 1–2 (16–17): 49–60.

Ślączka A. & Thompson S., 1981. A Revision of the Fluxoturbidite Concept Based on Type Examples in the Polish Carpathian Flysh. *Annales Societatis Geologorum Poloniae*, 51: 3–44.

Tokarska-Guzik B., Parusel J.B. & Chybiorz R., 2015. Ogólnodostępna baza danych bio- i georóżnorodności województwa śląskiego – integralna część Otwartego Regionalnego Systemu Informacji Przestrzennej BIOGEO-SILESIA ORSIP. *Przyroda Górnego Śląska*, 79: 20.

Unrug R., 1963. Istebna Beds – a fluxoturbidity formation in the Carpathian Flysch. *Annales Societatis Geologorum Poloniae*, 33: 49–92.

Unrug R. 1968. Kordyliera śląska jako obszar źródłowy materiału klastycznego piaskowców fliszowych Beskidu Śląskiego i Beskidu Wysokiego (Polskie Karpaty Zachodnie). *Rocznik Polskiego Towarzystwa Geologicznego*, 38: 81–164.

Żytko K., Gucik S., Oszczypko N., Zając R., Garlicka I., Nemčok J., Eliaš M., Menčik E., Dworak J., Stranik Z., Rakuš M., Matejovska O. 1989. Geological map of the Western Outer Carpathians and their foreland without Quaternary formations. In: Poprawa D. & Nemčok J. (eds.), *Geological Atlas of the Western Carpathians and their Foreland*. Państwowy Instytut Geologiczny, Warszawa.